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Artificial intelligence and smile design: An e-Delphi consensus statement of ethical challenges

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Abstract

Purpose: Smile design software increasingly relies on artificial intelligence (AI). However, using AI for smile design raises numerous technical and ethical concerns. This study aimed to evaluate these ethical issues.

Methods: An international consortium of experts specialized in AI, dentistry, and smile design was engaged to emulate and assess the ethical challenges raised by the use of AI for smile design. An e-Delphi protocol was used to seek the agreement of the ITU-WHO group on well-established ethical principles regarding the use of AI (wellness, respect for autonomy, privacy protection, solidarity, governance, equity, diversity, expertise/prudence, accountability/responsibility, sustainability, and transparency). Each principle included examples of ethical challenges that users might encounter when using AI for smile design.

Results: On the first round of the e-Delphi exercise, participants agreed that seven items should be considered in smile design (diversity, transparency, wellness, privacy protection, prudence, law and governance, and sustainable development), but the remaining four items (equity, accountability and responsibility, solidarity, and respect of autonomy) were rejected and had to be reformulated. After a second round, participants agreed to all items that should be considered while using AI for smile design.

Conclusions: AI development and deployment for smile design should abide by the ethical principles of wellness, respect for autonomy, privacy protection, solidarity, governance, equity, diversity, expertise/prudence, accountability/responsibility, sustainability, and transparency.

KEYWORDS
AI ethics, artificial intelligence, digital dentistry, oral healthcare, smile design

The reconstruction of dental esthetics is often a complex procedure that requires careful analysis of oral conditions and multidisciplinary treatments involving close collaboration between clinicians and dental laboratories.[1] The concept of "Smile design" was introduced as a process to address this complexity through a compre-hensive evaluation of the existing smile characteristics, identification of desired changes, and simulation of proposed treatment outcomes. This ultimately results in planning and creating an aesthetic smile through coordinated modification of dental, gingival, and facial features.

The concept of smile design has evolved over the last two decades. Earlier on, it was carried out manually by hand-drawing on the patient's photographs using simple pencils and markers. This was replaced by digital drawings on digital photographs and later by processing 3D files produced by intraoral and facial scanners. More recently, 4D technology has also been incorporated into the smile design workflow to capture the patient's smile motion using digital sensors.[2–7]

Smile design using digital technology, such as tools like digital smile design (DSD), simulates and previews projected treatment outcomes, enabling clinicians to digitally create and plan new smile designs prior to initiating care. Smile design software allows for pre-visualization of the anticipated result, supporting treatment planning, communication and involves three critical components: (1) image acquisition, (2) image analysis, and (3) treatment planning.

Image acquisition involves obtaining digital photographs and videos to capture the patient's baseline smile characteristics. Image analysis involves processing the acquired images in order to diagnose the esthetic problems, and treatment planning involves using digital tools to simulate proposed aesthetic changes. All these digital technologies have enhanced communication and patient experience, but they are relatively complex to integrate into everyday practice due to the significant amount of time, energy, expertise, and costs involved.[2,6–8] For these reasons, artificial intelligence (AI) has been introduced into smile design software to automate part of the process.

AI is a computer-based process aimed at reproducing human intelligence.[9] This revolutionary technology has a range of applications in esthetic dentistry and smile design.[10–13] AI software (AIS) can be operated through smartphone apps or cloud-based software to perform various tasks, such as facial analysis (anatomical landmark and plane location), image alignment and adjustment, face type classification, two-dimensional and three-dimensional teeth segmentation, automatic smile design, or live treatment simulation.[14–17]

AIS for smile design is recently gaining popularity in clinical practice. However, there is a perception that smile design software could be used as a marketing tool for "selling" treatments, rather than helping clinicians and patients identify medical needs.[17,18] The use of this technology has raised many ethical questions that, until now, have received little or no attention.[18,19] The lack of clear guidelines and literature on the ethical implications of this technology, and the fact that dentists and patients are mostly learning about this technology from un-vetted sources of information, such as social media and YouTube, pose potential risks to patients and clinicians.[14–16]

Eleven ethical fundamental principles have been proposed for the use of AI in dentistry: diversity, transparency, wellness, privacy protection, solidarity, equity, prudence, law and governance, sustainable development, accountability, responsibility, respect for autonomy, and decision-making.[20] However, so far, the relevance of these principles when using AI for smile design has not been addressed.

A well-established method designed to evaluate ethical concerns on a given issue is the use of the e-Delphi process. This is a structured communication technique designed to achieve consensus among experts through a series of iterative surveys, allowing for informed judgments on complex topics.[21] The Delphi process has already been successfully used to reach consensus on topics related to AI in dentistry.[19,20] Given the limited knowledge regarding the ethics of using AIS for smile design, the objective of this study was to identify and define, using an e-Delphi process, the potential ethical challenges that could arise from using AIS for smile design.

METHODS

To identify the ethical challenges of using AI for smile design, a questionnaire was adapted from the 10 categories of the Montreal Declaration for AI Ethics (prudence, equity, privacy, responsibility, democratic participation, solidarity, diversity inclusion, well-being, respect for autonomy, and sustainable development).[16] The Topic Group for Dental Diagnostics and Digital Dentistry of the ITU-WHO Focus Group on Artificial Intelligence for Health, identified 11 ethical principles to be considered when developing, implementing, or receiving AI applications in dentistry.[20] These ethical principles include wellness, respect for autonomy, privacy protection, solidarity, governance, equity, diversity, expertise/prudence, accountability/responsibility, sustainability, and transparency.

All the members of the Topic Group ($n = 90$) were contacted and invited to participate in an online e-Delphi process following an established methodology.[19,20] The goal of the e-Delphi process is to reach a consensus on a particular topic or issue by aggregating opinions and refining responses through multiple rounds to obtain diverse views into a cohesive statement or set of recommendations. The group of participants consisted of dentists with a background of being researchers, methodologists, journal editors and reviewers, regulatory professionals, policymakers, and educators in the field of AI in dentistry from 15 nationalities (Brazil, Bulgaria, Egypt, France, Germany, India, Lebanon, Morocco, Nepal, Nigeria, Serbia, South Korea, Spain, Turkey, and the United States). All participants were informed about the aim of the study, and they were asked to express their acceptance to participate.

The two-staged e-Delphi was conducted between March and April 2023. Following the Guidance on Conducting and Reporting Delphi Studies (CREDES), experts iteratively responded to questionnaires anonymously, allowing for controlled feedback rounds. Participants were asked about their agreement regarding a list of ethical principles classified into 11 categories (wellness, respect for autonomy, privacy protection, solidarity, governance, equity, diversity, expertise/prudence, accountability/responsibility, sustainability, and transparency). The agreement was ranked using a scale from 1 to 10 where 10 meant "fully agree" and 1 meant "not agree at all." The first round was planned and closed after

2 weeks, and two reminders were sent to the panelists. The survey was conducted using a customized online platform (Google Forms), and survey data were extracted after the end of the first round. During the analysis, panelist responses were considered in "agreement" when they reported a score of 7 or higher. General agreement regarding an item was reached when at least 70% of all participants agreed.[19,20] Four items did not obtain agreement after the first round and were reformulated before a second round. The reformulation was based on previous studies regarding ethics in dentistry, and the items were edited to a clearer version, as clinicians were not familiar with the items.

RESULTS

A total of 28 participants, 31.1% of the members of the AI for dentistry ITU/WHO group, completed the survey and the e-Delphi process. Regarding participants' experience with smile design software, 53.6% reported using smile design software routinely or sometimes, 10.7% rarely used it (less than three times), and 35.7% never used it. During the first round of the e-Delphi process, participants agreed on seven principles (diversity, transparency, wellness, privacy protection, prudence, law and governance, and sustainable development) out of the 11 ethical principles defined by the Montreal Declaration for AI Ethics (≥70% of the participants gave a mark of 7 or higher for these items). However, participants disagreed on four principles (equity, accountability and responsibility, solidarity, and respect for autonomy), which were further discussed for reformulation.

The statement on the principle of solidarity was modified from "AIS might target or trigger more patients from a less privileged background who might have had less access to dental care" to "AIS for smile design has the potential to improve management of patients with less access to dental care." The statement on the principle of equity was changed from "AIS might not be as accurate with patients with different skin tones, gum pigmentation, and dental genetic profiles" to "AIS for smile design should be as accurate as possible with patients of different ethnicities." The statement on the principles of accountability and responsibility was changed from "AIS could reinforce overconfidence in dentists over the system's ability and in patients over the accuracy of the automated system; AIS can make the chain of deontological responsibility unclear and inoperant" to "AIS for smile design should not create overconfidence of dentists and patients regarding the clinical outcomes." The statement on the principle of respect for autonomy was changed from "AIS could reinforce a patient's perception that they must be treated when it is not needed, timely or appropriate" to "AIS should not reinforce a patient's perception that they must be treated with smile design when it is not needed, timely or appropriate." In the second round of the e-Delphi process, agreement was reached on these four items (Table 1).

DISCUSSION

AI has been introduced into the smile design process with the promise of automation and improvement. However, this has been done with limited considerations towards the ethical implications of the technology. Here we show how the e-Delphi process helps delineate the ethical principles relevant to the use of AI for smile design.

A set of statements was delineated based on 11 ethical principles that could serve as a foundational framework for effectively developing and utilizing AIS for smile design. These principles articulate the precise characteristics and features that AIS should embody. Based on the 11 ethical items, AIS for smile design should be transparent, user-friendly, understandable, adaptable, fair, pertinent, well-being-focused, healthcare-supportive, interpretable, accessible, responsible, protected, monitored, and regulated.[16,20]

The e-Delphi method used in the present study is an iterative, multi-stage process that involves the systematic solicitation and collection of expert opinions through electronic means. It's an adaptation of the Delphi method, which has been used for consensus-building among experts in various fields, now enhanced with digital tools for efficiency and broader reach.[19,20]

The agreement of clinicians about seven principles (diversity, transparency, wellness, privacy protection, prudence, law and governance, and sustainable development) shows that these items might be more familiar to them. On the other hand, four principles were not agreed upon in the first round (equity, accountability and responsibility, solidarity, and respect for autonomy). The fact that some dentists involved in answering the e-Delphi process initially overlooked these principles during the first round, suggests a need of reformulation for several items, but also that dentists and clinicians might not be familiar with these principles. This point highlights the need for more information and increased awareness regarding the importance of these aspects when utilizing AI tools.

The pace of AI development could explain why most of the young start-ups that commercialize these tools do not adhere to current AI ethics guidelines, such as explaining the accuracy of AI or the decision-making process.[19] This behavior of start-up AI companies has been previously reported and is mainly attributed to numerous parameters that evolve in response to shifting market demands, and the lack of agency to act on ethical values.[21–24] In the context of start-ups that commercialize AIS for smile design, several ethical concerns could be problematic for patients and clinicians, such as questions regarding data privacy or the accountability of users.[22,25]

Moreover, the World Health Organization (WHO) has released guidelines for using AI in healthcare. The guidelines emphasize the importance of data protection, cybersecurity, and ensuring transparency in AIS.[26] Given that AIS depend on extensive datasets, encompassing personal and

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TABLE 1 List of ethical items and potential risks emulated when using AIS for smile design.

AI ethic items	Ethical risk emulated	Agreement, Median, (25th/75th percentiles)
Wellness	AIS for smile design could reinforce a negative perception in a patient over their teeth and body imperfection. AIS could generate in patients a need to receive care (maybe costly) by providing a simulation of a smile that is not adequate. AIS could favor commercial interest over the patient's well-being and over-treatment beyond necessary or sufficient.	23/28 8 (7–9)
Respect for autonomy	AIS should not reinforce a patient's perception that they must be treated with smile design when it is not needed, timely or appropriate.	27/28 10 (9–10)
Privacy protection	The images of patients/clients' faces, smiles, or teeth should be protected. The data used should not be used to train algorithms without explicit consent. If a private company provides AIS for smile design, photos of patients' faces and smiles might not be resold or shared without consent.	26/28 10 (9–10)
Solidarity	AIS for smile design has the potential to improve management of patients with less access to dental care.	23/28 9 (7–10)
Governance	The development and usage of AIS in smile design should follow applicable regulations and oversight.	28/28 10 (8–10)
Equity	AIS for smile design should be as accurate as possible with patients of different ethnicities.	28/28 10 (10–10)
Diversity	AIS for smile design might operate simulations and suggest changes based on one esthetic model of a smile that is culturally formatted and biased.	22/28 8 (8–10)
Expertise/ prudence	Developing and using AIS in for smile design requires knowledge, skills, and consideration. Clinicians should command the required digital literacy to interpret AIS and its outcomes and act upon it appropriately.	27/28 10 (9–10)
Accountability/ responsibility	AIS for smile design should not create overconfidence of dentists and patients regarding the clinical outcomes	25/28 9 (8–10)
Sustainability	AIS should foster sustainability in line with UN Sustainable Development Goals (SDGs). Resources used to develop or use AIS for smile design should be critically appraised against sustainability gains by implementing AI in care.	26/28 9 (8–10)
Transparency	A thorough documentation of the model is necessary. The usage of AIS for smile design in the clinical environment should be clearly communicated to patients.	25/28 10 (8–10)

Note: The results for the four items (equity, accountability and responsibility, solidarity, and respect for autonomy) are the results of the second round of the e-Delphi process.

sensitive information, apprehensions arise regarding data privacy, collection, storage, and utilization methods, especially when collaboration and sharing with third parties is involved. It becomes imperative to uphold stringent data privacy and security standards across all collaborating entities, given that any mishandling or misuse of data can lead to severe consequences. Mitigating these challenges necessitates implementing robust data protection measures, including encryption, access controls, and data anonymization techniques.[20,24,27] Organizations must also conform to pertinent regulations and standards, such as the General Data Protection Regulation (GPDR) and jurisdiction-specific data protection laws.[28] In the future, several strategies could be employed to narrow the gap between AI ethics principles and practices.[20] One such strategy is ECCOLA, an innovative and iterative method proposed for implementing AI ethics in collaboration with researchers and clinicians.[27]

Another limiting aspect of the current practice that warrants discussion is the lack of transparency for patients and clinicians. Indeed, a consent form should ensure sufficient explanations to enable patients to make informed choices. Clinicians should also be equipped with the knowledge that allows them to choose when and how to apply AIS for smile design and be able to verify or explain the results generated by AIS. Among the layers of transparency, external transparency (clinicians to patients), internal transparency (AIS providers to clinicians), and those from within (AIS providers to themselves) can be identified.[28] Moreover, having a transparent website or brochure with information about the AIS, the training procedure, and the data protection strategy is necessary. There is also a need for clinical trials in the field to evaluate the performance of these medical devices and patient satisfaction regarding various outcomes.

In everyday practice, various expectations could arise from an AIS for smile design, including proposing diverse treatment alternatives graded by the severity of the intervention, predicting the stability of the result, fostering a conversation among patients, clinicians, and dental technicians about the pros and cons of different treatment plans, and disclosing all potential complications or data usage, sharing, and storage policies. One critical problematic aspect of using AIS for smile design is that results will be based on an accepted rationale. As aesthetics is subjective, biases can be anticipated concerning nationality, culture, lifestyle, age, sex, religion,

and so on. None of the current software mentioned training their model with a diverse dataset. Therefore, we should not strive for an unbiased algorithm, as such does not exist, but for a precisely biased one, biased to uphold the standards on which users agree. This will guide future research in two directions: developing transparent open-box algorithms to monitor the decision-making process and international discussion and guidelines on universal standards regarding the extent to which natural dentition can be sacrificed to achieve aesthetic results.

Several limitations could be identified in the present work. Investigations will be necessary to update this work and initiatives, such as the e-Delphi proposed here, to facilitate the integration of international AI ethics recommendations.[15] Lastly, the present results, observations, and suggestions must be interpreted carefully. Some of the authors of this article are from European countries facing a specific AI ethics context, including GDPR and the EU AI Act. This continental specificity could significantly influence the interpretation of the practices highlighted and discussed here, as many countries worldwide are more flexible regarding data protection and questions related to AI ethics. Moreover, only a part of the e-Delphi participants were routine users of smile design software, which means that the results presented here should be carefully interpreted as a partial capture of the community. The results would have been different if this work had only questioned a group of specialists in aesthetics dentistry and smile design. However, this community also had a limited interest because of its limited knowledge of artificial intelligence, and even more so on questions of AI ethics. This point suggests involving all stakeholders in the field in future works to promote AI ethics for smile design that will be inclusive and sustainable for all.[25]

CONCLUSION

This work first emulated and proposed possible AI ethics challenges when practitioners and patients use AI for smile design. Following an e-Delphi protocol, 11 items were emulated, and agreement was obtained. This work paves the way for further development of AIS and opens the discussion of how we can act for more trustworthy AI in dentistry. Further investigations and developments are required to deeply investigate this question and include patients in the process, but also to adapt the ethical challenges locally, according to the legal framework and regulations.

CONFLICT OF INTEREST STATEMENT
No conflicts of interest to disclose.

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How to cite this article: Rokhshad R, Karteva T, Chaurasia A, Richert R, Mörch C-M, Tamimi F, et al. Artificial intelligence and smile design: An e-Delphi consensus statement of ethical challenges. J Prosthodont. 2024;1–6.
https://doi.org/10.1111/jopr.13858