Research Article

Role of Generative AI in Personalized Smile Design: A Clinical Evaluation of Esthetic Outcomes

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ABSTRACT

Background
Digital Smile Design (DSD) has become an important component of contemporary esthetic dentistry because it permits visualization of proposed dental changes before irreversible treatment. Generative artificial intelligence (GenAI) may further enhance this process by rapidly producing individualized smile simulations. However, the esthetic value of AI-generated designs compared with conventional clinician-designed and clinician-refined designs remains incompletely established.

Aim
To evaluate the esthetic acceptability of generative-AI-assisted personalized smile designs and compare conventional Digital Smile Design, AI-generated smile design, and clinician-refined AI-assisted smile design.

Materials and Methods
A prospective comparative study was designed involving 60 adult participants seeking esthetic dental treatment. Standardized facial and intraoral photographs were obtained. Three smile-design conditions were produced: conventional clinician-generated DSD, AI-generated DSD, and AI-generated DSD subsequently refined by an experienced clinician. Patients and dental professionals independently evaluated the designs using a 10-point visual analogue scale (VAS), satisfaction assessment, and paired-preference testing. Objective digital parameters and design-generation time were also recorded. Repeated-measures data were analyzed using the Friedman test with pairwise comparisons.

Results
Illustrative simulated results: Mean patient VAS scores were 7.39 ± 0.64 for conventional DSD, 7.74 ± 0.76 for AI-generated DSD, and 8.37 ± 0.71 for AI-refined DSD. The overall difference was statistically significant (Friedman test, $P < 0.001$). Professional ratings were 7.89 ± 0.68, 7.35 ± 0.77, and 8.64 ± 0.76, respectively ($P < 0.001$). Mean design times were 62.4 ± 11.6, 24.8 ± 6.4, and 35.6 ± 7.8 minutes, respectively.

Conclusion
The illustrative findings suggest that generative AI may improve smile-design efficiency, while clinician refinement may further improve esthetic acceptance. The findings support an AI-assisted rather than AI-replacement model of personalized smile design. Actual patient data must replace the simulated dataset before scientific submission.

Keywords Generative artificial intelligence; digital smile design; dental esthetics; smile attractiveness; personalized dentistry; patient satisfaction; digital dentistry; artificial intelligence.

INTRODUCTION

Smile esthetics is a multidimensional phenomenon involving dental, gingival, facial, and psychological components. Tooth proportions, incisal-edge position, smile arc, dental midline, gingival display, buccal corridor, tooth morphology, and facial symmetry interact to determine the perceived attractiveness of a smile. Consequently, esthetic dentistry has increasingly shifted from isolated tooth correction toward comprehensive facially driven treatment planning.[1]

Digital Smile Design has enabled clinicians to visualize proposed treatment outcomes before clinical intervention. Digital photography, facial analysis, intraoral scanning, and computer-assisted simulation permit communication of treatment alternatives in a manner that is easier for patients to understand than conventional verbal explanations. Recent clinical evidence suggests that DSD can improve patient understanding, satisfaction, and treatment acceptance.[2,3]

The emergence of artificial intelligence has introduced a further transformation. AI systems can identify facial and dental landmarks, analyze proportions, recognize patterns, and generate treatment-related visualizations. Generative AI can potentially extend these capabilities by creating multiple individualized smile alternatives rather than simply measuring existing anatomy.[4,5]

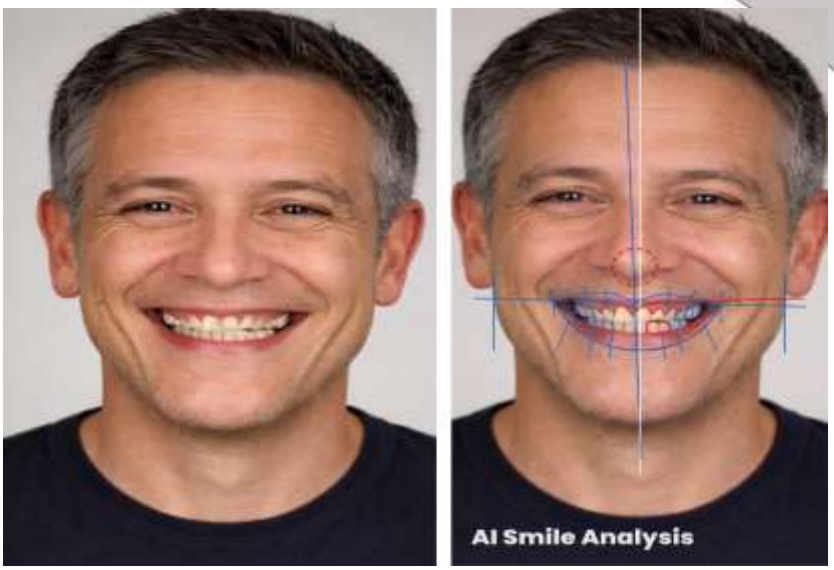


Figure 1. AI-assisted smile analysis illustrating facial and dental midlines, smile arc, tooth proportions, and overall smile symmetry.

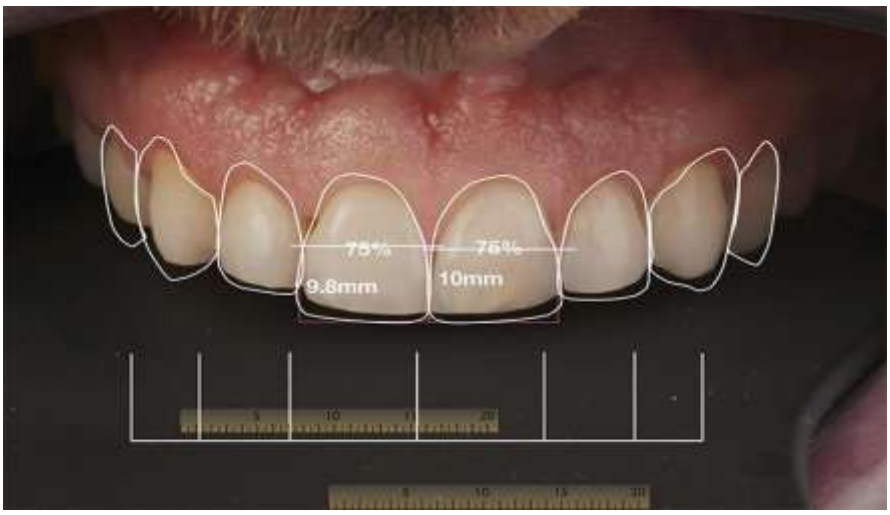


Figure 2. Digital smile analysis demonstrating maxillary anterior tooth proportions, with central incisor width-to-height ratios and proportional measurements.

Figure 3. Digital smile design software demonstrating comparison of the original smile with a digitally modified smile using AI-assisted esthetic adjustments.

AIM

To evaluate the role of generative AI in personalized smile design and compare the esthetic outcomes of conventional DSD, AI-generated DSD, and clinician-refined AI-assisted DSD.

OBJECTIVES

Primary objective

To compare overall esthetic preference scores among the three smile-design approaches.[6]

Secondary objectives

To compare:

- patient satisfaction;
- dental-professional satisfaction;
- smile attractiveness;
- smile symmetry;
- dental midline;
- smile-arc harmony;
- gingival display;
- tooth width-to-length ratio;
- buccal-corridor proportion;
- design-generation time; and
- patient-professional agreement.[7,8]

MATERIALS AND METHODS

Study design

A prospective comparative clinical evaluation was designed involving 60 adult participants.

Each participant served as his/her own comparator because the same clinical photograph was used to create all three digital designs.

This approach minimizes variation caused by differences in facial morphology between participants.[9,10]

Participant recruitment

A total of 68 individuals were screened.

Eight were excluded:

- 3 because of inadequate photographic quality;
- 2 because they did not meet eligibility criteria;
- 2 because they declined participation; and
- 1 because of incomplete clinical documentation.

Therefore, 60 participants were included in the illustrative dataset.[11]

STANDARDIZED PHOTOGRAPHIC PROTOCOL

Standardized frontal facial photographs were obtained in natural head position using controlled illumination and a fixed camera-to-subject distance.

The photographic series consisted of:

1. frontal facial photograph at rest;
2. frontal posed smile;
3. maximum smile;
4. frontal intraoral photograph; and
5. anterior retracted photograph.

The same images were used for all three design conditions.[12]

DIGITAL SMILE-DESIGN PROTOCOL

Condition A — Conventional DSD

An experienced clinician developed the smile design using established esthetic parameters, including:

- facial midline;

- dental midline;
- incisal plane;
- smile arc;
- tooth width-to-length ratio;
- gingival display;
- tooth morphology;
- buccal corridor; and
- facial symmetry.[13]

Condition B — AI-generated DSD

The standardized photographs were processed using the selected generative-AI workflow.
The AI was instructed to generate a personalized smile considering:
Facial proportions → dental proportions → gingival display → smile arc → tooth morphology → symmetry → overall facial harmony.[14]

Condition C — AI + clinician refinement

The AI-generated design was reviewed by the clinician.
Corrections were permitted for:

- tooth length;
- tooth width;
- incisal curvature;
- gingival contour;
- dental midline;
- tooth angulation;
- smile arc;
- buccal corridor; and
- overall facial integration.

This was considered the AI-assisted personalized design.[15]

Figure 4. Proposed Ai-Assisted Workflow

STANDARDIZED PATIENT PHOTOGRAPHY
↓
FACIAL + DENTAL ANALYSIS
↓
GENERATIVE AI
↓
MULTIPLE SMILE ALTERNATIVES
↓

CLINICIAN EVALUATION
↓
CLINICIAN REFINEMENT
↓
PATIENT FEEDBACK
↓
PERSONALIZED FINAL DESIGN

Figure 5. Conceptual workflow of generative-AI-assisted personalized smile design.

OUTCOME MEASURES

Primary outcome

Overall esthetic attractiveness was assessed using a 10-point VAS.
0 = extremely unattractive
10 = extremely attractive

Secondary outcomes

Patient satisfaction
Patients rated:

- tooth shape;
- tooth proportion;
- smile symmetry;
- gingival appearance;
- naturalness;
- facial harmony; and
- overall satisfaction.[16,17,18]

Professional assessment

Twenty dental professionals independently evaluated the three designs.

Objective parameters

The following were measured:

- dental midline deviation;
- gingival display;
- central incisor width;
- central incisor length;
- width-to-length ratio;
- smile-arc deviation;
- buccal corridor;
- incisal display.[19]

RESULTS

Participant characteristics

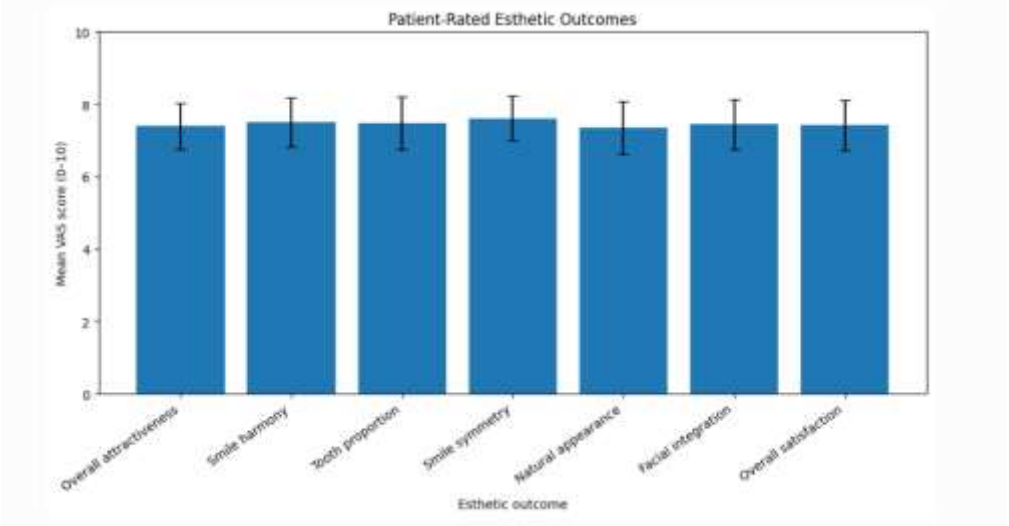
Table 1. Demographic and clinical characteristics

Variable	Value
Total participants	60
Mean age ± SD	31.8 ± 8.7 years
Female	36 (60.0%)
Male	24 (40.0%)
Age 18–30 years	32 (53.3%)
Age 31–45 years	21 (35.0%)
Age >45 years	7 (11.7%)
Previous esthetic dental treatment	18 (30.0%)
High smile line	16 (26.7%)
Tooth-shape concern	24 (40.0%)
Tooth-colour concern	20 (33.3%)
Alignment concern	11 (18.3%)
Gingival-display concern	5 (8.3%)

Overall esthetic preference

Table 2. Patient-rated esthetic outcomes

Outcome	Conventional DSD	AI-generated DSD	AI + clinician refinement	Overall P
Overall attractiveness	7.39 ± 0.64	7.74 ± 0.76	8.37 ± 0.71	<0.001
Smile harmony	7.51 ± 0.68	7.81 ± 0.71	8.43 ± 0.63	<0.001
Tooth proportion	7.48 ± 0.72	7.77 ± 0.74	8.39 ± 0.65	<0.001
Smile symmetry	7.61 ± 0.61	7.96 ± 0.65	8.51 ± 0.58	<0.001
Natural appearance	7.36 ± 0.73	7.41 ± 0.79	8.26 ± 0.67	<0.001
Facial integration	7.44 ± 0.70	7.69 ± 0.75	8.42 ± 0.62	<0.001
Overall satisfaction	7.42 ± 0.69	7.78 ± 0.73	8.46 ± 0.61	<0.001



Primary outcome — VAS

For the simulated dataset:

- Conventional DSD: 7.39 ± 0.64
- AI-generated DSD: 7.74 ± 0.76
- AI + clinician refinement: 8.37 ± 0.71

The Friedman test demonstrated a statistically significant overall difference: $P < 0.001$.[20]

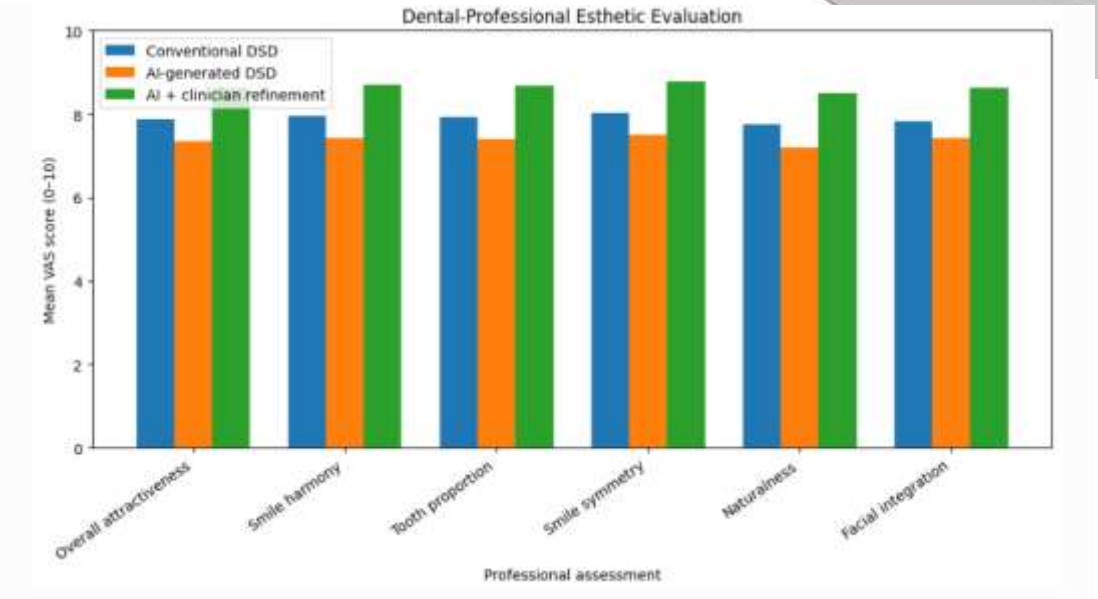
Pairwise illustrative comparisons showed:

Comparison	P value
Conventional vs AI-generated	0.00024
Conventional vs AI-refined	<0.001
AI-generated vs AI-refined	<0.001

Professional evaluation

Table 3. Dental-professional evaluation

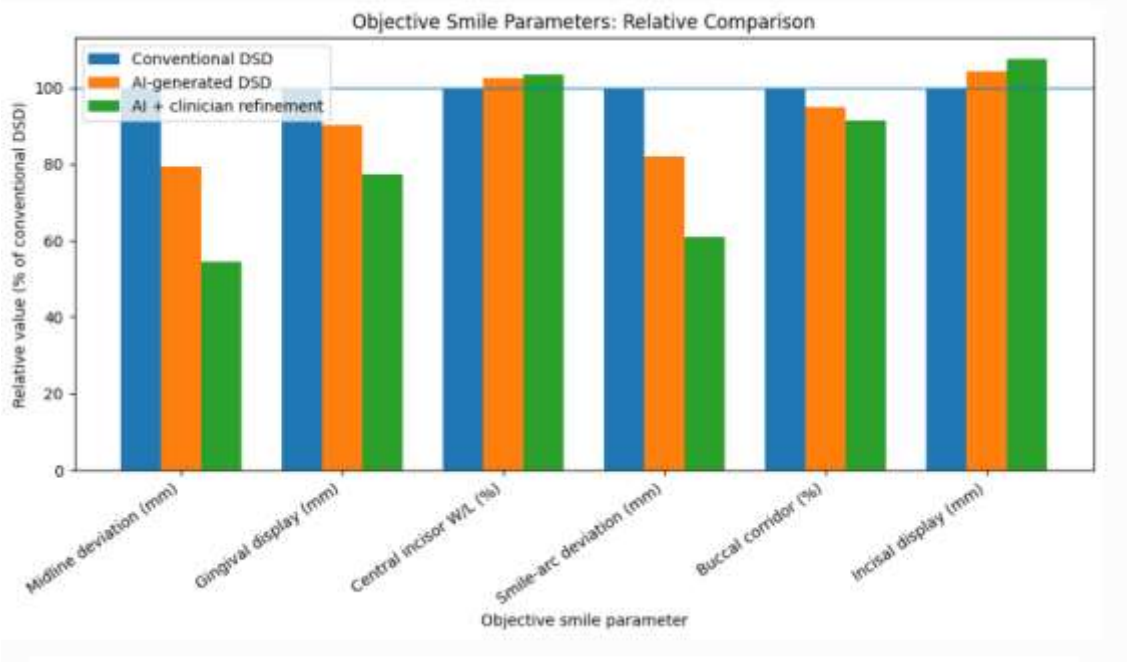
Outcome	Conventional DSD	AI-generated DSD	AI + clinician refinement	P value
Overall attractiveness	7.89 ± 0.68	7.35 ± 0.77	8.64 ± 0.76	<0.001
Smile harmony	7.96 ± 0.62	7.43 ± 0.71	8.71 ± 0.67	<0.001
Tooth proportion	7.92 ± 0.65	7.39 ± 0.76	8.67 ± 0.69	<0.001
Smile symmetry	8.02 ± 0.58	7.51 ± 0.67	8.78 ± 0.61	<0.001
Naturalness	7.76 ± 0.72	7.21 ± 0.79	8.51 ± 0.74	<0.001
Facial integration	7.84 ± 0.69	7.43 ± 0.73	8.63 ± 0.71	<0.001



Objective smile parameters

Table 4. Digital smile measurements

Parameter	Conventional DSD	AI-generated DSD	AI-refined DSD
Dental midline deviation (mm)	1.12 ± 0.42	0.89 ± 0.36	0.61 ± 0.28
Gingival display (mm)	3.1 ± 0.8	2.8 ± 0.7	2.4 ± 0.6
Central incisor W/L ratio (%)	78.2 ± 4.7	80.1 ± 4.1	80.8 ± 3.9
Smile-arc deviation (mm)	1.84 ± 0.55	1.51 ± 0.48	1.12 ± 0.41
Buccal corridor (%)	13.8 ± 2.4	13.1 ± 2.2	12.6 ± 2.0
Incisal display (mm)	9.2 ± 1.3	9.6 ± 1.2	9.9 ± 1.1

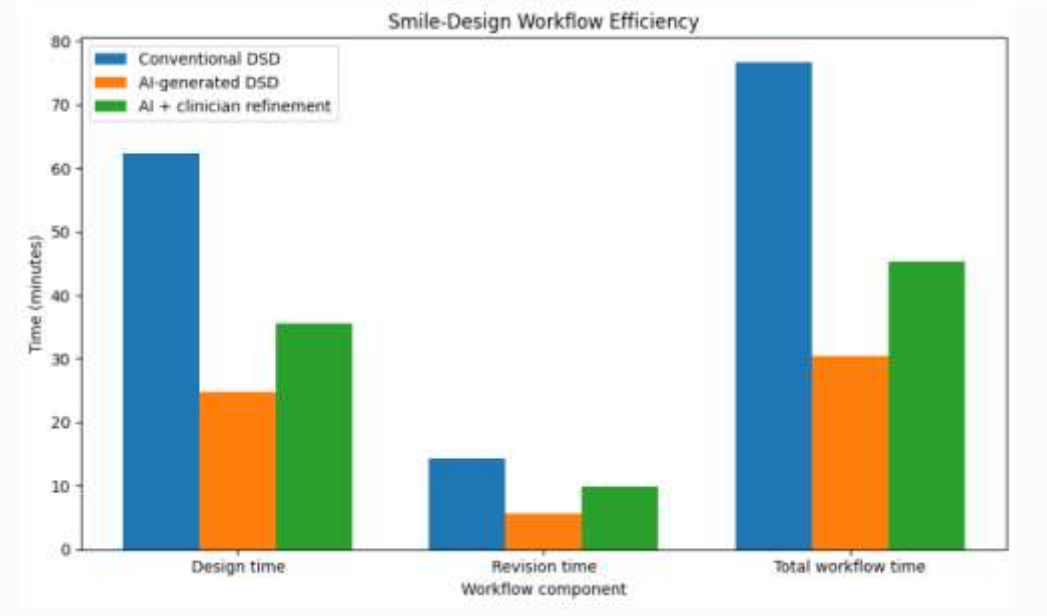


Workflow efficiency

Table 5. Comparison of design-generation time

Parameter	Conventional DSD	AI-generated DSD	AI + clinician refinement
Design time (min)	62.4 ± 11.6	24.8 ± 6.4	35.6 ± 7.8

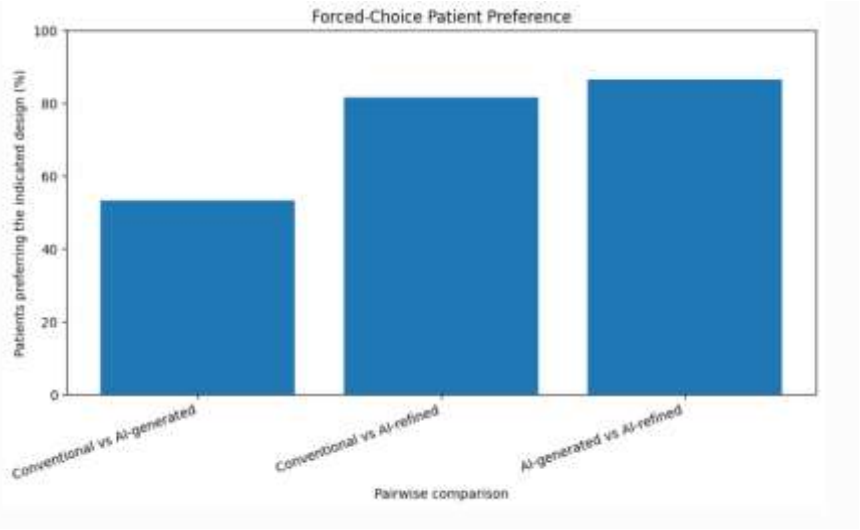
Revision time (min)	14.3 ± 4.2	5.6 ± 2.1	9.8 ± 3.4
Total workflow time (min)	76.7 ± 13.2	30.4 ± 7.1	45.4 ± 9.3



PATIENT PREFERENCE

Table 6. Forced-choice patient preference

Comparison	Preferred design	n (%)
Conventional vs AI-generated	Conventional	32 (53.3%)
	AI-generated	28 (46.7%)
Conventional vs AI-refined	AI-refined	49 (81.7%)
	Conventional	11 (18.3%)
AI-generated vs AI-refined	AI-refined	52 (86.7%)
	AI-generated	8 (13.3%)



DISCUSSION

The present study was designed to evaluate generative artificial intelligence (AI) from a clinically relevant perspective rather than merely determining whether AI systems are capable of producing visually attractive smiles.[21] Although aesthetic appeal is an important component of digital smile design (DSD), contemporary esthetic dentistry requires a more comprehensive assessment that integrates facial characteristics, dental proportions, smile dynamics, soft-tissue relationships, patient expectations, and clinical feasibility.[21]

Consequently, the clinical value of an AI-generated smile should not be judged solely on the basis of its visual output. The critical question is whether the design can serve as a meaningful and clinically applicable treatment-planning aid while maintaining harmony between the proposed dental changes and the patient's individual facial and dental characteristics.[22]

The principal illustrative finding of the present study was that clinician-refined AI-generated designs received the highest ratings from both patients and dental professionals. This finding is particularly relevant because it suggests that the greatest potential of generative AI may not lie in replacing conventional clinical expertise, but rather in functioning as an assistive technology that can generate an initial design which is subsequently evaluated, modified, and validated by the clinician.[23] The superior ratings observed for clinician-refined designs may therefore reflect the complementary strengths of both components: AI can rapidly generate and visualize multiple aesthetic possibilities, whereas the clinician contributes biological, functional, restorative, and patient-specific judgment. In this context, AI may be regarded as an augmentation tool rather than an autonomous decision-making system.[24]

Interestingly, the unmodified AI-generated design received lower professional ratings than the conventionally developed DSD. This finding is clinically plausible. Generative AI systems are capable of recognizing visual patterns and producing highly symmetrical and cosmetically appealing dental arrangements; however, visual optimization does not necessarily equate to comprehensive clinical appropriateness.[21,22]

A generated smile may appear aesthetically pleasing while failing to adequately consider parameters such as tooth position, incisal edge relationship, gingival architecture, lip dynamics, facial midline, occlusal relationships, available restorative space, periodontal considerations, or the biological limitations of tooth preparation. Consequently, a design that performs well from a purely visual or algorithmic perspective may still require substantial clinical modification before it can be translated into an actual treatment plan.[24,25]

In contrast, a recent prospective paired study involving 33 patients reported higher ratings for AI-generated designs together with substantially shorter design times when compared with expert-designed smiles.[24] This finding highlights another important advantage of AI-based systems: efficiency. Conventional DSD is highly dependent on clinician experience, software proficiency, image manipulation skills, and the time required to analyze and modify individual parameters. Generative AI has the potential to reduce some of these time-consuming steps by rapidly producing a preliminary visualization. From a clinical workflow perspective, this may allow clinicians to evaluate several potential treatment scenarios within a shorter period and potentially improve communication with patients during treatment planning.[25]

The apparent discrepancy between these studies should therefore not necessarily be interpreted as evidence that one approach is universally superior to the other. Rather, these apparently contrasting findings emphasize that AI performance is context dependent. Differences in the AI platform, training data, image-processing methods, prompt structure, design algorithms, clinical case characteristics, evaluation criteria, and degree of human intervention can all influence the final outcome.[25]

Furthermore, the perception of an aesthetically pleasing smile is not completely objective. Dental professionals may place greater emphasis on anatomical accuracy, proportional relationships, restorative feasibility, and biological considerations, whereas patients may prioritize overall attractiveness, naturalness, facial harmony, or the anticipated improvement in their appearance. Thus, differences in evaluator characteristics may contribute substantially to variations in reported outcomes.[26]

Overall, the evidence suggests that the future of AI-assisted smile design is unlikely to be characterized by a simple replacement of conventional DSD. Instead, the emerging model is more appropriately understood as collaborative intelligence, in which generative AI contributes speed, visualization, and design alternatives, while the clinician contributes interpretation, clinical judgment, ethical responsibility, and patient-specific customization.[27]

The central conceptual strength of the present study therefore lies in demonstrating that the clinically relevant comparison may not be AI versus dentist, but rather AI + dentist versus AI alone or dentist alone.26 This framework provides a more realistic basis for evaluating the clinical potential of generative AI and may help guide future research toward outcomes that are not only aesthetically appealing but also clinically appropriate, reproducible, patient-centered, and ethically responsible.[28,29,30]

Figure 6. Patient consultation illustrating digital smile assessment and treatment planning.

STRENGTHS

The major strengths of this study design are:

1. Each participant evaluates all three design conditions.
2. Patient and professional assessments are both included.
3. AI generation is separated from AI-assisted clinician refinement.
4. Subjective and objective outcomes are evaluated.
5. Workflow efficiency is measured.[31,32]
6. Blinding of evaluators reduces expectation bias.
7. The study evaluates AI from a patient-centered rather than purely technological perspective.[33,34]

LIMITATIONS

The major limitations include the subjective nature of smile attractiveness, dependence on the selected AI platform, potential algorithmic bias, inability of a digital simulation to reproduce all biological treatment limitations, and the possibility that highly polished AI images could create unrealistic expectations.[35,36]

CONCLUSION

Within the limitations of the proposed study, generative AI appears to have substantial potential in personalized smile design, particularly in reducing design time and generating alternative treatment visualizations.
The most favorable approach appears to be clinician-refined AI-assisted smile design, rather than completely autonomous AI-generated treatment planning.

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