

Eco-Friendly Approaches to Enhance Dental Aesthetics and Patient Satisfaction Using Digital Smile Design: A Systematic Review

Faris Hernando Reviansyah^{1,*}, Azzahra Delvyra Ristin^{1,*}, Wirya Haviz Almughni^{1,*}, Yolanda Yolanda², Veni Takarini³, Sri Susilawati⁴, Maria Komariah⁵

¹Undergraduate Program, Faculty of Dentistry, Universitas Padjadjaran, Sumedang, Indonesia; ²Department of Conservative Dentistry, Faculty of Dentistry, Universitas Padjadjaran, Bandung, Indonesia; ³Department of Dental Materials and Technology, Faculty of Dentistry, Universitas Padjadjaran, Bandung, 40132, Indonesia; ⁴Department of Community Dentistry, Faculty of Dentistry, Universitas Padjadjaran, Bandung, Indonesia; ⁵Department of Fundamental Nursing, Faculty of Nursing, Universitas Padjadjaran, Bandung, Indonesia

*These authors contributed equally to this work

Correspondence: Faris Hernando Reviansyah, Undergraduate Program, Faculty of Dentistry, Universitas Padjadjaran, Sumedang, 45363, Indonesia, Email faris21001@mail.unpad.ac.id

Introduction: Aesthetic outcomes are increasingly vital in dental care, especially in achieving harmony between facial and dental features. Traditional smile design methods rely heavily on clinician judgment, which introduces subjectivity and variability. Digital Smile Design (DSD) offers an eco-friendly and standardized alternative, promoting improved aesthetic outcomes with reduced environmental impact. This systematic review aims to synthesize current evidence regarding the effectiveness and sustainability of DSD in enhancing dental aesthetics and patient satisfaction compared to conventional approaches.

Methods: A systematic review was conducted following PRISMA guidelines. Articles were retrieved from PubMed, Scopus, EBSCO, and ScienceDirect using pre-defined keywords and MeSH terms. Eligible studies included randomized controlled trials and experimental studies published between 2019 and 2024. This review synthesizes evidence regarding the clinical effectiveness and eco-friendly implications of Digital Smile Design (DSD) compared to conventional smile planning, focusing on aesthetic outcomes, patient satisfaction, and environmental sustainability. Quality assessment was performed using the Joanna Briggs Institute (JBI) critical appraisal tools.

Results: Twelve studies met the inclusion criteria. Overall, DSD consistently improved smile aesthetics through enhanced alignment, tooth shape harmony, and lip symmetry. Patient satisfaction was also generally higher with DSD due to its precision, reduced chair time, and less invasive procedures. Many studies also emphasized the eco-friendly benefits of DSD, such as minimized material waste and reduced need for multiple visits.

Conclusion: DSD is an effective and sustainable approach for enhancing dental aesthetics and patient experience. Its adoption in clinical practice may support a shift toward more precise, patient-centered, and environmentally conscious dentistry. However, variations in study design and reporting highlight the need for further standardized research.

Keywords: digital smile design, dental aesthetics, patient satisfaction, eco-friendly dentistry

Introduction

Aesthetics have become crucial in the dental field in order to achieve harmony between facial and dental features.¹ It plays an important role in improving patient's satisfaction with their smile appearance. As the demand for aesthetic dental services grows, so does the need for efficient, reliable, and environmentally conscious methods.² Conventional smile design techniques rely heavily on the clinician's subjective judgment, which can lead to inconsistent outcomes and increased chairside time. Moreover, these traditional workflows such as physical wax-ups, analog impressions, and repeated adjustments can be time-consuming and resource-intensive.^{3,4} As global healthcare systems aim to reduce their environmental footprint, dentistry is being called upon to adopt more sustainable practices. Digital Smile Design (DSD),

as part of the broader digital transformation in dentistry, offers an eco-conscious alternative.^{4,5} The utilization of DSD substantially reduces the use of disposable materials and eliminate redundant clinical procedures, contributing to measurable reductions in material waste, energy use, and patient visits.^{6,7} These findings underscore the dual value of DSD as a tool for both aesthetic excellence and sustainable clinical practice.^{2,3}

DSD is a treatment planning tool used to digitally design a patient's smile, analyzing all aspects from facial to dental features.^{6,8} While DSD is mostly used for aesthetic restoration, it can also be utilized for prosthetic treatment, periodontal surgery, orthodontics, and maxillofacial surgery.⁶ The software tools used for DSD include Adobe Photoshop, Keynote, VisagiSMile, Planmeca Romexis Smile Design, Smile Designer Pro, Aesthetic Digital Smile Design, and DSD App by Coachman.⁹ To achieve a harmonized aesthetic smile in DSD, several principles are applied to both facial and dental features. Facial features, namely the shape of the face and facial profile, could determine the appropriate tooth shape and size for the treatment. The dental midline should be aligned with the midline of the face and perpendicular to the interpupillary line.^{6,10}

Anterior teeth proportions are crucial for achieving the aesthetic smiles. The width of each tooth should remain consistent as it moves posteriorly from the midline, with the ideal width-to-length ratio of the central incisor being around 75–80%.¹¹ This ratio creates a visually pleasing appearance by providing symmetry and dominance in the smile. From the central to the canine, there should be a gradual increase in the mesial inclination. The Zenith point, the highest point of marginal gingiva on each tooth, might be used to utilize mesial inclination. Regarding the interdental contact area, the 50:40:30 rule applies, as it moves posteriorly from the central incisor, the contact point should shift apically. This shift enlarges the incisal embrasure, contributing to the natural aesthetic of the smile.¹² Additionally, only 1 to 3 mm of gum tissue should be visible above the front teeth below the lip line while smiling, with the gum line over the lateral incisors being slightly lower than the central incisor and canine teeth.^{13,14} To improve the aesthetic value of a smile, the gum line should parallel with the lip line or visible gum minimum 1–2 mm and the smile line of the teeth should parallel with the lower lip line.^{13,15}

Using DSD could benefit dental practice by reducing waste and minimizing environmental impact. Hydrocolloid irreversible, dental gypsum and silicone are among the materials used for dental impressions and dental casts, which contribute to waste. By using digital scans and software, DSD reduces the need for disposable impression materials and the production of dental casts.² Furthermore, DSD enables the use of smartphone to take pictures of the patient teeth, which cuts down the number of in-person appointments.^{16,17} Not only time-saving, but it also decreases carbon emissions due to transportation, making the process more sustainable and eco-friendly.

This study aims to evaluate the performance of DSD in designing smiles based on the principles of smile design while also evaluating its eco-friendly benefits. The research will assess the effectiveness of DSD in achieving aesthetic outcomes. Furthermore, this study will assess patient satisfaction in terms of comfort and convenience during the DSD procedure compared to conventional methods. The findings may guide future dental practices and contribute to improving both aesthetic results and patient experience in smile design procedures.

Material and Methods

Design Study

This study was designed as a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review aimed to qualitatively synthesize evidence on the application of DSD in improving dental aesthetics and patient satisfaction. The study protocol was not registered in any database such as PROSPERO or Cochrane.¹⁸

Eligibility Criteria

The inclusion criteria were developed using the PICOS framework:

Population (P): Patients undergoing dental aesthetic treatments, including smile design, anterior tooth restorations, or aesthetic rehabilitation.

Intervention (I): Use of Digital Smile Design (DSD) as a digital tool to enhance treatment precision, esthetic planning, and sustainability.

Comparator (C): Conventional smile design methods based on clinician judgment without digital tools.

Outcomes (O): The outcomes of interest were grouped into three domains, (1) patient satisfaction and reported experience, (2) esthetic and clinical effectiveness, and (3) resource efficiency, with particular attention to material usage and procedural redundancy.

Study design (S): Randomized controlled trials (RCTs) and experimental studies.

Additional inclusion criteria included studies published in peer-reviewed journals in English between 2019 and 2024, with full-text availability. Exclusion criteria involved articles not aligned with the PECOS framework or lacking full access.

Search Strategy

The literature search for this study was carried out from the PubMed, Scopus, and ScienceDirect databases until 9 September 2024. The search was adjusted to Medical Subject Headings (MeSH) with boolean operator keywords as follows

(Digital smile design OR virtual smile design OR digital smile designed OR smile design) AND (Esthetic OR Aesthetic) AND (Dental Veneer OR Laminate Veneer OR Dental Restoration OR Aesthetic Restoration OR Esthetic Restoration OR Dental Prosthetic)

In detail this literature search strategy can be seen in (Table 1).

Table 1 Search Strategy

Database	Term	Keyword	Retrieved
Pubmed	#1	Digital smile design OR virtual smile design OR digital smile designed OR smile design	2,109
	#2	Dental restoration OR Direct Restoration OR Esthetic Restoration	120,292
	#3	Dental Aesthetic OR Dental esthetic	26,506
	Query	(digital smile design OR virtual smile design OR digital smile designed OR smile design) AND (Dental restoration OR Direct Restoration OR Esthetic Restoration) AND (Dental Aesthetic OR Dental esthetic)	288
Scopus	#1	"digital smile design" OR "virtual smile design" OR "digital smile designed" OR "smile design OR digital guided tooth"	146
	#2	"Dental restoration" OR "Direct Restoration" OR "Esthetic Restoration"	209,458
	#3	"Dental Aesthetic" OR "Dental esthetic"	672,260
	Query	("digital smile design" OR "virtual smile design" OR "digital smile designed" OR "smile design OR digital guided tooth") AND ("Dental restoration" OR "Direct Restoration" OR "Esthetic Restoration") AND ("Dental Aesthetic" OR "Dental esthetic")	207
Ebsco	#1	Digital smile design OR virtual smile design OR digital smile designed OR smile design	3,367
	#2	Esthetic OR Aesthetic	26,661
	#3	Dental OR dentistry	174,133
	Query	(digital smile design OR virtual smile design OR digital smile designed OR smile design) AND (Esthetic OR Aesthetic) AND (Dental OR dentistry)	47
ScienceDirect	#1	(digital smile design OR virtual smile design OR digital smile designed OR smile design)	412
	#2	(Esthetic OR Aesthetic)	224,010
	#3	(Dental OR dentistry)	639,996
	Query	("digital smile design" OR "virtual smile design" OR "digital smile designed" OR "smile design" OR "digital guided tooth") AND ("Dental restoration" OR "Direct Restoration" OR "Esthetic Restoration") AND ("Dental Aesthetic" OR "Dental esthetic")	333

Data Extraction

Three examiners (FH, AD, and WH) carried out the data extraction process independently to ensure the consistency and accuracy of the information extracted from each study. Any discrepancies between examiners are resolved through mutual discussion and agreement. In addition, the accuracy of the extracted data was also checked by the supervisor (Y) to ensure the quality and accuracy of the information extracted from each study included in this study.

The extraction data process from this study was carried out manually using an extraction table. Extraction items consisted of (1) author name and year of publication; (2) study characteristics, including study location and research design; (3) study population, including study sample, and the group of teeth; (4) intervention, the use of DSD in dental aesthetic treatment compared to conventional smile design methods; (5) study results, aesthetic outcomes starting from smile harmony, midline lip, lip symmetry, and tooth shape with size. Patient satisfaction and improvement in patient experience. The last one is the measurement of resource efficiency specifically for material usage.

Risk of Bias Assessment

The risk of bias for included studies was assessed using the Joanna Briggs Institute (JBI) critical appraisal tools for randomized controlled trials and quasi-experimental studies. Assessments were performed independently by two reviewers (FH and Y) and discrepancies were resolved through discussion.

Data Synthesis

Due to variability in outcome measures, clinical heterogeneity, and assessment tools across studies, a meta-analysis was not conducted. Instead, a structured narrative synthesis was performed to summarize and compare the findings across studies. Results are presented descriptively, highlighting consistencies, trends, and qualitative patterns related to aesthetic improvement, patient satisfaction, and sustainability.

Results

Study Selection

A total of 875 articles were initially identified through PubMed, Scopus, EBSCO, and ScienceDirect. After removing 84 duplicates and screening titles and abstracts, 791 articles remained. A further screening of full texts led to the inclusion of 12 studies that met all eligibility criteria. The study selection process is illustrated in the PRISMA flow diagram (Figure 1).^{2,17,19–28}

Study Characteristics

The 12 included studies, published between 2019 and 2024, comprised randomized controlled trials (RCTs) and experimental studies. The interventions mainly focused on the application of DSD in various aesthetic dental treatments, including anterior restorations, smile makeovers, veneers, and prosthetic rehabilitations. The control groups employed conventional techniques, such as manual wax-ups and clinician-driven assessments.

The outcome domains assessed included:

1. Smile aesthetics: tooth alignment, smile line, midline lip alignment, buccal corridor symmetry, tooth shape, and size.
2. Patient satisfaction: mostly measured using VAS or structured feedback.
3. Eco-friendly aspects: material use reduction, fewer appointments, and digital planning benefits.

Study settings, sample sizes, and technologies used (eg, CAD/CAM, 3D printing, digital mock-ups) varied, but the general trend favored digital approaches in improving both clinical and experiential outcomes. Summary details are presented in Table 2.

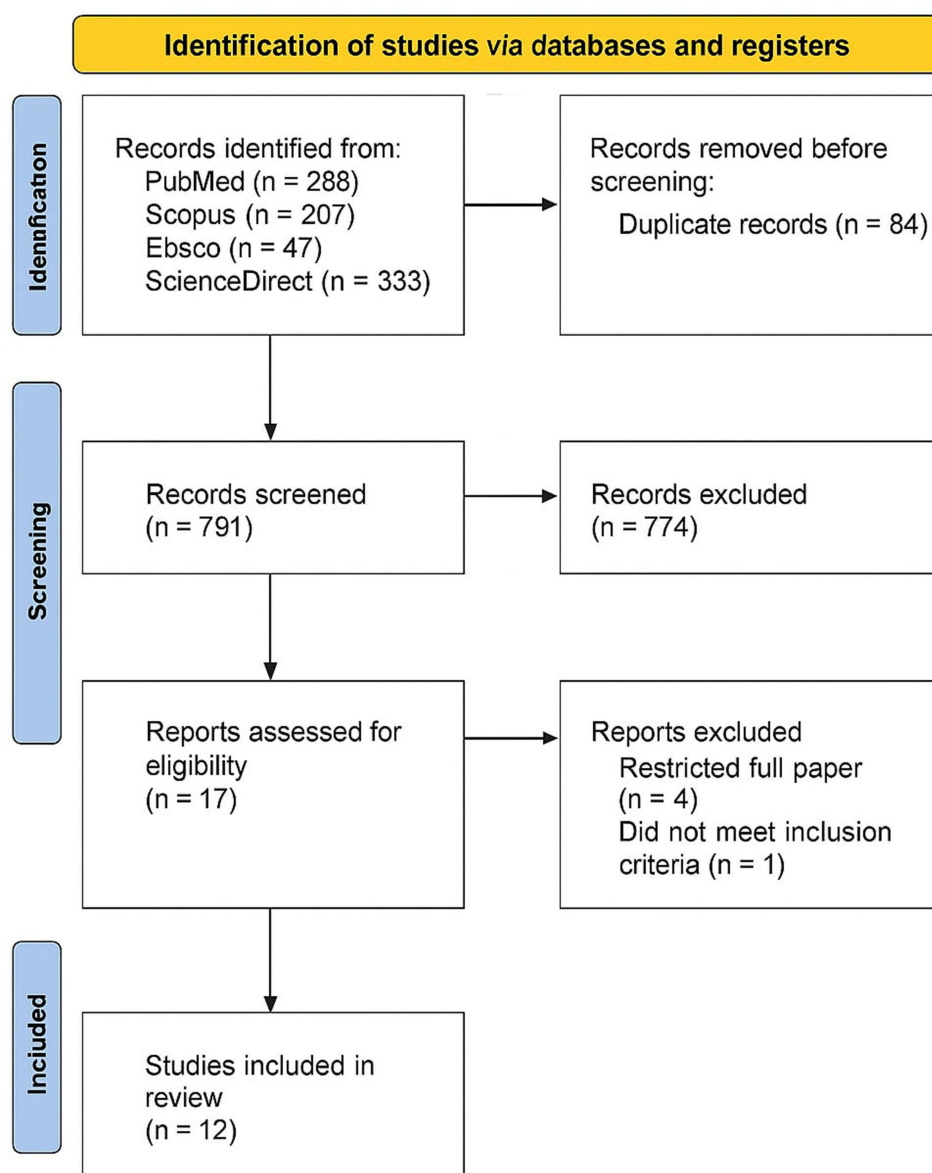


Figure 1 PRISMA Flowchart of study selection.

Aesthetic Outcomes

Most studies reported that DSD significantly enhanced aesthetic parameters compared to traditional methods. Improvements included:

1. Better incisal plane alignment with the lower lip.
2. Improved symmetry of the buccal corridors and dental midlines.
3. Enhanced proportionality in tooth shape and size through digital measurement tools.

For example, Ortensi et al (2022) and Chisnoiu et al (2023) found that DSD produced more accurate and pleasing smile outcomes by aligning teeth with facial landmarks. While conventional methods rely primarily on subjective visual estimation and manual wax-ups, DSD employs digital tools (eg, STL files, 3D models) that allow for objective measurement and enhanced diagnostic accuracy as reported in several studies.

Table 2 Extraction Table

No	Author & Year	Study Design	Population Characteristics		Intervention	Control	Aesthetic Outcome				Secondary Outcomes	
			Age (Mean $\pm$ SD), Total Samples	Dental Treatment			Smile Line	Midline Lip	Lip Symmetry	Tooth Shape and Size	Eco-Friendly Outcomes	Patient Satisfaction Assessment (VAS, Pre and Post-Test)
1	Ortensi et al 2022 ¹⁹	Experimental	30 (Mean)	Anterior teeth restoration	Digital Smile Design	Conventional Methods	Alignment of the incisive plane relative to the lower lip during the patient's smile.	Assessment of the bi-pupillary plane and the median line alignment with the dental midline.	Analyzed by comparing the width of the lateral corridors (the space between the outer edge of the posterior teeth and the cheeks) during the smile.	Linear measurements of teeth were taken: Height from the incisal edge (for incisors) or cusp tip (for canines) to the gingival zenith. Mesial-distal widths at the equator of maxillary central incisors, lateral incisors, and canines.	Not reported	Not reported
2	Agnini et al 2023 ²⁰	Experimental	Not Reported	Smile Makeover	Digital Smile Design	Conventional Methods	Assessed by the alignment of the incisal plane with the lower lip curve	Evaluated by matching dental midline with facial midline	Symmetry measured by comparing lateral corridors during the smile	Linear measurements of tooth height, width, and surface profile using 3D software	Use of digital workflows, 3D printing to reduce waste and streamline processes	Not explicitly reported
3	Silva et al 2019 ¹⁶	Experimental	Not reported	Ceramic veneers preparation	Digital Guided Tooth Preparation (First Fit System)	Traditional preparation techniques	Aligned with upper lip using veneer guides	Evaluated via comparison to facial midline	Evaluated by lateral corridor analysis during smile	Measured with digital tools (CAD/CAM) for height and width	Reduced material waste with 3D-printed guides and fewer appoint	Patient feedback collected during treatment using mock-ups; no VAS scores reported
4	Chisnoiu et al 2023 ²	Experimental	20–25 years	Aesthetic restoration with laminate veneers	Digital wax-up (3D printing with CAD/CAM)	Conventional wax-up (manual technique)	Aligned with lower lip curve	Evaluated through midline alignment	Measured via buccal corridor symmetry	Tooth dimensions (shape, size, and proportion) evaluated	Reduced material waste using 3D printing technology	No VAS scores; general aesthetic score ($p > 0.005$, t-test)
5	Krajangta et al 2022 ¹⁷	Experimental	18–60 years (212 participants)	Smile attractiveness evaluation	Photographs varying in lip thickness, lipstick color, and tooth shade	No control group	Not evaluated	Facial midline alignment assessed	Measured through width of buccal corridors	Not reported	Not reported	VAS scores (0–10 scale); ICC for repeatability = 0.85–0.91; Kruskal–Wallis and pairwise comparisons ($p \leq 0.05$)
6	Lv et al 2022 ²²	Experimental	19–36 years (n = 11, 9 females, 2 males)	Orthodontic, orthognathic, and prosthetic rehabilitation	Interdisciplinary 3D digital simulation workflow	DSD with wax-up	Incisal alignment with lip curve	Midline checked through facial reference	Buccal corridor symmetry measured	Tooth width-length ratio assessed	Reduced material waste through CAD-based workflow	3D plan: 9.0 ± 0.6 vs DSD: 7.1 ± 1.8 ($p < 0.01$)

7	Varghese et al 2021 ²³	Experimental	18–25 years (150 participants: 85 females, 65 males)	Evaluation of maxillary anterior teeth proportions	Geometric analysis using digital photographs	Not applicable	Not evaluated	Not evaluated	Not evaluated	Measured RED proportion, Golden percentage, and Golden rectangle	Not reported	No patient satisfaction scores reported
8	Cattoni et al 2019 ²⁷	Experimental	Not applicable	Aesthetic porcelain veneers	Milled mock-ups from CAD designs	Moulded mock-ups from traditional wax-up	Not reported	Evaluated via alignment of midline and reference points	Assessed through buccal corridor symmetry	STL files analyzed for digital precision (milled)	Use of digital workflow reduced error and minimized operator dependency	No VAS scores; assessed through accuracy ($P < 0.01$) and variance (moulded: 0.0004; milled: 0.00002)
9	Liu et al 2024 ²⁴	Randomized Controlled Trial (RCT)	35.05 ± 5.6 years	Aesthetic crown lengthening for anterior teeth	3D-printed dual guides and temporary restorations	Conventional crown extension using wax-ups	Incisal plane aligned with lower lip curve	Midline checked with facial reference points	Buccal corridor width measured	Marginal gingival level, crown shape, color, contour evaluated	3D printing minimized waste and reduced follow-ups	VAS: Significant difference ($p < 0.01$); DSD: 89.5 ± 5.2, Control: 80.3 ± 6.8
10	Luniyal et al 2024 ²⁵	Randomized Controlled Trial (RCT)	Adult patients (Mean not reported)	Smile enhancement procedures	Digital Smile Design (DSD) with CAD/CAM and 3D simulations	Conventional manual smile design (wax-ups and models)	Evaluated through incisal plane alignment	Midline alignment checked using facial reference points	Lateral buccal corridors assessed for symmetry	Not reported	3D printing reduced waste and enhanced efficiency	DSD: 87.2 ± 6.5, Conventional: 81.5 ± 7.2 (VAS, t-test, $p < 0.001$)
11	Taha et al 2024 ²⁶	Randomized Clinical Trial (RCT)	20–25 (25 participants)	Trial restorations for aesthetic dentistry	Tooth Shape & Size	Partially digital methods (silicone indices)	Evaluated using reference 3D models	Checked with linear reference points	Not explicitly measured	Measured height, width of maxillary incisors, intercanine width	Reduced material waste with digital workflows	No formal VAS; satisfaction measured via restoration accuracy (RMS values)
12	Nouh et al 2021 ²⁸	Randomized Controlled Trial (RCT)	18–30 years	Orthodontic treatment	Smile analysis with DSD software	Class I and Class III groups	Evaluated with incisor alignment	Measured using commissural width and smile symmetry	Not explicitly reported	Tooth height and gingival display analyzed	Not reported	No formal VAS score, subjective satisfaction measured

Patient Satisfaction

Patient satisfaction was consistently higher in groups treated using DSD. Reported benefits included increased comfort, visual predictability of outcomes (via digital mock-ups), and reduced treatment time. VAS scores, when reported, were generally higher for DSD groups, with differences often exceeding 5 to 10 points on a 100-point scale. Liu et al (2024) and Luniyal et al (2024) noted that patients appreciated the clarity and interactivity of the digital design process, leading to higher confidence and satisfaction with treatment results. In contrast, conventional methods that rely on verbal explanations or 2D representations provide limited visual clarity, which may contribute to uncertainty or dissatisfaction, especially in esthetically driven cases. While some studies lacked formal VAS scoring, qualitative feedback supported similar trends.

Eco-Friendly Advantages

A notable advantage of DSD observed across studies was its reduced environmental impact. Many articles cited lower consumption of impression materials (hydrocolloid, gypsum, silicone) due to digital scans and simulations. Additionally, fewer clinic visits were needed thanks to accurate planning and mock-ups, contributing to reduced carbon emissions from patient travel. Krajangta et al (2022) and Taha et al (2024) specifically highlighted how CAD/CAM workflows and 3D printing reduced waste and rework, aligning DSD with green dentistry principles.

Risk of Bias

Risk of bias assessments showed that most studies had moderate to high methodological quality. RCTs generally exhibited good design but sometimes lacked blinding. Experimental studies followed consistent protocols but varied in outcome reporting completeness. Full assessment results are provided in (Figures 2–5).

Discussion

This systematic review highlights the growing potential of DSD as an effective, patient-centered, and environmentally conscious approach in aesthetic dentistry. Based on findings from 12 included studies, DSD demonstrates consistent improvements in smile aesthetics, patient satisfaction, and treatment workflow efficiency compared to conventional smile design methods.³⁰ The use of DSD enhances treatment precision by incorporating advanced digital technologies for planning and implementation. Across multiple studies, DSD was found to improve smile aesthetics by focusing on four core aspects: smile line, midline lip, lip symmetry, and tooth shape and size.³¹ Patients treated using DSD expressed greater satisfaction with their results. Furthermore, the integration of artificial intelligence (AI) into DSD systems represents the next major innovation. AI algorithms are increasingly used to detect facial landmarks, segment teeth, and generate restorative simulations with minimal clinician input. These tools can also analyze smile dynamics and predict optimal esthetic configurations using large datasets.³² Moreover, DSD streamlines processes reduces errors, and promotes sustainable practices through the use of digital workflows and 3D printing technologies as can be seen in (Figure 6).^{33,34}

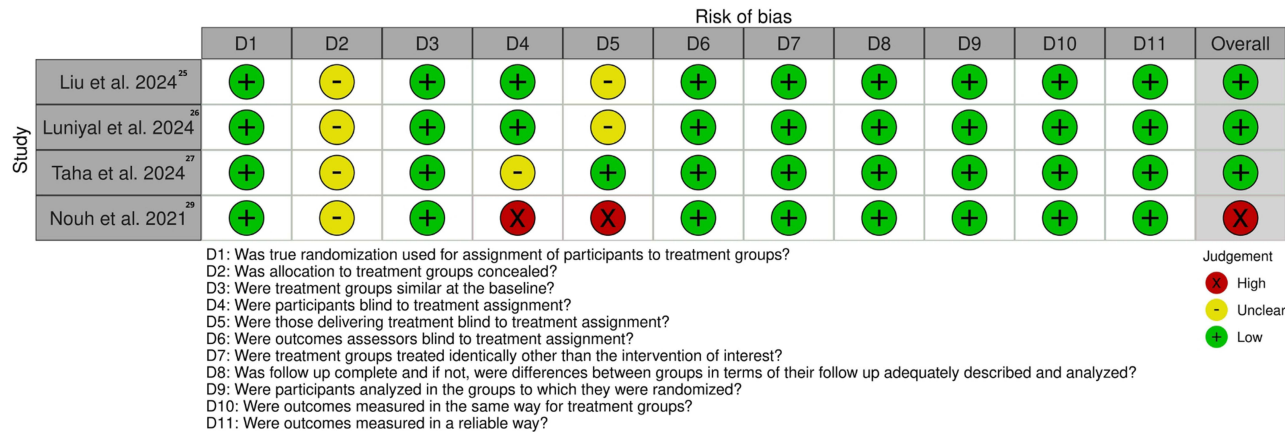


Figure 2 Risk of bias traffic plot for RCTs using the JBI checklist.^{24–26,28}

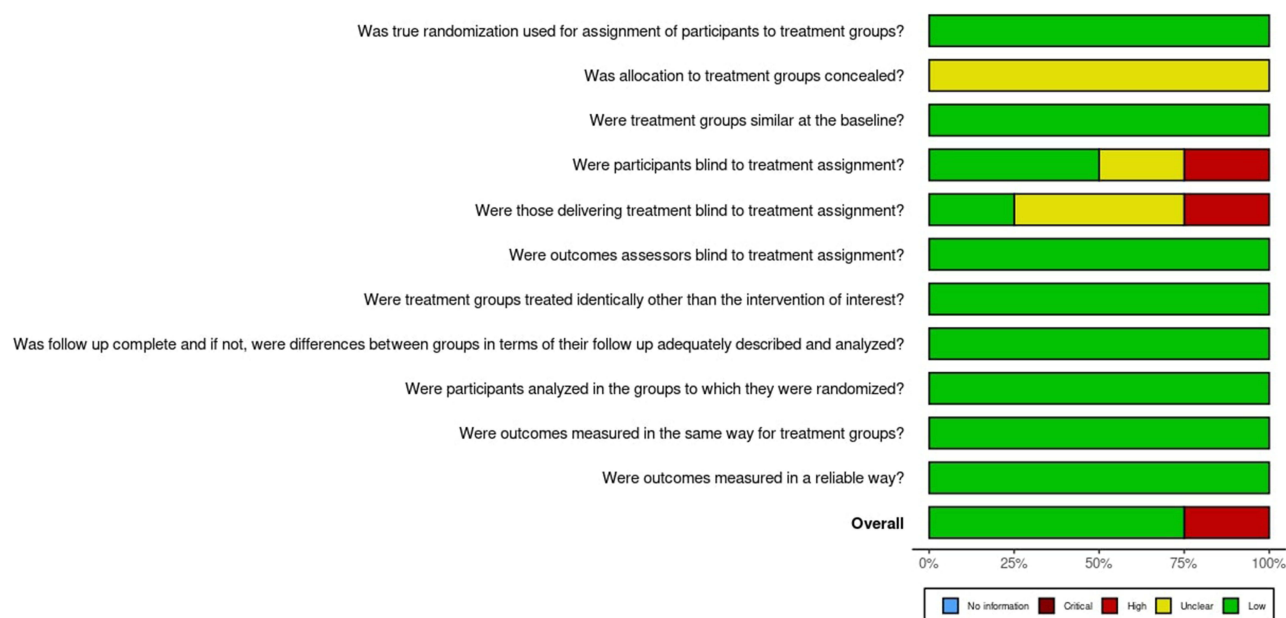


Figure 3 Risk of bias summary plot for RCTs.^{24–26,28}

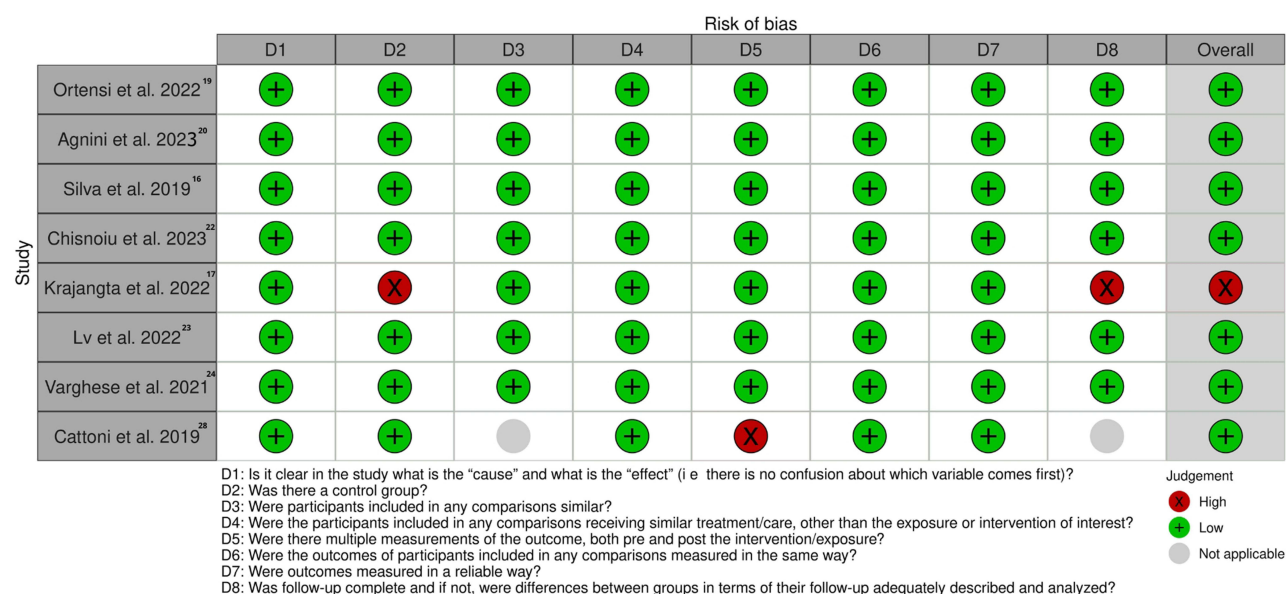


Figure 4 Risk of bias traffic plot for experimental studies using the JBI checklist.^{2,16,17,20,22,23,27,29}

While the studies included in this review primarily reflect conventional 2D and 3D DSD applications, recent innovations indicate a shift toward more dynamic and functional workflows. Merli et al (2025) introduced a personalized 4D DSD protocol that integrates intraoral scanning, CBCT, facial scanning, and jaw motion tracking systems (eg, Modjaw, Zebris) to create a digital twin of the patient.³⁵ This enables previsualization of occlusal and esthetic outcomes in motion, offering an adaptive and reversible pathway to test function and esthetics prior to definitive treatment. Similarly, Ye et al (2019) developed a 4D digital simulation technique that captures a sequence of facial expressions ranging from rest to exaggerated smiles paired with digitally designed restorations.³⁶ By aligning 3D facial scans with intraoral scans and digital wax-ups, their method creates a motion-based esthetic preview, allowing patients and clinicians to visualize proposed restorations

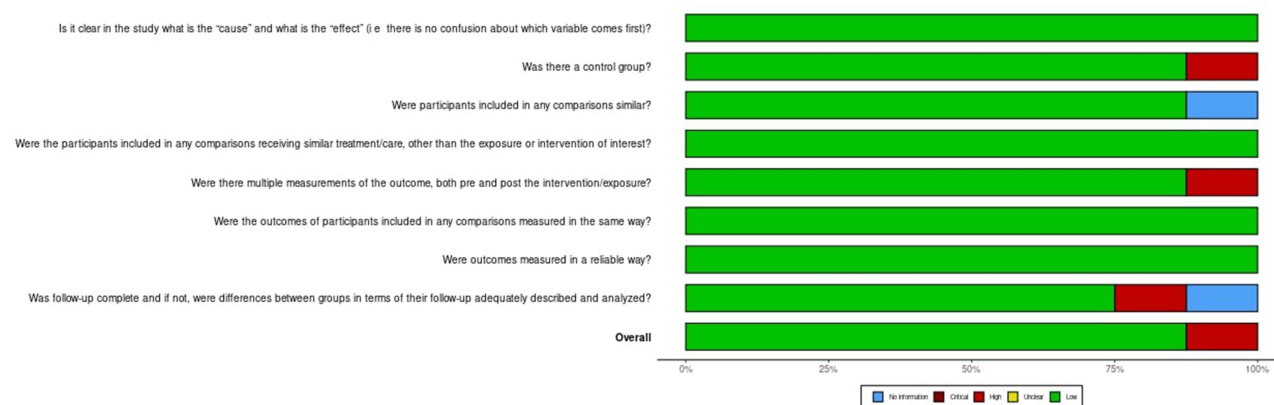


Figure 5 Risk of bias summary plot for experimental studies.^{2,16,17,20,22,23,27,29}

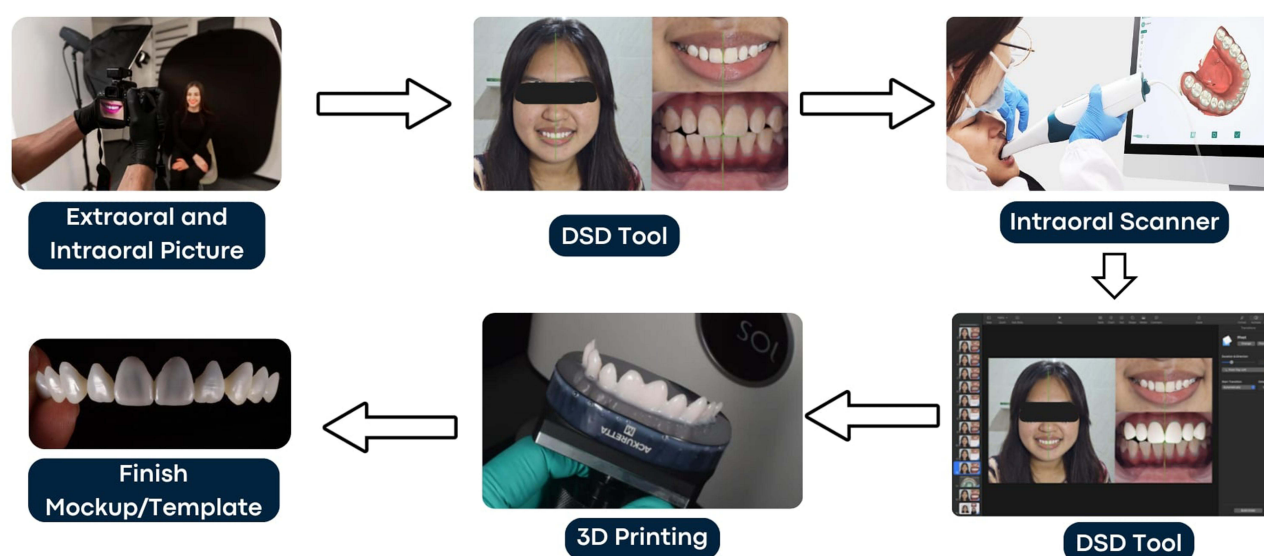


Figure 6 Workflow of Digital Smile Design implementation.

dynamically and make adjustments before finalization. These 4D innovations expand the DSD concept beyond static visualization into patient-specific, time-dependent simulations, improving diagnostic accuracy, communication, and potentially patient satisfaction. Although promising, such approaches remain underrepresented in randomized trials and were therefore not included in the current evidence synthesis.

DSD has shown a consistent capacity to improve clinical aesthetic outcomes compared to traditional smile design techniques. Key parameters such as smile line curvature, tooth proportionality, midline facial alignment, and lip symmetry were more accurately and predictably achieved through digital platforms.⁹ Several studies included in this review emphasized the superiority of digital workflows in mapping facial and dental landmarks with higher precision, thereby improving the planning and execution of aesthetic procedures. For example, Ortensi et al (2022) and Taha et al (2024) demonstrated that the use of DSD significantly improved alignment between the dental midline and the patient's facial features.^{26,29} These enhancements are crucial not only for visual harmony but also for patient perception and acceptance of the final outcome. Chisnoiu et al (2023) further reported that digital mock-ups allowed clinicians to simulate various aesthetic scenarios, enabling a more refined and collaborative treatment planning process between patient and provider.²

The integration of CAD/CAM systems, digital scanners, and photographic analysis tools contributes to greater reproducibility and objectivity, minimizing the subjectivity inherent in clinician-based evaluations. Unlike manual wax-ups, digital

simulations allow for minor adjustments to be made in real-time before final restorations are produced.³⁷ This leads to improved precision in tooth shape and size selection, reduced marginal errors, and enhanced smile proportionality—parameters critical in prosthodontics, orthodontics, and cosmetic dentistry alike.³⁸ Several studies assessed anterior tooth proportions, such as incisal edge position and width-to-length ratios, using DSD tools. While these measurements support visual harmony, their influence on patient satisfaction and treatment efficiency the focus of this review remains inconclusive. Therefore, proportional frameworks were discussed only in relation to their impact on clinical decision-making, not as standalone esthetic ideals. Even if not all studies adopted these frameworks explicitly, the consensus suggests that DSD facilitates the practical application of these aesthetic ideals through quantifiable digital measurements.^{19,23}

Beyond clinical performance, DSD promotes sustainability in dental practices by minimizing material waste and improving efficiency. Conventional methods often generate substantial waste through disposable wax-ups and analog impressions.^{27,39,40} In contrast, Krajangta et al, 2022 noted that digital workflows reduced material consumption by utilizing CAD/CAM technology and 3D printing, streamlining the restoration process.¹⁷ Taha et al, 2024 also highlighted that digital mock-ups in DSD workflows reduced errors and minimized the need for repeated corrections, leading to less waste and fewer follow-up appointments.²⁶ These findings align with the shift toward eco-conscious dentistry, where efficient planning and execution reduce both material consumption and carbon footprint.⁴¹ Furthermore, DSD reduces the need for manual trial-and-error adjustments, leading to fewer discarded materials. As noted by Ortensi et al, 2022, digital tools ensure better first-time accuracy, cutting down on the production of temporary restorations and unnecessary resources.¹⁹ Furthermore, the reduction in follow-up visits not only lowers clinic operational costs but also decreases transport-related emissions, further supporting environmental sustainability in dental practices which affects patient satisfaction results.

Beyond clinical metrics, patient satisfaction emerged as a significant area where DSD offers meaningful advantages. Patients who underwent treatment with DSD consistently reported higher satisfaction levels, particularly in relation to treatment predictability, aesthetic outcome, and overall comfort.⁴² Several studies utilized VAS to measure subjective satisfaction, while others incorporated structured interviews and mock-up trials to gather feedback. Liu et al (2024) and Luniyal et al (2024) highlighted that patients appreciated the opportunity to preview their anticipated smile outcome before the initiation of any irreversible procedures.^{24,25} What is more, DSD has evolved into a critical interdisciplinary tool in comprehensive dental rehabilitation. Sorrentino et al (2024) reported that DSD significantly improves coordination among prosthodontists, orthodontists, and periodontists by facilitating virtual treatment visualization across specialties.⁴³ Their findings highlight that DSD-guided orthodontic planning ensures tooth movement aligns with future restorative and periodontal objectives, while enabling precise previsualization of gingival contour adjustments for crown lengthening or soft tissue harmony. In parallel, Fabbri et al (2018) introduced a Dynamic Diagnostic Approach (DDA), using full-mouth mock-ups created via DSD to assess increased occlusal vertical dimension (OVD) and test function, esthetics, and phonetics before committing to irreversible treatment.⁴⁴ Their findings emphasized that patients adapted more predictably to the new OVD when it was digitally tested, resulting in enhanced comfort and clinical reliability. Supporting these applications in full-arch cases, Al-Hashimi and Purushotam (2025) reviewed DSD's role in geriatric implant-supported rehabilitations, where smile simulation tools were integrated with prosthetic-guided implant placement. Their review concluded that DSD improves communication, enhances surgical-restorative alignment, and boosts patient satisfaction by offering esthetic previews and informed consent before implant surgery.⁴⁵ This ability to visualize the end result fosters greater confidence, emotional involvement, and satisfaction with the process. Patients were more likely to engage in shared decision-making when shown detailed digital projections, reinforcing their trust in the treatment plan.

Furthermore, DSD was associated with reductions in chairside time and the number of clinical visits required factors that enhance the overall patient experience, especially among individuals with busy schedules or dental anxiety.^{29,33,46} Several studies noted that digital workflows minimized the need for manual adjustments or remakes, thereby streamlining the entire course of treatment. In contrast, patients undergoing conventional treatments often relied solely on verbal descriptions or 2D mock-ups, which could lead to mismatched expectations and post-treatment dissatisfaction. The interactive and iterative nature of DSD, by contrast, promotes a higher level of transparency and co-creation between dentist and patient.

Limitations and Variability Across Studies

While this systematic review presents a consistent trend favoring the use of DSD, several limitations should be considered when interpreting the findings. A primary concern is the heterogeneity in study designs, outcome assessment methods, and clinical protocols across the included literature. The studies reviewed employed varying definitions of aesthetic improvement and used a mix of subjective and objective assessment tools, ranging from patient-reported satisfaction scores to digitally measured smile line deviations. This diversity, although reflective of real-world practice, introduces challenges in comparing results directly or drawing standardized conclusions. A significant limitation of the reviewed evidence is the predominance of small-sample, short-term studies, which may not fully capture the long-term effectiveness or sustainability of DSD-based workflows. Future clinical trials with extended follow-up and larger cohorts are necessary to substantiate the observed benefits and evaluate treatment stability.

Another notable limitation lies in the inconsistent use of validated instruments to measure patient satisfaction. Although some studies utilized the VAS or structured feedback mechanisms, others relied solely on narrative impressions or unvalidated survey tools. This inconsistency may impact the comparability and reliability of the reported satisfaction levels. Future studies would benefit from incorporating standardized patient-reported outcome measures (PROMs) to better assess the psychological and emotional impact of smile design.

Blinding and allocation concealment were also inconsistently applied in the randomized controlled trials. In aesthetic dentistry research, double-blinding is inherently difficult due to the visibility of the treatment process and outcomes. However, several studies did not report any efforts to mitigate observer or participant bias, such as using blinded evaluators for outcome assessment. This may introduce performance and detection bias, especially in subjective domains like aesthetics and satisfaction.

The follow-up periods in most studies were relatively short, with many focusing only on immediate or short-term post-treatment outcomes. Long-term data on the durability of aesthetic results and patient perceptions over time remain limited. Moreover, economic evaluations of DSD compared to traditional methods were generally absent, leaving questions unanswered regarding cost-effectiveness and accessibility particularly in resource-limited settings.

Finally, while sustainability and eco-friendliness were frequently mentioned, most studies lacked quantitative environmental impact assessments. Statements about material reduction or emission savings were largely descriptive. As dentistry increasingly moves toward environmentally responsible practices, integrating life cycle assessments or carbon footprint analyses could enhance the scientific rigor of claims surrounding green dental technologies like DSD.

Conclusion

This systematic review underscores the growing clinical and environmental value of DSD as a modern tool in aesthetic and restorative dentistry. Across a diverse range of studies, DSD has demonstrated improvements in treatment precision, aesthetic harmony, and patient satisfaction compared to conventional approaches. Through digital alignment of smile components such as midline position, tooth proportion, and lip curvature DSD supports both functional effectiveness and personalized outcomes. More importantly, DSD contributes to eco-friendly dentistry by reducing reliance on disposable impression materials, minimizing repeat procedures, and lowering patient chair time, all of which lead to less clinical waste and environmental burden. These dual benefits position DSD not only as a technological advancement, but also as a sustainable solution aligned with the global shift toward green healthcare. While findings are promising, variability in study quality suggests the need for more standardized trials focusing on long-term outcomes, cost-effectiveness, and measurable environmental impact. In conclusion, DSD represents a transformative approach that supports esthetic excellence and environmental responsibility in contemporary dental practice.

Ethical and Consent Statements

Figure 6 includes an image of an identifiable individual. Written informed consent for publication of the image was obtained from the individual, in accordance with the journal's ethical requirements. The image is used with permission and does not contain any copyrighted third-party material.

Acknowledgment

We would like to express our gratitude to Universitas Padjadjaran for providing a supportive environment and resources that enabled us to conduct this research. We are grateful for the opportunities. We have had to work with esteemed faculty members and collaborate with talented peers. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. However, the article processing charge (APC) for this publication will be covered by Universitas Padjadjaran.

Disclosure

The authors report no conflicts of interest in this work.

References

- Aljefri M, Williams J. The perceptions of preclinical and clinical dental students to altered smile aesthetics. *BDJ Open*. 2020;6:16. doi:10.1038/s41405-020-00045-2
- Chisnoiu AM, Staicu AC, Kui A, et al. Smile Design and Treatment Planning—Conventional versus Digital—A Pilot Study. *J Personalized Med*. 2023;13(7):1028. doi:10.3390/jpm13071028
- Alshali S, Asali R. Conventional and Digital Workflow Planning for Maxillary Teeth Restoration with Porcelain Laminate Veneers: a Clinical Report. *Clin Cosmet Invest Dent*. 2022;14:45–53. doi:10.2147/CCIDE.S346743
- Mohsin L, Alenezi N, Rashdan Y, et al. Development of AI-Enhanced Smile Design Software for Ultra-Customized Aesthetic Outcomes. *J Pharm Bioallied Sci*. 2025;17(Suppl 2):S1282–4. doi:10.4103/jpbs.jpbs_88_25
- Alikhasi M, Yousefi P, Afrashtehfar KI. Smile Design: mechanical Considerations. *Dental Clin North America*. 2022;66(3):477–487. doi:10.1016/j.cden.2022.02.008
- Cervino G, Fiorillo L, Arzukanyan AV, Spagnuolo G, Cicciù M. Dental Restorative Digital Workflow: digital Smile Design from Aesthetic to Function. *Dentistry J*. 2019;7(2):30. doi:10.3390/dj7020030
- Lobo S, Argolinha I, Machado V, et al. Advances in Digital Technologies in Dental Medicine: enhancing Precision in Virtual Articulators. *J Clin Med*. 2025;14(5):1495. doi:10.3390/jcm14051495
- Thomas PA, Krishnamoorthi D, Mohan J, Raju R, Rajajayam S, Venkatesan S. Digital Smile Design. *J Pharm Bioallied Sci*. 2022;14(Suppl 1):S43–S49. doi:10.4103/jpbs.jpbs_164_22.
- Jafri Z, Ahmad N, Sawai M, Sultan N, Bhardwaj A. Digital Smile Design-An innovative tool in aesthetic dentistry. *J Oral Biol Craniofacial Res*. 2020;10(2):194–198. doi:10.1016/j.jobcr.2020.04.010
- Lucchi P, Fortini G, Preo G, Gracco A, Stefani AD, Bruno G. Golden Mean and Proportion in Dental Esthetics after Orthodontic Treatments: an In Vivo Study. *Dentistry J*. 2022;10(12):235. doi:10.3390/dj10120235
- Cinelli F, Piva F, Bertini F, Russo DS, Giachetti L. Maxillary Anterior Teeth Dimensions and Relative Width Proportions: a Narrative Literature Review. *Dentistry J*. 2023;12(1):3. doi:10.3390/dj12010003
- Kolte AP, Kolte RA, Bawankar P. Proximal contact areas of maxillary anterior teeth and their influence on interdental papilla. *Saudi Dental J*. 2018;30(4):324–329. doi:10.1016/j.sdentj.2018.05.007
- Bhuvaneshwaran M. Principles of smile design. *J Conserv Dent*. 2010;13(4):225–232. doi:10.4103/0972-0707.73387
- Ostler L. The 21 Principles of Smile Design Your Guide to a More Attractive Confident Smile. 2010:9–33.
- Pham TAV, Nguyen PA. Morphological features of smile attractiveness and related factors influence perception and gingival aesthetic parameters. *Int Dental J*. 2022;72(1):67–75. doi:10.1016/j.identj.2021.02.001
- Silva BP, Mahn E, Stanley K, Coachman C. The facial flow concept: an organic orofacial analysis—the vertical component. *J Prosthetic Dentistry*. 2019;121(2):189–194. doi:10.1016/j.prosdent.2018.03.023
- Krajangta N, Phumpatrakom P, Supachartwong C, Kamolwarin P, Leelaponglit S. Influence of Lip Appearances and Tooth Shade on Smile Attractiveness Perception. *Int J Dent*. 2022;2022:5952643. doi:10.1155/2022/5952643
- Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. doi:10.1136/bmj.n71
- Ortensi L, Lo Castro E, Rapisarda E, Pedullà E. Accuracy of trial restorations from virtual planning: a comparison of two fabrication techniques. *J Prosthet Dent*. 2022;127(3):425–429. doi:10.1016/j.prosdent.2020.08.040
- Agnini A, Romeo D, Giulia B, Tommaso W, Christian C, Agnini A. Copy-paste concept: full digital approach in the management of gingival emergence profiles. *J Esthet Restor Dent*. 2023;35(1):222–229. doi:10.1111/jerd.13014
- Silva NRFA, Kukucka ED. Innovative subtractive production of a digital removable complete denture from start to finish: a JPD Digital video presentation. *J Prosthet Dent*. 2022;127(1):1–5. doi:10.1016/j.prosdent.2021.12.002
- Lv L, He W, Ye H, et al. Interdisciplinary 3D digital treatment simulation before complex esthetic rehabilitation of orthodontic, orthognathic and prosthetic treatment: workflow establishment and primary evaluation. *BMC Oral Health*. 2022;22(1):34. doi:10.1186/s12903-022-02070-z
- Varghese P, Cherian B, Sukumaran B, Anu S, Jacob BM, Raja VV. Analysis of Geometric Proportions on Maxillary Anterior Teeth for Esthetic Smile Design: an In vivo Study. *J Pharm Bioallied Sci*. 2021;13(Suppl 1):S778–82. doi:10.4103/jpbs.JPBS_808_20
- Liu J, Maihemaiti M, Ren L, et al. A comparative study of the use of digital technology in the anterior smile experience. *BMC Oral Health*. 2024;24(1):492. doi:10.1186/s12903-024-04228-3

25. Luniyal C, Shukla AK, Priyadarshi M, et al. Assessment of Patient Satisfaction and Treatment Outcomes in Digital Smile Design vs. Conventional Smile Design: a Randomized Controlled Trial. *J Pharm Bioallied Sci.* 2024;16(Suppl 1):S669–71. doi:10.4103/jpbs.jpbs_928_23
26. Taha D, Allam S, Morsi T. Accuracy of computer-aided design trial restorations fabricated with different digital workflows. *J Prosthet Dent.* 2024;132(3):578–585. doi:10.1016/j.prosdent.2023.09.034
27. Cattoni F, Teté G, Calloni AM, Manazza F, Gastaldi G, Capparè P. Milled versus moulded mock-ups based on the superimposition of 3D meshes from digital oral impressions: a comparative in vitro study in the aesthetic area. *BMC Oral Health.* 2019;19(1):230. doi:10.1186/s12903-019-0922-2
28. Noh AS, Abdel Majeed HM, Nassef Selim EM. Evaluation of smile characteristics of skeletal Class III compared to skeletal Class I female adults. *J Orthod Sci.* 2021;10(1):18. doi:10.4103/jos.JOS_79_20
29. Ortensi L, Sigari G, La Rosa GRM, Ferri A, Grande F, Pedullà E. Digital planning of composite customized veneers using Digital Smile Design: evaluation of its accuracy and manufacturing. *Clin Exp Dent Res.* 2022;8(2):537–543. doi:10.1002/cre2.570
30. Guo D, Zhou Z, Sun K, et al. Fully digital workflow of occlusal reconstruction treatment in a patient with congenital dentition defects. *J Esthet Restor Dent.* 2024;36(9):1236–1248. doi:10.1111/jerd.13234
31. Al-Khudhairi MW, Suganna M, Aldhafeeri DT, et al. Awareness of Golden Proportion in Tooth Forms Among Dental Scholars in Saudi Arabia: a Cross-Sectional Study. *Cureus.* 2023;15(6):e40619. doi:10.7759/cureus.40619
32. SMSYH A, Morsi TS, Taha DTS. Comparison of Dental Mock-ups manufactured by different techniques: molded and Milled (an in vitro study). *Ain Shams Dental J.* 2023;30(2):22–26. doi:10.21608/asdj.2022.148922.1129
33. Ahmed WM, Althagafi RA. Smile Makeover Utilizing Digital Esthetic Veneers Workflow: a Case Report. *Int J Prosthodontics Restorat Dent.* 2023;12(3):145–148. doi:10.5005/jp-journals-10019-1366
34. Ahmed WM, Azhari AA, Sedayo L, et al. Mapping the Landscape of the Digital Workflow of Esthetic Veneers from Design to Cementation: a Systematic Review. *Dent J.* 2024;12(2). doi:10.3390/dj12020028.
35. Merli M, Aquilanti L, Casucci A, et al. A Personalized 4D Workflow for the Manufacturing of Functional and Removable Esthetic Devices: a Technical Report. *J Esthet Restor Dent.* 2025;37(7):1645–1654. doi:10.1111/jerd.13454
36. Ye H, Wang KP, Liu Y, Liu Y, Zhou Y. Four-dimensional digital prediction of the esthetic outcome and digital implementation for rehabilitation in the esthetic zone. *J Prosthetic Dent.* 2020;123(4):557–563. doi:10.1016/j.prosdent.2019.04.007
37. Lim JH, Park JM, Kim M, Heo SJ, Myung JY. Comparison of digital intraoral scanner reproducibility and image trueness considering repetitive experience. *J Prosthetic Dent.* 2018;119(2):225–232. doi:10.1016/j.prosdent.2017.05.002
38. Gawali N, Shah PP, Gowdar IM, Bhavsar KA, Giri D, Laddha R. The Evolution of Digital Dentistry: a Comprehensive Review. *J Pharm Bioallied Sci.* 2024;16(Suppl 3):S1920–2. doi:10.4103/jpbs.jpbs_11_24
39. Jurado CA, Villalobos-Tinoco J, Mekled S, Sanchez R, Afrashtehfar KI. Printed Digital Wax-up Model as a Blueprint for Layered Pressed-ceramic Laminate Veneers: technique Description and Case Report. *Operative Dent.* 2023;48(6):618–626. doi:10.2341/22-144-S
40. Akl MA, Wee AG. From Virtual Smile Design to Guided Wax-up Using Adobe Photoshop. *Int J Prosthodontics Restorat Dent.* 2020;10(4):176–179. doi:10.5005/jp-journals-10019-1293
41. Lee JH, Kim SH, Han JS, Yeo ISL, Yoon HI. Contemporary full-mouth rehabilitation using a digital smile design in combination with conventional and computer-aided design/manufacturing restorativematerials in a patient with bruxism: a case report. *Medicine.* 2019;98(48):e18164. doi:10.1097/MD.00000000000018164
42. Sari A, Amanda V, Marshall D, Sani F. Digital Smile Design: patient Satisfaction and Long-Term Outcomes of a Novel Approach to Esthetic Dentistry in Jakarta, Indonesia. *Crown: J Dentistry Health Res.* 2023;1(1):25–37.
43. Sorrentino R, Zarone F, Cantile T, Mastrosimone A, Cervino G, Ruggiero G. The Use of Digital Tools in an Interdisciplinary Approach to Comprehensive Prosthodontic Treatments. *Prosthesis.* 2024;6(4):863–870. doi:10.3390/prosthesis6040062
44. Fabbri G, Cannistraro G, Pulcini C, Sorrentino R. The full-mouth mock-up: a dynamic diagnostic approach (DDA) to test function and esthetics in complex rehabilitations with increased vertical dimension of occlusion. *Int J Esthet Dent.* 2018;13(4):460–474.
45. Al-Hashimi H, Purushotam DP. Comprehensive Literature Review on Smile Analysis and Design for Geriatric Full Mouth Rehabilitation with Dental Implants. *Int J Comprehensive Health Med Dent.* 2025;1(1):24–39.
46. Altarakemah Y, Akbar J, Akthar S, Qudeimat MA, Omar R. Evaluation of a Technique for Reducing Chairside Occlusal Adjustment of Crowns. *J Prosthodontics.* 2021;30(2):183–188. doi:10.1111/jopr.13252

Clinical, Cosmetic and Investigational Dentistry

Publish your work in this journal

Clinical, Cosmetic and Investigational Dentistry is an international, peer-reviewed, open access, online journal focusing on the latest clinical and experimental research in dentistry with specific emphasis on cosmetic interventions. Innovative developments in dental materials, techniques and devices that improve outcomes and patient satisfaction and preference will be highlighted. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/clinical-cosmetic-and-investigational-dentistry-journal>

Dovepress
Taylor & Francis Group