UNIVERSIDADE FERNANDO PESSOA

DIGITAL SMILE DESIGN VS CONVENTIONAL DESIGN METHODS IN ORAL REHABILITATION: AESTHETIC OUTCOMES AND PATIENTS SATISFACTION. A SYSTEMATIC REVIEW

[Design de sorriso digital vs métodos de design convencionais em reabilitação oral: resultados estéticos e satisfação dos doentes. Uma revisão sistemática]

Dissertação de Mestrado

[Mestrado Integrado em Medicina Dentária]

Sara Maria Laddomada

Orientador:

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ABSTRACT

The focus of this thesis is to evaluate whether Digital Smile Design (DSD) enhances the rehabilitative outcomes and patient communication compared to traditional design methods in oral rehabilitation. The question this thesis aims to answer is: "Does DSD improve rehabilitative outcomes and patient communication compared to traditional methods?" To address this question, the PICO model was adopted as the research framework. The systematic review was performed in alignment with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. Data collection involved extensive searches across electronic databases such as PubMed, Google Scholar, and MDPI, ensuring a comprehensive review of relevant literature. Articles were retrieved using keywords and these terms were combined with Boolean operators ("AND," "OR," "NOT") to refine the search. Strict inclusion and exclusion criteria were applied. Only human clinical trials were included to ensure relevance and applicability. Systematic reviews, meta-analyses, studies conducted on animals, and articles in languages other than English were excluded to maintain the focus and quality of the data. The assessment of methodological quality was carried out using the tool Robins-I for Randomized Controlled Trial, Non-randomized comparative study (quasi-experimental), Pilot observational study and Clinical Case Report.

Keywords: “DSD”; “aesthetic outcomes digital smile design”; “digital smile design”; “digital workflow”; “traditional prosthetics”; “aesthetic outcomes”.

RESUMO

O foco desta tese é avaliar se o *Digital Smile Design* (DSD) melhora os resultados da reabilitação e a comunicação com o paciente em comparação com os métodos tradicionais de planeamento no âmbito da reabilitação oral. A questão que esta tese procura responder é: "O DSD melhora os resultados de uma reabilitação oral e a comunicação com o paciente em comparação com os métodos tradicionais?" Para abordar esta questão, foi adotado o modelo PICO como enquadramento metodológico. A revisão sistemática foi realizada em conformidade com as diretrizes PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*). A recolha de dados envolveu pesquisas extensivas em bases de dados eletrónicas como *PubMed, Google Scholar* e MDPI, assegurando uma revisão abrangente da literatura relevante. Os artigos foram selecionados através de palavras-chave combinadas com operadores booleanos ("AND", "OR", "NOT") para refinar a pesquisa. Foram aplicados critérios rigorosos de inclusão e exclusão. Apenas ensaios clínicos realizados em humanos foram incluídos, de forma a garantir a relevância e aplicabilidade. Foram excluídas revisões sistemáticas, meta-análises, estudos realizados em animais e artigos redigidos em línguas diferentes do inglês, de modo a manter o foco e a qualidade dos dados. A avaliação da qualidade metodológica foi realizada utilizando a ferramenta Robins-I, aplicável a ensaios clínicos randomizados, estudos comparativos não randomizados (quase-experimentais), estudos observacionais piloto e relatos de caso clínico.

Palavras-chave: “DSD”; “resultados estéticos digital smile design”; “digital smile design”; “fluxo de trabalho digital”; “prótese tradicional”; “resultados estéticos”.

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LIST OF ACRONYMS, ABBREVIATIONS AND ACRONYMS

2D	Two Dimensional
3D	Three Dimensional
CAD/CAM	Computer Aided Design/Computer Aided Manufacturing
DSD	Digital Smile Design
IC	Interproximal Contact
Mod	Moderate
OC	Occlusal Contact
PICO	Population, Intervention, Comparison, Outcome
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
RCT	Randomized Controlled Trial
VAS	Visual Analog Scale

1.INTRODUCTION

1.1. Development of the topic

1.1.1. Historical Evolution of Dental Aesthetics

The discipline of dental medicine has experienced a profound transformation over the past century, evolving from a field primarily focused on alleviating pain, restoring masticatory function, and preventing infection, to one that places increasing emphasis on aesthetics and patient-centered care (Gürel et. al., 2008).

In its early stages, aesthetic outcomes were considered secondary to function, often resulting in restorations that lacked visual harmony and integration with the facial structure.

As dental materials advanced and interdisciplinary collaboration became more common, aesthetic considerations gained prominence, particularly in prosthodontics and cosmetic dentistry. This shift was largely driven by growing patient awareness and demand for treatments that not only restored function but also improved visual appeal (Pimentel et al., 2016).

In recent years, esthetic planning in dentistry had begun to rely heavily on principles such as the smile line, gingival height and contour, and facial proportion, marking the transition to a visually focused and patient-specific approach to care (McLaren et al., 2013). Restorations became more natural-looking, symmetrical, and customized, aligning with the patient's facial features and individual desires.

In this evolving context, the development of new digital tools was inevitable. Among these, Digital Smile Design (DSD) emerged as a leading protocol.

DSD provides a comprehensive digital framework for planning aesthetic and functional outcomes, integrating facial analysis, intraoral scanning, and digital simulations into the treatment workflow (Coachman et al., 2012).

1.1.2. From Function to Aesthetics in Modern Dentistry

Modern dentistry has progressively shifted away from a purely functional approach to embrace an integrated aesthetic vision, where form and function coexist in harmonious

balance. The focus is no longer limited to simple dental alignment or shade matching, but extends to evaluating the relationship between teeth, lips, facial contours, and even the patient's personality traits.

This evolution reflects in healthcare, oriented toward personalized treatments and greater patient involvement in decision-making processes. In this context, tools such as facial photography, video recordings of the smile, and digital simulations have become essential for capturing not only the static features, but also the dynamic expression of the smile.

The concept of "dental composition" has been enriched by analytical parameters such as tooth-to-tooth proportion, axial inclination, alignment, and golden ratio proportions, as demonstrated in the foundational studies by Lombardi (1973) and Levin (1978).

It has been shown that the aesthetic perception of a smile is strongly affected by the width of the dental arch, the order of the anterior teeth, and the degree to which they are visible from a frontal viewpoint. Central incisors, in particular, play a dominant role in dental composition and are often perceived as either too long or too short depending on the observer's visual habits. Individual variations, such as subjective aesthetic preferences, must therefore guide the clinician in achieving a balance between canonical rules and personalized adjustments (Fradeani, 2004).

Supporting this personalized approach, DSD introduces an innovative and interactive methodology that integrates all these variables in a visual and precise way, improves the accuracy of aesthetic simulations, reduces treatment times, and significantly increases patient satisfaction through co-design of the final smile. (Corsalini et al., 2024)

Also, DSD enables dynamic management of dental proportions and integration with soft tissue and facial lines, overcoming the limitations of traditional techniques such as manual wax-ups or plaster models (Alshali & Asali., 2022). The ability to digitally simulate aesthetic changes before the clinical phase strengthens patient trust and improves communication, leading to more predictable and shared outcomes. (Corsalini et al., 2024)

DSD is not just a technical evolution, but a conceptual transformation that values individuality, facial harmony, and the patient's active involvement, combining scientific precision and artistic sensitivity in a truly multidisciplinary approach (Alshali & Asali., 2022).

1.1.3. Traditional Smile Design Methods

Traditionally, the aesthetic dental rehabilitation began with a meticulous clinical evaluation. This included detailed photographic records, radiographs, periodontal assessments, and physical impressions from which plaster study models were created (Gurrea & Bruguera, 2014). These models provided a tangible, three-dimensional representation of the patient's dentition and were used as a foundation for planning.

From these models, a diagnostic wax-up was made by hand, often by a dental technician. This manual simulation served as a visual and functional guide, capturing the visualized outcome. Once the wax-up was approved, a silicone index was molded and filled with a resin-based material to create a direct intraoral mock-up.

This temporary structure allowed both the clinician and the patient to preview and evaluate the proposed smile directly in the mouth, giving perception not only into aesthetics but also into phonetics and occlusion (Gurrea & Bruguera, 2014).

If the mock-up was accepted, the process moved toward tooth preparation and the placement of provisional restorations. Eventually, the final restorations were crafted in the dental laboratory and delivered, completing the transformation.

Throughout this process, a strong reliance on communication between the clinician and the dental technician was crucial.

Photographs, shade guides, detailed notes, and models had to be interpreted with skill and precision. Each piece of information transferred from the clinic to the lab held the potential to elevate or compromise the final result (Fradeani, 2004).

Yet, despite its long-standing efficacy, the traditional approach came with some limitations. The analog nature of each step made it vulnerable to inconsistencies and errors. The workflow depended heavily on the abilities of the technician, and the patient's role was often limited to passive observation. Visualizing the final result required imagination, and misalignments between expectation and outcome were common (Cattoni et al., 2016). This method, though time-tested, offered limited interactivity and predictability, especially in cases where patient expectations were high and personalization was predominant (Cattoni et al. 2016).

1.1.4. Digital Smile Design (DSD)

Digital Smile Design (DSD) emerged as a transformative solution. Unlike analog workflows, DSD is based in the philosophy of harmonizing dental structures with facial dynamics, expressions, and proportions. It brings together the scientific and artistic dimensions of dentistry, offering clinicians a digital framework to evaluate, simulate, and plan restorative procedures with a level of accuracy previously unattainable (Coachman et al., 2012).

DSD is based on the principle of facially driven design. Rather than working in isolation, each tooth is evaluated in the context of the lips, smile line, and facial symmetry. This approach begins with high-resolution digital photography and facial analysis, which form the foundation for virtual design. Intraoral scans are then used to capture precise data on tooth position and morphology, which are digitally layered with facial references to simulate the ideal smile (Coachman et al., 2012).

These simulations are brought to life through specialized software. These platforms allow for both 2D and 3D modeling, and include libraries of tooth shapes and arrangements that can be adapted to suit each individual's facial features (Lin et al., 2018). Once a design is finalized, it can be translated into a physical mock-up or final restoration using CAD/CAM technologies, streamlining fabrication and ensuring fidelity between the plan and the result.

The benefits of this digital approach are multiple. Clinicians gain enhanced visualization and predictability. Communication between team members becomes more efficient, and patients are no longer passive recipients but active participants who can visualize their treatment outcomes before any irreversible steps are taken (Corsalini et al., 2024). Interdisciplinary cases benefit from the shared clarity that digital planning provides, allowing prosthodontists, orthodontists, and technicians to collaborate in a more harmonious way.

However, as with any technological advancement, DSD is not without its challenges. The initial financial investment in digital tools and training can be substantial, and learning how to use the digital tools can be hard for some people (Zavolski, 2021).

Despite these hurdles, the rise of DSD marks a significant leap forward in aesthetic dentistry. It empowers clinicians with tools for more precise, efficient, and personalized care, while fostering deeper engagement and satisfaction among patients. In doing so, it

bridges the gap between vision and outcome, transforming smiles with both science and sensitivity (Alshali & Asali, 2022).

1.2. Research Background

The aesthetics of the smile represent a fundamental aspect of oral rehabilitation, influencing not only masticatory function but also self-perception and patients' quality of life. This systematic review aims to critically evaluate and compare **Digital Smile Design and conventional smile design methods** in oral rehabilitation. The focus is on analyzing their impact on **aesthetic outcomes** and **patient satisfaction**, which are essential metrics for the success of rehabilitative treatment.

Research question:

Does Digital Smile Design (DSD) improve rehabilitative outcomes and patient communication compared to traditional methods?

1.3. Objectives of the Study

By reviewing and synthesizing available scientific literature, this thesis seeks to study the true value of DSD, identify its strengths and limitations, and offer practical guidance to clinicians aiming to optimize patient care in aesthetic and functional rehabilitation.

In recent years, dentistry has shifted its focus from mere functionality to achieving harmony between dental structures and facial aesthetics. This evolution has led to the development of new digital tools, particularly Digital Smile Design (DSD), that distinguishes itself from previous analog methods like plaster models, in-mouth mock-ups, and diagnostic wax-ups (Coachman et al., 2012).

Smile design plays a critical role in creating personalized, predictable, and visually pleasing outcomes. While conventional methods are still widely used due to their practicality and cost-effectiveness, they often rely heavily on the clinician's and technician’s skill and allow limited patient involvement in treatment planning. This can introduce variability in results and less predictability in aesthetic outcomes (Gurrea & Bruguera, 2014).

Digital Smile Design (DSD) is a digital workflow that uses clinical photography, intraoral

scans, and 2D/3D software to simulate and plan the aesthetic and functional results of oral rehabilitation. It enables clinicians to analyze facial symmetry, gingival lines, and tooth proportions in detail, and present a virtual preview of the expected outcome. This process not only enhances diagnostic precision but also fosters interactive communication between patient and clinician (Chisnoiu et al., 2023).

By integrating technologies such as CAD/CAM, 3D printing, and augmented reality, DSD promotes a multidisciplinary and efficient workflow, particularly valuable in complex rehabilitations (Zavolski, 2021).

As demonstrated by Liu et al. (2024) and Corsalini et al. (2024), DSD significantly improves soft tissue management, reduces treatment time, and increases patient satisfaction by providing greater control and visibility of the treatment process.

Traditional smile design relies on well-established analog tools such as wax-ups, physical models, and mock-ups. These techniques have long been proven effective and are still widely adopted. However, they often involve longer treatment times and are limited by manual craftsmanship, making them less adaptable to rapid changes or patient feedback (Cattoni et al., 2016).

Although traditional workflows are still valid in many clinical scenarios, their subjective nature and limited visualization tools can reduce patient engagement and the precision of aesthetic predictions. As noted by Chisnoiu et al. (2023), while conventional techniques may deliver satisfactory results, they may not always align with the increasing expectations of today's patients for visualization and customization.

Several recent studies have investigated the outcomes of DSD in comparison to conventional planning techniques. Liu et al. (2024) found that digital planning improved both clinical results and patient satisfaction, especially in anterior aesthetic rehabilitation. Corsalini et al. (2024), in a randomized controlled trial, demonstrated that patients treated with a fully digital workflow experienced improved prosthesis fit, reduced impression times, and greater satisfaction compared to those treated with conventional or hybrid workflows.

A pilot study by Chisnoiu et al. (2023) showed no statistically significant aesthetic differences between digital and conventional mock-ups, but noted the superior flexibility and efficiency of the digital approach. Meanwhile, Zavolski et al. (2021) and Alshali & Asali (2022) illustrated through clinical cases that DSD allows for more refined planning,

although traditional methods can still achieve valid results when used with skill and experience.

Patient satisfaction tends to be higher with DSD, due to better communication, improve visualization of expected results, and greater participation in treatment decisions, (Regragui et al., 2024).

One of the most notable advantages of Digital Smile Design lies in its ability to generate accurate digital simulations, allowing clinicians to conduct a comprehensive facial and dental analysis.

This not only enhances aesthetic precision but also ensures that the proposed treatment is harmoniously integrated with the patient's unique facial features (Alshali & Asali, 2022). The workflow is highly efficient and repeatable, reducing variability and enabling consistent outcomes across different cases and operators (Corsalini et al., 2024).

Moreover, DSD facilitates clear and effective communication both within the clinical team and with the patient. The ability to visually present the proposed results strengthens interdisciplinary collaboration and fosters patient understanding and engagement, making the treatment journey more transparent and personalized (Liu et al., 2024).

From an operational standpoint, the digital approach helps to reduce chairside time and minimizes the number of follow-up appointments, as much of the planning is completed before the clinical phase. This not only improves clinical efficiency but also enhances the overall patient experience (Chisnoiu et al., 2023). Finally, the predictability of both aesthetic and functional outcomes is significantly increased, thanks to the integration of precise digital measurements and virtual modeling. This predictability empowers clinicians to plan with greater confidence and reduces the probability of unexpected adjustments during or after treatment.

While Digital Smile Design offers numerous advantages, it also presents certain limitations that must be carefully considered. First and foremost, the initial investment required for the acquisition of digital equipment, software licenses, and training can be substantial, making it a less accessible option for smaller practices or for clinicians who are early in their careers (Zavolski, 2021).

Additionally, DSD involves a technological learning curve. Dentists must become proficient not only in the use of digital tools, but also in interpreting digital data accurately to translate virtual designs into clinically successful outcomes. Without adequate training,

there is a risk that the digital planning process may not fully reflect the clinical reality, potentially compromising treatment quality (Corsalini et al., 2024).

Another limitation is the dependence on technology, which introduces the possibility of software malfunctions, data loss, or integration issues between different systems. These technical challenges may delay the workflow or create additional work during the planning or fabrication phases (Alshali & Asali, 2022).

Lastly, although DSD enhances treatment predictability, it does not guarantee superior results in every clinical situation. Several studies, including those by Alshali & Asali (2022), have shown that traditional analog methods, when performed with high clinical expertise, can still achieve excellent aesthetic and functional outcomes. Therefore, the success of a smile design protocol depends not only on the tools used, but also on the clinician's ability to integrate digital and conventional approaches according to the specific needs of each patient. Digital workflows must be implemented with care, and the operator's expertise remains a critical factor in the success of any rehabilitation plan.

Despite some limitations, DSD represents a significant advancement in prosthodontic and aesthetic dentistry. It facilitates greater personalization, fosters trust between clinician and patient, and aligns with the principles of modern, evidence-based, and patient-centered care (Regragui et al., 2024). However, conventional techniques should not be dismissed: when used skillfully, they remain a valuable tool, especially in contexts where digital integration is limited or not practicable (Fradeani, 2004).

The integration of digital and analog methods may represent the most effective and balanced approach, adapting to the specific needs of each case (Chisnoiu et al., 2023).

2. MATERIALS AND METHODS

2.1 Research Design and PICO Framework

To elaborate the research question, the **PICO strategy** was used (cf. Table 1), focusing on the comparison between **Digital Smile Design (DSD)** and **conventional smile design methods**, and their impact on **aesthetic outcomes** and **patient satisfaction**. The main research questions guiding this review are:

"Does the use of Digital Smile Design (DSD) improve aesthetic outcomes in oral rehabilitation compared to conventional methods?" and

"Does the application of DSD lead to higher patient satisfaction with the final aesthetic result and the overall treatment experience?"

Table 1

Pico Strategy

Criteria	Determinants
P (Population)	Patients undergoing oral rehabilitation requiring aesthetic and functional improvements.
I (Intervention)	Digital Smile Design (DSD), incorporating digital mock-ups, 3D simulations, and enhanced patient communication
C (Comparison)	Conventional smile design methods, including plaster models, diagnostic wax-ups, and analog techniques.
O (Outcome)	Improved rehabilitative outcomes (aesthetic and functional) and enhanced patient communication and satisfaction.

For the selection of the articles systematic review protocol was used according to PRISMA (Preferred Reporting Items Systematic review and Meta-Analyses) diagram was completed.

To carry out this study, an electronic bibliography search was carried out in the PubMed

and Google Scholar databases. It was carried out using the following keywords “DSD; aesthetic outcomes digital smile design; digital smile design; digital workflow; traditional prosthetics; smile design; aesthetic outcomes” combined with Boolean operators ("AND," "OR," "NOT") to refine the search.

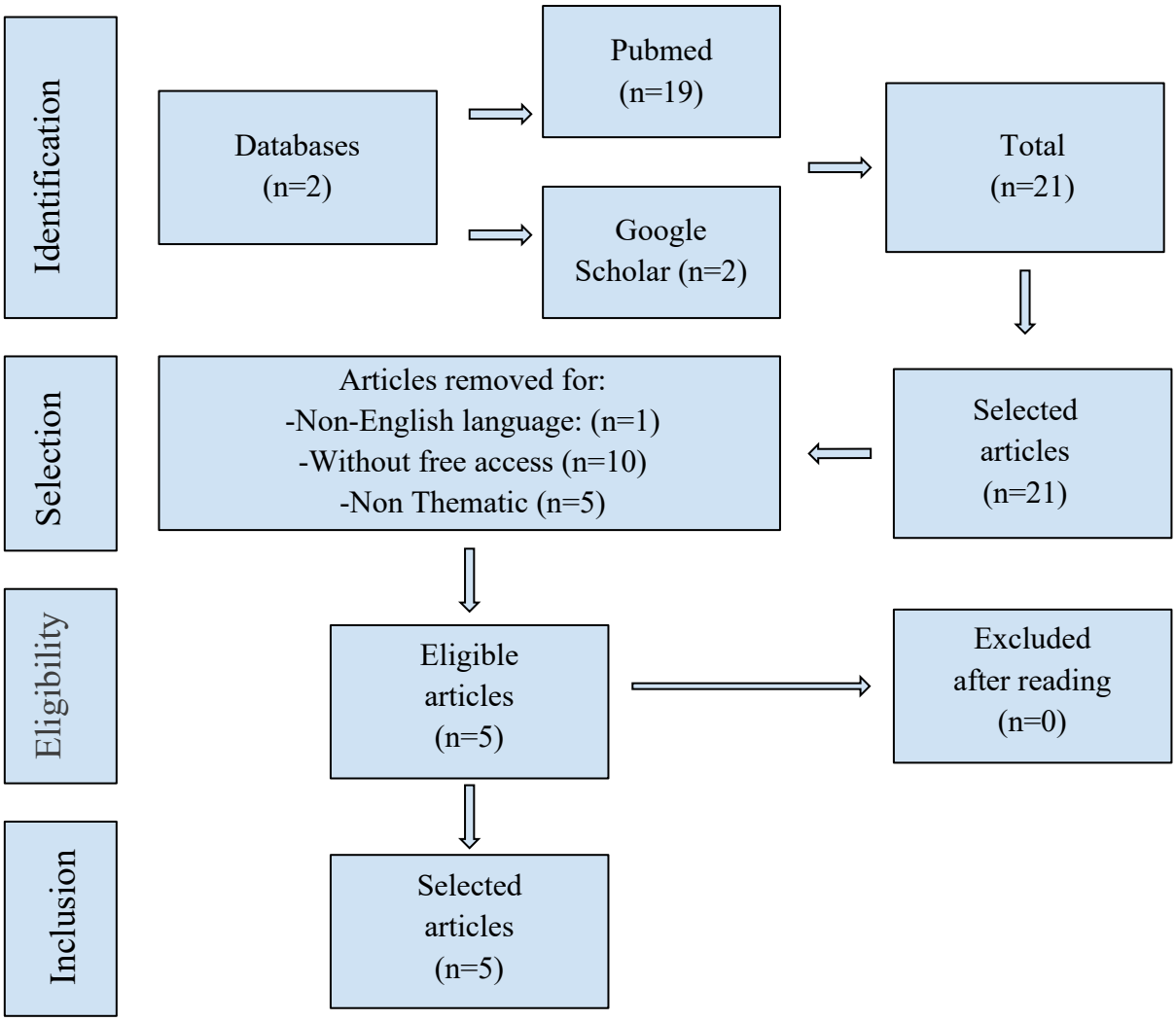
2.2 Inclusion and Exclusion Criteria

The inclusion criteria restricted the search to articles written in English, with twenty years as temporal limit (2004-2024). The exclusion criteria were studies not performed in humans.

Initially, the total number of articles was 19 on Pub-Med and 2 on Google Scholar databases, after reading the titles and abstracts, discarding those that did not find adequately align with the topic under study or whose availability was unfeasible. Subsequently, the last screening was determined after a complete analysis of the total content of each article, resulting in the final selection of 5 articles (cf Figure 1).

Figure 1

PRISMA Flowchart



2.3 Risk of Bias Assessment

To evaluate the methodological quality of the selected articles, the **ROBINS-I tool (Risk of Bias in Non-randomized Studies - of Interventions)** was applied to all included studies.

This tool, developed by the Cochrane Bias Methods Group, is specifically designed to assess the risk of bias in studies that investigate the effect of interventions but are not randomized controlled trials. In this review, ROBINS-I was uniformly applied to ensure consistency across studies with varying designs, including randomized trials, comparative observational studies, and clinical case reports.

The tool assesses seven domains of bias: confounding, selection of participants, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes, and selection of reported results. For each domain, the risk of bias was judged as low, moderate, high, or critical, depending on the clarity, completeness, and methodological rigor of the information provided.

In cases where information was clearly stated and methodologically sound, the response was marked as "low risk". When data were partially reported or unclear, a "moderate risk" was assigned. Finally, when methodological flaws or missing data significantly compromised reliability, a "high risk" classification was given.

Among the five studies analyzed, two were classified as having a moderate overall risk of bias, while the remaining three were considered to have a high risk of bias. These results reflect the heterogeneity in study designs and reporting standards across the available literature on Digital Smile Design versus conventional planning methods in oral rehabilitation (cf. Table 2).

Table 2

Risk of Bias

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Overall
Corsalini et al.	Low	Low	Low	Mod.	Mod.	Low	Low	Mod.
Liu et al.	Mod.	Mod.	Low	Low	Mod.	Low	Low	Mod.
Chisnoiu et al.	High	High	Low	Mod.	Low	Mod.	Low	High
Zavolski et al.	High	High	Low	High	Low	Low	Low	High
Alshali e Asali.	High	High	Low	High	Low	Low	Low	High

Note: Q1 – Bias due to confounding; Q2 – Bias in the selection of participants; Q3 – Bias in the classification of interventions; Q4 – Bias due to deviations from intended interventions; Q5 – Bias due to missing data; Q6 – Bias in measurement of outcomes; Q7 – Bias in selection of the reported result; Mod. – Moderate.

3. RESULTS

3.1. Characteristics of the Included Studies

This review included five studies published between 2021 and 2024 that directly compared Digital Smile Design (DSD) with traditional smile design methods in oral rehabilitation. These studies comprise one randomized controlled trial (RCT), one observational cohort study, one pilot study, and two clinical case reports. Despite the heterogeneity in design and sample sizes, each study contributes valuable insights regarding the clinical outcomes and patient-centered implications of digital versus analog approaches.

3.2. Aesthetic Outcome Analysis

3.2.1. Corsalini et al. (2024)

Corsalini and colleagues conducted an RCT involving 60 patients, randomly assigned to three groups: fully digital workflow, hybrid (digital + analog) workflow, and fully conventional workflow. The study evaluated interproximal contact (IC), occlusal contact (OC), impression-taking time, and patient satisfaction.

Clinical Outcomes: The digital group achieved the highest accuracy in interproximal (mean score 2.92/4) and occlusal contact (mean 1.3/3), significantly outperforming the conventional group ($p < 0.001$). The impression time for the digital group was also dramatically shorter (101 seconds versus 360+ seconds in the conventional group).

Patient Experience: Patients in the digital group reported significantly greater satisfaction on the Visual Analog Scale (VAS), with a mean score of 1.48 (lower = better experience) versus 4.23 in the conventional group, emphasizing improved comfort and reduced chair time.

3.2.2. Liu et al. (2024)

Liu et al. conducted a prospective observational study with 30 patients undergoing anterior aesthetic rehabilitations using DSD protocols. The study emphasized precision in aesthetic outcomes and patient satisfaction.

Clinical Outcomes: DSD enabled precise alignment of teeth and gingival contours in harmony with facial features. The virtual design closely matched the final restorations, confirming the reliability of the digital mock-up.

Patient Experience: 90% of patients expressed increased confidence and engagement during treatment planning. The study highlighted enhanced visualization and co-design capabilities as key to improved patient satisfaction.

3.2.3. Chisnoiu et al. (2023)

This pilot study compared traditional mock-up techniques and DSD among 10 patients. Both patient and clinician evaluations were recorded for aesthetic quality and efficiency.

Clinical Outcomes: No statistically significant difference was found in the aesthetic ratings between the two methods. However, DSD facilitated a quicker workflow and easier integration of facial proportions into the smile design.

Patient Experience: Patients using DSD felt more involved in the planning process. Although aesthetic results were similar, the psychological and emotional engagement was higher among DSD users.

3.2.4. Alshali & Asali (2022)

This case report compared three smile design methods (traditional, 2D, and 3D DSD) on a single patient requiring anterior veneers.

Clinical Outcomes: The 3D DSD method offered the most precise preview and fit; however, the patient ultimately selected the conventionally fabricated feldspathic veneers for their superior translucency.

Patient Experience: The digital planning process increased the patient's understanding and participation. Although the final aesthetic choice favored a traditional technique, the DSD workflow enhanced the patient's sense of involvement and confidence.

3.2.5. Zavolski et al. (2021)

Zavolski presented a case report involving a complete anterior rehabilitation with a fully digital workflow, incorporating intraoral scanning, DSD, and CAD/CAM fabrication.

Clinical Outcomes: The digital approach delivered precise prosthetic fit and excellent aesthetic integration. Workflow efficiency improved with reduced lab turnaround times.

Patient Experience: The patient valued the preview and co-planning process, expressing a strong sense of trust and satisfaction. The report concluded that DSD can strengthen the therapeutic alliance between patient and clinician.

Across all studies, DSD consistently improved patient communication and engagement. Its visual nature allowed patients to preview expected results, offer feedback, and feel empowered throughout the treatment process. Even in cases where conventional techniques were used for the final restoration, the incorporation of DSD in the planning phase elevated patient satisfaction by enhancing understanding, transparency, and confidence in the treatment plan. (cf. Table 3)

Table 3

Studies design method, aesthetic outcomes and patient satisfaction

Study	Design Method	Aesthetic Outcomes	Patient Satisfaction
Corsalini et al. (2024)	DSD vs Hybrid vs Conventional	DSD group showed highest interproximal and occlusal accuracy	Highest in DSD group (VAS 1.48 vs 4.23 conventional)
Liu et al. (2024)	DSD vs Conventional	DSD showed superior PES and WES scores, especially at 3–6 months	90% engagement improvement; enhanced communication
Chisnoiu et al. (2023)	DSD vs Conventional	No significant differences; both methods similar in aesthetics	Higher involvement and emotional engagement in DSD group
Alshali & Asali (2022)	3D DSD vs Traditional	3D DSD provided best preview and precision; final veneers were conventional for optical reasons	Patient better understood and engaged in DSD phase, despite choosing traditional final result
Zavolski et al. (2021)	Fully Digital (DSD included)	Excellent esthetic integration with prosthetic fit in DSD workflow	Strong trust and satisfaction from co-design in DSD planning

All studies agree on the increased patient engagement, trust, and understanding facilitated by the visual and interactive nature of DSD.

4. DISCUSSION

4.1. Interpretation of Findings

This systematic review examined five studies: Corsalini et al. (2024), Liu et al. (2024), Chisnoiu et al. (2023), Alshali & Asali (2022), and Zavolski (2021)—to investigate the clinical impact of Digital Smile Design (DSD) in comparison to traditional methods. These works, although different in methodology and scope, converge on one important point: DSD offers a modern, precise, and emotionally engaging alternative to conventional approaches. The evidence suggests a transformative shift in how clinicians and patients alike conceive and live aesthetic rehabilitation.

Among these, Corsalini et al. (2024) presented the strongest quantitative data in a randomized controlled trial, highlighting significant improvements in both objective clinical markers such as interproximal and occlusal contacts and subjective indicators like comfort and satisfaction. The digital workflow not only streamlined procedures like impression-taking but also improved patient experience. These findings align with other reports in the literature (Cattoni et al., 2016; Coachman et al., 2012), reinforcing that DSD is not merely a technological novelty but a valid clinical enhancement.

Liu et al. (2024) deepened this perspective by emphasizing the harmony between planned and final results. Their study showed that digital simulations allowed restorations to be more precisely tailored to the patient's facial structure, leading to outcomes that were not only functionally effective but also satisfying. Patients were no longer just recipients of care but they became collaborators, shaping their own rehabilitative treatment.

Chisnoiu et al. (2023), although working with a smaller sample in a pilot study, corroborated these advantages. The study found that while traditional and digital mock-ups both led to acceptable aesthetic outcomes, patients favored the DSD method for its speed, clarity, and interactivity.

Zavolski's (2021) single-case report brought a deeply human element into focus. The use of DSD and CAD/CAM tools helped demystify each step of the treatment process for the patient. By visualizing their future smile, the patient felt less anxious, more informed, and more involved. In an era where trust and transparency are increasingly essential in healthcare, this is not a trivial outcome.

Finally, the case study from Alshali & Asali (2022) revealed that even when DSD produces the most accurate previews, final choices may still hinge on tactile or optical preferences. Their patient ultimately chose feldspathic veneers crafted by hand, citing their superior natural aesthetics. However, the DSD preview had empowered her to make that decision with full confidence, illustrating that the strength of DSD lies not only in planning but in communication and empowerment.

4.2. Patient-Centered Advantages

DSD's most immediate and tangible benefit lies in its ability to revolutionize communication. Across all five studies, this theme emerged consistently. No longer limited to verbal descriptions or static 2D images, patients were presented with dynamic, personalized simulations that brought their treatment options to life. This form of digital visualization and planning bridged the gap between expectation and reality.

Liu et al. (2024) found that 90% of patients reported feeling more engaged in their care due to DSD. The realism of the visuals, combined with the ability to provide input during the planning phase, transformed patients from observers to participants. DSD enhances not only communication but also emotional investment, leading to higher adherence and satisfaction.

Even in studies like Alshali & Asali (2022), where the patient opted for traditional materials, the value of DSD as a co-design platform was not diminished. On the contrary, the digital preview served as a visual map, guiding the patient through options and helping her express her aesthetic priorities. In Zavolski’s (2021) report, the psychological benefits were particularly vivid: the patient's anxiety decreased once she saw her future smile. This emotional dimension, often overlooked in technical discussions, may well be one of DSD’s greatest strengths.

4.3. Limitations and Considerations

However, while the reviewed literature paints a largely positive picture, limitations must be acknowledged. Methodologically, the sample remains narrow. Only Corsalini et al. (2024) employed a randomized controlled trial design. The others ranged from observational studies to single-case reports, making cross-study comparisons and

statistical inferences difficult.

Sample sizes were also limited. Chisnoiu et al. (2023) and the case reports by Alshali & Asali (2022) and Zavolski (2021 provided detailed insight but had limited scope. As a result, the findings may not be generalizable to wider clinical populations. Long-term data is also lacking. While immediate satisfaction and aesthetic results are promising, the long-term stability, maintenance, and functionality of DSD-based rehabilitations remain largely unverified in these studies.

Furthermore, DSD's effectiveness is heavily dependent on technological access and user proficiency. A practice without digital cameras, scanners, or design software may struggle to implement DSD effectively. Similarly, a clinician unfamiliar with digital workflows may find the learning curve steep. This digital divide may unintentionally widen inequalities in aesthetic dental care.

Also crucial is the realization, as highlighted by Alshali & Asali (2022), that digital precision does not automatically translate to clinical perfection. Factors such as light reflection, translucency, and biomaterial behavior cannot yet be fully replicated in simulations. The artistry and judgment of the clinician remain irreplaceable.

4.4. Clinical Relevance and Future Direction

Despite these challenges, the clinical relevance of DSD is undeniable. It elevates planning accuracy, shortens treatment timelines, and enhances patient-clinician alignment (Corsalini et al., 2024). Particularly in anterior aesthetic rehabilitations, where patient's expectations run high, DSD offers a structure for visualizing success before a single tooth are touched and treated (Liu et al., 2024).

Looking ahead, the trajectory of DSD is interlaced with the future of digital dentistry itself. As artificial intelligence and machine learning continue to evolve, their integration with DSD platforms may unlock even greater capabilities like automated diagnostics, predictive design algorithms, and real-time case simulations (Regragui et al., 2024). These innovations could have the potential to make workflows more efficient and outcomes more predictable.

At the same time, cost-effectiveness and accessibility must be addressed. Initial investments remain high, and while early adopters benefit, widespread implementation

requires more inclusive technological models and training opportunities (Zavolski, 2021). Studies evaluating economic impact alongside clinical outcomes will be vital.

Hybrid workflows may also represent a great spot between innovation and tradition. Combining the structured precision of digital planning with the nuanced craft of analog execution can yield results that are both technically excellent and resonant (Chisnoiu et al., 2023). In this context, interdisciplinary collaboration is essential.

Finally, education will play a decisive role. The future of DSD depends on equipping the next generation of clinicians with the skills to use digital tools meaningfully. Training programs must emphasize not just software, but communication, aesthetics, and the ethical implications of co-designing care with patients (Fradeani, 2004).

In sum, Digital Smile Design is more than a workflow, it is a paradigm shift. Rooted in technology but animated by human connection, DSD stands as a bridge between precision and personalization (Coachman et al., 2012). Its promise lies not only in what it can do but in how it reshapes the clinician-patient relationship, inviting collaboration, clarity, and confidence into every step of the aesthetic journey and process.

4.5. Limitations of the study

While this systematic review offers valuable insights into the comparative effectiveness of Digital Smile Design (DSD) and traditional aesthetic planning methods, several limitations must be acknowledged that may influence the strength and generalizability of the conclusions drawn. One of the primary limitations lies in the heterogeneity of the study designs included in the analysis. Among the five selected articles, only one employed a randomized controlled trial model while the others consisted of observational studies, a pilot study, and individual case reports. This methodological variability, along with differing clinical contexts and objectives, limits the possibility of performing direct comparisons and reduces the statistical power of the evidence.

Another significant limitation is the small sample sizes observed in most studies. The pilot study and the case reports, for example, featured only one or a handful of patients, making it difficult to generalize findings across broader populations. Such small cohorts are inherently vulnerable to selection bias and do not capture the variability present in real-world clinical practice.

Furthermore, the absence of long-term follow-up data across all five studies represents a notable gap. While short-term satisfaction and aesthetic success were consistently reported, the durability and functional stability of DSD-based rehabilitations over time remain unverified.

In addition, the subjective nature of aesthetic outcomes presents a further challenge. What one patient thinks is beautiful or satisfying result may not align with another's expectations, especially given the influence of cultural norms, personal experiences, and psychological perception. Although most studies attempted to standardize satisfaction measures through tools like the Visual Analog Scale (VAS), the inherently individualized response to aesthetics introduces variability that complicates objective comparison.

A final consideration is the technological dependency of the DSD workflow itself. Successful implementation requires advanced equipment, compatible software, and, crucially, clinician proficiency with digital tools. Practices without access to high-end technology or sufficient training may not be able to replicate the outcomes observed in digitally advanced settings, introducing a potential bias in favor of well-equipped clinics. Therefore, future research must strive for more standardized protocols, diverse and representative sample populations, and longitudinal data to fully validate the clinical and experiential benefits of DSD.

5. CONCLUSION

5.1. Summary of Main Findings

This systematic review, based on the analysis of five peer-reviewed studies, confirms the growing relevance of Digital Smile Design (DSD) as a key tool in contemporary aesthetic dentistry. The evidence demonstrates that DSD improves diagnostic accuracy, optimizes clinical workflow, and strengthens communication between clinician and patient. The possibility of digitally visualizing therapeutic outcomes enhances patient trust, satisfaction, and adherence, with positive effects not only on functional aspects but also on psychological well-being. Also, several studies have shown that the use of DSD leads to more predictable and consistent aesthetic results, without replacing the clinician's skills and artistic sensibility.

5.2. Final Considerations

Digital Smile Design (DSD) represents a significant advancement in aesthetic rehabilitation, providing an objective and visual framework that amplifies the clinician's abilities. Literature shows that digital workflows reduce clinical time, minimize the number of visits, improve planning quality, and enhance surgical and prosthetic precision. At the same time, comparative studies emphasize that conventional techniques, particularly in wax-up modeling or in the choice of highly aesthetic materials such as feldspathic ceramics, may still offer advantages in terms of naturalness, translucency, and color rendering. Digital simulations serve as a reliable blueprint, enabling greater predictability and consistency in aesthetic outcomes. However, as highlighted by Alshali & Asali (2022), clinical success also depends on factors such as material properties, operator skill, and biological context. In that specific case, although the patient valued the accuracy and clarity of the 3D DSD preview, the final choice favored conventionally fabricated feldspathic veneers for their superior translucency. This example underscores that digital planning does not negate the value of traditional artistry, but rather complements it. Therefore, DSD should not be regarded as a substitute, but rather as a powerful complement to clinical judgment and artisanal expertise. Its full potential emerges in hybrid workflows, which combine the predictability of digital planning with the consolidated experience of traditional methods. It is precisely within this synergy that

the true strength of modern aesthetic dentistry lies: it's a dialogue between technological innovation and artisanal craftsmanship, capable of merging the precision of digital design with the aesthetic sensibility refined through years of clinical practice. In other words, the hybrid workflow is not a simple sum of two approaches, but a bridge that connects the technical rigor of computer-based planning with the subtle artistry of human judgment and skilled hands. This dynamic and flexible approach makes it possible to tailor each treatment to the individual patient's needs, transforming rehabilitation into a unique, calibrated, and profoundly personalized process. From this perspective, DSD becomes not merely a clinical tool but a medium of co-creation that actively involves the patient. The digital anticipation of the final result fosters constructive dialogue, strengthens trust, and stimulates an emotional investment that renders the therapeutic journey not only more effective but also more meaningful.

5.3. Recommendations for Clinical Practice

In light of the analyzed evidence, it is clear that DSD should be used with particular focus in anterior aesthetic cases, where patient expectations are highest and visual outcomes are paramount. Its successful implementation, however, requires continuous professional training: the modern clinician must not only master technical skills related to digital photography, facial analysis, and CAD/CAM integration, but also refine communication and relational abilities to engage patients at every stage of treatment. Involving the patient in the digital design process fosters transparency, strengthens trust, and enhances their sense of participation in the therapeutic journey. Equally important is the need to maintain an open and flexible approach, recognizing that in many cases the integration of digital planning with traditional craftsmanship give the best results, balancing technological precision with aesthetic sensibility. This hybrid model represents the most promising path today, as it does not force an exclusive choice between tradition and innovation but rather embraces their collaboration. The choice of restorative materials must also be approached critically, weighing not only the advantages of digital simulations but also the intrinsic characteristics of ceramics and resins, which in specific clinical contexts may remain irreplaceable. In conclusion, Digital Smile Design stands out as a transformative resource for aesthetic dentistry, capable of elevating the technical quality of treatment while amplifying its emotional value. Through a conscious and balanced use that merges digital innovation with clinical expertise and artisanal artistry, it is possible to achieve

rehabilitations that are not only functionally and aesthetically excellent but also deeply meaningful for the patient.

Ultimately, the synthesis of current evidence suggests that Digital Smile Design is not only a valuable adjunct to aesthetic dentistry but also a catalyst for the evolution of clinical practice. By bridging digital innovation with traditional expertise, DSD paves the way for more predictable, efficient, and emotionally engaging treatments. Its relevance extends beyond mere technical precision: the individual is no longer a passive recipient but an active participant in the creation of their own smile. As technologies become increasingly accessible and integrated, the hybrid workflow emerges as the most promising paradigm for the future of aesthetic dentistry. In this light, DSD should be embraced not simply as a tool, but as a transformative approach capable of redefining standards of care, elevating both the scientific rigor and the human meaning of dental rehabilitation.

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