

Responsible use of Artificial intelligence in dentistry: dentists' perspectives

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Abstract: The introduction of Artificial intelligence (AI)-based dental applications into clinical practice could play a significant role in improving diagnosis accuracy and reforming dental care, but its implementation relies on the readiness of the dentists as well as of health system to adopt it in everyday practice. Prospective anonymous online survey was conducted among experienced dentists and final year-undergraduate students of the School of Dental medicine at the University of Belgrade ($n = 281$) in order to investigate their current perspectives and readiness to accept AI into practice. Responders ($n = 193$) in the present survey, especially final year-undergraduates, showed lack of immediate readiness to adopt AI in the dental practice and underlying reasons, as shown by logistic regression analyses, are lack of knowledge about the AI technology, associated with the fear of being replaced by AI as well as the lack of regulatory policy. Female dentists perceived ethical issues more significant than men when it comes to AI implementation in the practice. Present article resumed the dentists's perceived responsibility while using AI through the lens of: the dentist experience and qualification, prudent use of AI, and existence of conflict of interest.

Keywords: artificial intelligence; ethics; dentistry; conflict of interest 

1. Introduction

With its robust ability to integrate large sets of clinical data, AI has shown potential as useful medical tool in diagnosis [1] and clinical decision making [2]. Currently, many dentists are racing toward integrating AI system into diagnostics, prognostics and dental treatment, however, as AI system adoption expands throughout the dental sector, questions about legal and ethical dilemmas when using this technology become ever more pertinent [3–5]. Imagine you are a patient whom dentist recommends the tooth extraction for orthodontic treatment and the dentist's recommendation is based on the analysis of an Artificial Intelligence (AI) system, which recommended this treatment plan based on cephalometric analysis. The decision to extract teeth for orthodontic treatment is sensitive and difficult because it is based mainly on the practitioner's experiences, and it is irreversible [6]. Now, what if due to wrong decision based on AI estimation about tooth extraction, undesirable results occur, such as failure of anchorage control, abnormal inclination of the anterior teeth or improper occlusion [7], and orthodontic treatment could not be finished? Who to blame? Laws and legal framework are not specifically defined for AI use in dentistry. Currently defined medical liability in legal frameworks are inadequate, thus may not encourage safe use of AI in clinical decision-making [8]. The certainty is that

AI use in clinical decision-making needs dentist surveillance and the role of dental practitioners is crucial in preventing dental complications as well as in reviewing AI system [9–10]. Thus, dentists' knowledge and perspectives towards AI systems use in dentistry pave the way for AI systems adoption in the dental practice, and at the same time, may impose which issue of the AI use doctrine concerns the most, and should be resolved as first.

2. Materials and Methods

A 25-items questionnaire was used, prepared based on a review of literature assessing attitudes towards AI and dental ethics, as well as on informal discussions with available practicing dentists and health ethics researchers [11–12]. The internal consistency of the questionnaire was then tested in a pilot study among a group of 30 dentists working at the University of Belgrade. This study was conducted in accordance with the code of ethics of the World Medical Association (Declaration of Helsinki) and the investigation was approved by the Ethical committee of School of Dental medicine (number 36/7, 2022.). This prospective anonymous online survey was conducted between February and April 2022. Invitations were sent to experienced dentists working at the University ($n = 151$) and students of the final year of undergraduate studies ($n = 130$). Participation was voluntary. As the research project was clearly described in the note accompanying the questionnaire, filling out the questionnaire by the respondents was regarded as their consent for participation in the study. The questionnaire consists of four parts that aim to provide information on: demographic data, previous experience with the application of artificial intelligence in dental practice, attitudes towards artificial intelligence, and responsibility issues related to the application of artificial intelligence. The data were collected and managed using SPSS Version 28.0 (IBM, Armonk, NY, USA). All our data were categorical. Descriptive statistics were presented as frequencies and proportions for discrete measures. A two-sided chi-square test was used to calculate group differences. Univariate and multivariate logistic regression were used to investigate whether the participants' gender, working experience or academic (PhD) and clinical expertise (specialization) are significantly associated or predicted questionable attitudes and perspectives. p -value of less than 0.05 was considered significant.

3. Results

3.1. Participants

From a total of 281 invitations sent, 193 responses were obtained, 76 from students and 117 from the experienced dentists. However, there were questions where we obtained 191–192 responses. Demographic data of the participants were presented in Table 1.

Table 1. Demographic data of the survey participants.

Characteristic	Participants, Number (percentage)
Age group (year)	
<30	96 (49.7%)
30–45	57 (29.5%)
>45	40 (20.7%)
Gender	
Male	55 (28.5%)
Female	138 (71.5%)
Working experience (years)	
student	76 (39.4%)
<10	56 (29.0%)
>10	61 (31.6%)
Postgraduate degree	
PhD	39 (20.4%)
Specialization	61 (32.3%)
none	94 (48.7%)

3.2. Previous experience with- and attitudes toward AI use

As a measurement of internal consistency of the questionnaire items in two area: Attitudes and Perspectives, Cronbach alpha was estimated and it was 0.76 for Attitudes and 0.78 for Perspectives.

The results show that even 27.1% of participants are not familiar with AI use in dentistry/medicine and only 10.9% of them are currently using or is familiar with AI dental applications. Although majority is of opinion that AI use would improve efficiency and quality of dentist's work, less than half of them had affirmative response to whether AI should be used in the dental practice. Regarding ethical issues, as the most significant was considered the lack of regulatory policy followed by issue of not specified data protection and privacy issues. (Table 2). Moreover, women were more aware than men of ethical issues significance associated with AI use in dental practice (Figure 1).

Table 2. Attitudes toward AI use in dentistry and perspectives toward ethical issues associated with AI use.

QUESTION-ATTITUDES	ANSWER-YES (number)	ANSWER-PARTLY (number)	ANSWER-NO (number)
ARE YOU FAMILIAR WITH THE AI APPLICATIONS USE IN HEALTH CARE	28 (14.6%)	112 (58.3%)	52 (27.1%)
DO YOU USE OR FAMILIAR WITH USAGE OF CURRENT APPLICATIONS OF AI-BASED DENTAL SOFTWARE (ORCA Dental AI, Denti AI, VideahHealth, Pearl, Glidewell.io, Smilecloud, DentalXrai Pro, Dental Analytics, Dental monitoring, AssistDent etc)?	21 (10.9%)	83 (43.0%)	89 (46.1%)
DO YOU THINK AI COULD REPLACE DENTISTS IN A DENTAL PRACTICE?	7 (3.6%)	62 (32.3%)	123 (64.1%)
DO YOU THINK AI COULD IMPROVE THE QUALITY OF DENTAL WORK IN A DENTAL PRACTICE?	99 (51.3%)	78 (40.4%)	16 (8.3%)
DO YOU THINK AI COULD IMPROVE THE EFFICACY OF DENTISTS IN A DENTAL PRACTICE?	110 (57.3%)	70 (36.5%)	12 (6.2%)
DO YOU THINK AI SHOULD BE USED IN A DENTAL PRACTICE?	93 (48.7%)	86 (45.0%)	12 (6.3%)
AI APPLICATIONS IN DENTISTRY SHOULD BE INCORPORATED IN UNDERGRADUATE DENTAL CURRICULA?	88 (45.8%)	77 (40.1%)	27 (14.1%)
AI APPLICATIONS IN DENTISTRY SHOULD BE INCORPORATED IN POSTGRADUATE DENTAL CURRICULA?	130 (68.1%)	51 (26.7%)	10 (5.2%)
QUESTION-PERSPECTIVES	ANSWER-VERY SIGNIFICANT	ANSWER-SIGNIFICANT	ANSWER-NON-SIGNIFICANT
HOW DO YOU ESTIMATE THE SIGNIFICANCE OF THE FOLLOWING ETHICAL ISSUE: The lack of assigned responsibility for consequences of AI-based decision	112 (58.0%)	72 (37.3%)	9 (4.7%)
HOW DO YOU ESTIMATE THE SIGNIFICANCE OF THE FOLLOWING ETHICAL ISSUE: The lack of transparent and representative data used for AI software development	110 (57.0%)	72 (37.3%)	11 (5.7%)
HOW DO YOU ESTIMATE THE SIGNIFICANCE OF THE FOLLOWING ETHICAL ISSUE: The lack of regulatory policy which governs AI use	134 (69.4%)	52 (26.9%)	7 (3.7%)
HOW DO YOU ESTIMATE THE SIGNIFICANCE OF THE FOLLOWING ETHICAL ISSUE: The data protection and privacy issues associated with AI use not specified	125 (64.8%)	58 (30.1%)	10 (5.1%)

According to the pre-investigation experience and the principle of the rank order scale, the basis for the classification of the three ranks is determined. The grading "yes" or "very significant" means the level of $\geq 80\%$; The grading "Partly" or "significant" means

the acceptance level of 20% and 79% (include 20% and 79%); The grading “No” and “non-significant” means the acceptance level of $\leq 19\%$.

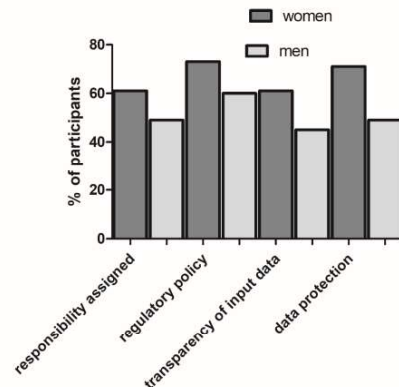


Figure 1. Gender differences in perspectives of the significance of different ethical issues associated with AI use. Bars represent the number of participants perceiving each ethical issue as very significant.

By using univariate logistic regression analysis, we found that lack of working experience (being student) was significantly associated with the lack of knowledge regarding AI use in medicine and dentistry (only 7.9% of them are familiar with AI use in medicine/dentistry), concern of being replaced by AI technology (8% replied as yes and 35% replied as partly) and with doubt in AI use in dentistry (only 34% of them think AI should be used in the dental practice). Students were more than experienced dentists concerned about lack of regulatory policy when using AI is in question (77% of them in comparison to 65% of experienced dentists considered this matter as highly significant). At the same time, having PhD or specialization were shown to be associated with knowledge of AI use in dentistry/medicine. Females considered questionable ethical issues as more significant than men (Table 3).

Table 3. Explanatory factors associated with the analyzed questionable attitudes and perspectives (results from univariate logistic regression analyses).

ATTITUDES AND PERSPECTIVES	Significant association with	Exp (B)	95%CI	P value
ARE YOU FAMILIAR WITH THE AI APPLICATIONS USE IN HEALTH CARE	Being student	0.575	0.35-2.98	p<0.05
	Holding PhD	6.671	3.21-13.86	p<0.001
	Having dental specialization	2.431	1.43-4.12	p<0.001
DO YOU USE OR FAMILIAR WITH USAGE OF CURRENT APPLICATIONS OF AI-BASED DENTAL SOFTWARE	Holding PhD	3.598	2.03-6.34	p<0.001
	Having dental specialization	1.794	1.13-2.85	p<0.005
DO YOU THINK AI COULD REPLACE DENTISTS IN A DENTAL PRACTICE?	Being student	1.763	1.04-2.96	p<0.005
DO YOU THINK AI SHOULD BE USED IN A DENTAL PRACTICE?	Being student	0.518	0.31-0.84	p<0.005
HOW DO YOU ESTIMATE THE SIGNIFICANCE OF THE FOLLOWING ETHICAL ISSUE: The lack of assigned accountability for consequences of AI-based decision	Being female	0.554	0.32-0.93	p<0.005

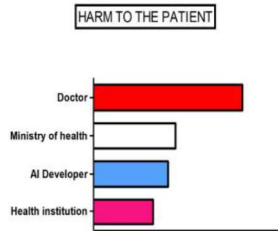
HOW DO YOU ESTIMATE THE SIGNIFICANCE OF THE FOLLOWING ETHICAL ISSUE: The lack of transparent and representative data used for AI software development	Being female	0.506	0.30-0.84	p<0.005
HOW DO YOU ESTIMATE THE SIGNIFICANCE OF THE FOLLOWING ETHICAL ISSUE: The lack of regulatory policy which governs AI use	Being female	0.446	0.25-0.77	p<0.005
	Being student	1.743	0.98-3.09	p<0.005
HOW DO YOU ESTIMATE THE SIGNIFICANCE OF THE FOLLOWING ETHICAL ISSUE: The data protection and privacy issues associated with AI use not specified	Being female	0.384	0.22-0.65	p<0.001
WHO SHOULD BE ACCOUNTABLE FOR FALSE AI-BASED DECISION DUE TO ALGORHYTMIC BIAS?	Being female	0.715	0.53-0.95	p<0.005

Results of multivariate logistic regression analysis revealed that being student is predicting factor of lack of AI use knowledge, fear of dentist being replaced by AI as well as skepticism concerning AI use in dental practice (Table 4).

Table 4. Explanatory factors predicting the analyzed questionable attitudes and perspectives (results from multivariate logistic regression analysis).

ATTITUDES	Significantly associated with- (predictor)	Exp (B)	95%CI	P value
ARE YOU FAMILIAR WITH THE AI APPLICATIONS USE IN HEALTH CARE		0.556	0.34-0.98	p>0.05
DO YOU THINK AI COULD REPLACE DENTISTS IN A DENTAL PRACTICE?		1.913	1.11-3.46	p>0.05
DO YOU THINK AI SHOULD BE USED IN A DENTAL PRACTICE?	Being student	0.510	0.29-0.87	p<0.01
ARE YOU FAMILIAR WITH THE AI APPLICATIONS USE IN HEALTH CARE	Holding PhD	5.49	2.32-13.02	p<0.001

Regarding responsibility, dentist is perceived as accountable if harm to the patient occurs due to AI use, AI developer is accountable for false AI recommendation due to algorithmic bias while Ministry of Health is regarded as responsible for AI accuracy monitoring, by most of the participants (Figure 2).



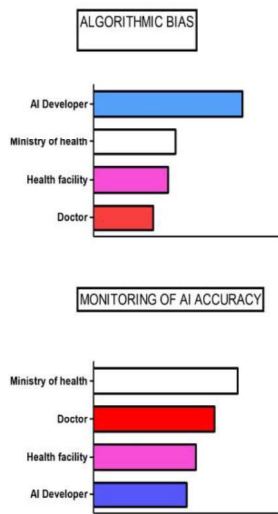
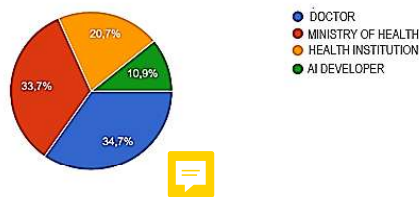


Figure 2. Dentists’- perceived responsibility when using AI in the dental practice. Bars represent the number of participants answering: WHO SHOULD BE ACCOUNTABLE IF HARM TO THE PATIENT OCCURS DUE TO FALSE OR BIASED AI-BASED DECISION? (A) WHO SHOULD BE ACCOUNTABLE FOR FALSE AI-BASED DECISION DUE TO ALGORITHMIC BIAS? (B) AND WHO SHOULD TAKE RESPONSIBILITY FOR MONITORING OF AI-BASED SOFTWARE ACCURACY? (C).

Considering issue of data management, the highest number of participants regarded Ministry of Health as responsible for data protection from misuse and cybercriminal, while considered that doctor and the Health institution where AI software is used, „own“ the data obtained. Almost all participants agreed that informed consent is necessary for data management (Figure 3).



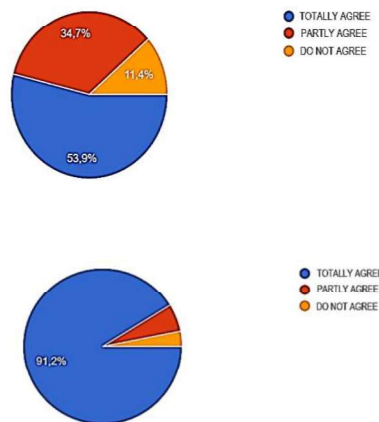


Figure 3. Dentists'- perceived data management control. Pie graphs represent the number of participants answering: WHO SHOULD TAKE RESPONSIBILITY FOR PROTECTION OF AI-DERIVED DATA FROM MISUSE/CYBERCRIMINAL? (A), THE DATA COLLECTED USING AI SHOULD BELONG TO The health institution/medical worker which uses AI? (B) AND AN INFORMED CONSENT IS NEEDED FOR COLLECTION, ANALYSES AND SHARING AI-DERIVED DATA? (C).

4. Discussion

Present survey consider the dentists's perceived responsibility while using AI through the lens of: the dentist experience and qualification, prudent use of AI, and existence of conflicts of interest

Dentist qualification

The results of the survey show that working experience and having specialization/PhD degree are associated with greater motivation and knowledge to use AI. Moreover, undergraduates are even skeptic about whether they should use AI in the practice at all. Such negative reactions regarding AI use will more likely slow the adoption of AI in the practice since both patients and health systems are sensitive to the dentists' reaction. Likewise, one's attitudes towards AI use in dentistry may impose which issue of the AI use doctrine should be solved first and before implementation of technology into practice. Namely, the skepticism of AI use in the present study associates with "anxiety" regarding lack of regulatory policies. Thus, if one's sceptic of AI use, then one favors more robust regulatory policy to be disclosed. The current unpreparedness of Belgrade University dental community for AI use underlies the evident lack of basic and continuing education regarding this subject, as well as by fear of risk that AI will replace dentist, both factors shown to be important previously also [13]. However, the present survey revealed that lack of a regulatory policy represents an important factor also, since it could leave both dentists and patients exposed to legal uncertainty when using AI.

One goal of AI use is enabling the general medical practitioner/dentist to achieve the level of sophistication in diagnosis or treatment of the specialist by using AI device as support in decision. Under such circumstances lack of experience/qualification of a dentist may represent an obstacle and matter of responsibility and liability [14]: the general

dentist is unqualified to perform at the level of a specialist. In line with this, educational program at the dental studies, as well as carefully planned and conducted AI use training are necessary in achieving responsible AI use in the dental practice. Majority of our participants consider that both undergraduate and postgraduate studies should offer insights into AI-guided technology.

Prudent use of AI in dentistry

Regulatory policy should govern AI use and accountability if harm to the patient occur

In this survey, dentists regarded lack of regulatory policy as AI-associated ethical issue of the highest significance. Noteworthy, women rated ethical issues as more significant than men. Indeed, previous studies showed that women's behavior is more consistent with their internal moral principles, and that they are more prone to experience moral emotions such as guilt and shame than men [15–16], which can influence their moral decision making. Regulatory policy includes information whether the AI was reviewed by FDA or another regulator, but also how and when doctors should use AI: whether they need to follow the AI recommendation always, overrule it in situations when they disagree with the recommendation, or something else. Noteworthy, there could be a difference in regulation of the mode of implementation depending on whether the AI recommendation was just an "informational" or the AI recommendation should be treated as a major clinical decision tool [17]. Under latter circumstances, what should the dentist do if he/she has the opposite recommendation? Should he/she reject the recommendation and record the reasons or consult about it with a colleague or a board of experts and then make a decision? Moreover, there is also ethical complexity regarding the multiple players in a healthcare system. Namely, even if dentist decides not to act according to AI recommendation, one could imagine pressures from other players in the chain of health care, such as from insurance company (for example, if the recommendation is to use AI, they will cover only treatment based on AI-based decision?). Currently, AI applications in dentistry are designed as a support in clinical decision and the results of the present survey show that dentists are aware of their own accountability when it comes to occurrence of medical error and harm to the patient while using AI system. Indeed, in the lack of case law on medical doctor/dentist use of AI, it is suggested that doctor is accountable for errors resulting from AI use: dentist may be liable for failing to critically evaluate AI recommendations, such as misusing AI decision-support tool as primary diagnostic tool, or if implements an improper AI system in dental practice. In general, health system instances (Ministry of Health and Health facility) may be liable for failing to provide training, updates, support, maintenance, or equipment for an AI algorithm [9].

As well as with other drugs or medical devices, adoption of AI in practice should follow approval by regulatory agencies [18]. Namely, if we consider AI as another "member of the dental team," then it is necessary to have information about its "expertise". On its latest update in 2022, FDA has authorized over 500 AI-enabled medical devices [19], mainly in the radiology sector. For the dental appliance, FDA approved: *VideaHealth's* artificial intelligence algorithm, which has been shown in clinical trials to lower the rate of missed cavities by more than 40% for dentists, while also reducing their incorrect caries diagnoses by about 15%; *Overjet's Dental Assist* software, which uses deep learning AI to automatically measure bone loss in X-rays speeding the amount of time it takes for dentists to diagnose and begin treating periodontal disease and *Pearl's Second Opinion* solution, which relies on computer vision AI to spot conditions like cavities, tartar and inflammation while also highlighting crowns, fillings, root canals, bridges and implants. However, regulatory practice of FDA has been questioned recently, where authors emphasized that there are no established best practices for evaluating commercially available algorithms to ensure their reliability and safety. Based on publicly available information on FDA approved devices, the authors concluded that almost all of the AI devices approved underwent only retrospective studies while substantial proportion of approved devices

have been evaluated only at a small number of sites, suggesting limited geographic diversity [20].

Performance of AI across representative populations or how to avoid algorithmic bias?

Presently, dentists identified doctors, health system, and algorithm developers as subjects to different, overlapping areas of accountability for AI use. While doctors and health system were considered accountable under AI use-associated malpractice, algorithm designers were considered accountable for failure of product safety and reliability. There is overall concern that in medical/dental AI, deficiencies in the representativeness of the data sets used to train the system may result in inadequate performance for different race, age, gender etc. For example, regarding the previously mentioned AI-based recommendation system for teeth extraction for orthodontic treatment, it has been shown that there are variations in cephalometric landmarks between Caucasian men and African-American Men [21]. If the training data was underinclusive of data of African-American men, the algorithm made for cephalometric analysis would likely give treatment recommendations that are not appropriate for the African-American population. What one should do in such cases? One possibility would be not to use AI. Or, perhaps to limit the use of this supportive tool only to specialists in orthodontics? Thus, when it comes to liability, algorithm developers could be accountable for injuries that result from poor design, failure to warn about risks, or manufacturing defects. On the other side, health system could be liable for injuries resulting from inaccurate AI system since it recommends which AI system should and which should not be used in clinical practice, thus failure to conform to the standard of care for each particular group, may be the result of wrong decision [9].

Data management control

Data management is one of the fundamental ethical issues dealing with acquiring, assessing and storage of data. Dentists should use collected data only to improve the patients' health as well as to improve the dental practice. On the other side, it is unethical to use data in ways that may harm or in any way adversely affect patients. One of the data management control keystone is data privacy. According to the General Data Protection Regulation (GDPR), patients have the right to know what personal data dentist has about them and how is she/he plan to use it, likewise, they have the right to restrict or ask her/him to stop processing or delete their data [22]. Therefore, in order to ensure data security, dentist should: limit the amount of personal data collected or delete data of no longer need; pseudonymize or anonymize personal data whenever possible; foster email security and device encryption and notify the patients if data breach occurs [22]. The results of the present questionnaire show that dentists consider as very significant the ethical problem of the lack of clearly defined guidelines on the protection of patient data during the AI use. Moreover, they perceive the Ministry of Health as the most responsible instance for solving this problem. Likewise, Ministry of Health dentists perceive as the most authoritative for protecting data from cybercriminal. Students and dentists from the University of Belgrade unequivocally agree that the written consent of the patient is necessary for the collection and processing of data during the application of AI.

Conflict of interest

The growing number of cases where dentists are involved in development of AI applications for dental use, as founders or Board members in companies engaged in AI-dental applications, impose the need to discuss liability matter under the circumstances of conflict of interest.

Dentist must disclose personal interests unrelated to the patient's health, whether research or economic, that may affect his/hers professional judgment. The liability issue exists due to the fact that the financial motive (to commercialize developed AI application) may compromise the reasoning of the dentist when it comes to decision making [23]. If

dentist is in conflict of interest and favors his/hers self-interest, it may violate his/hers binding legal duties such as fiduciary duties. Namely, legal system recognizes doctor's duties to patients as fiduciary duties, which oblige doctors to act in manner only to protect, not only patients' health, but also patient's overall interests from doctor's self-interest [24]. Under such circumstances, resolving a conflict of interest, could be achieved by avoidance of the dentist to be directly involved or, when avoidance is not necessary or not possible, by disclosing it. A feasible strategy for dentist's disclosure should be to inform patients, as well as general public, before treatment or research, and let the patients decide whether or not such interests are acceptable to them [24].

5. Conclusions

The skepticism about AI use which dental community showed in the present study associates with the evident lack of basic and continuing education regarding this subject, fear of risk that AI will replace dentist as well as "anxiety" regarding lack of regulatory policies. Thus, responsible use of AI in dentistry should be focused on using AI in promoting quality of oral and systemic health by:

- using of legitimately approved and regulated AI software
- obligatory education and training in AI-use and continuous monitoring of AI-based system performance in the particular group of patients.
- protection of patients and vigorous data management control
- extensively informing patients if there is doubt that AI system is used for reasons other than to improve patient health, such as when dentist or Health facility has conflict of interest.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1,

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Institutional Review Board Statement: All subjects gave their written informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the School of Dental Medicine, University of Belgrade (approval number 36/7, 2022.)

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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