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Review

Impact of Artificial Intelligence on Dental Education: A Review and Guide for Curriculum Update

Andrej Thurzo [1,*], Martin Strunga [1], Renáta Urban [1], Jana Surovková [1] and Kelvin I. Afrashtehfar [2,3,*]

[1] Department of Orthodontics, Regenerative and Forensic Dentistry, Faculty of Medicine, Comenius University in Bratislava, 81250 Bratislava, Slovakia
[2] Evidence-Based Practice Unit, Clinical Sciences Department, College of Dentistry, Ajman University, Ajman City P.O. Box 346, United Arab Emirates
[3] Department of Reconstructive Dentistry and Gerodontology, School of Dental Medicine, University of Bern, 3010 Bern, Switzerland
* Correspondence: thurzo3@uniba.sk (A.T.); kelvin.afrashtehfar@unibe.ch (K.I.A.)

Abstract: In this intellectual work, the clinical and educational aspects of dentistry were confronted with practical applications of artificial intelligence (AI). The aim was to provide an up-to-date overview of the upcoming changes and a brief analysis of the influential advancements in the use of AI in dental education since 2020. In addition, this review provides a guide for a dental curriculum update for undergraduate and postgraduate education in the context of advances in AI applications and their impact on dentistry. Unsurprisingly, most dental educators have limited knowledge and skills to assess AI applications, as they were not trained to do so. Also, AI technology has evolved exponentially in recent years. Factual reliability and opportunities with OpenAI Inc.'s ChatGPT are considered critical inflection points in the era of generative AI. Updating curricula at dental institutions is inevitable as advanced deep-learning approaches take over the clinical areas of dentistry and reshape diagnostics, treatment planning, management, and telemedicine screening. With recent advances in AI language models, communication with patients will change, and the foundations of dental education, including essay, thesis, or scientific paper writing, will need to adapt. However, there is a growing concern about its ethical and legal implications, and further consensus is needed for the safe and responsible implementation of AI in dental education.

Keywords: AI; generative AI; AI academic implementation; dentistry; AI plagiarism; ChatGPT; Midjourney; health professions; AI detectors; education curriculum

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Citation: Thurzo, A.; Strunga, M.; Urban, R.; Surovková, J.; Afrashtehfar, K.I. Impact of Artificial Intelligence on Dental Education: A Review and Guide for Curriculum Update. *Educ. Sci.* **2023**, *13*, 150. https://doi.org/10.3390/educsci13020150

Academic Editor: James Albright

Received: 24 December 2022
Revised: 17 January 2023
Accepted: 29 January 2023
Published: 31 January 2023

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1. Introduction

Current clinical trends and research advances in utilizing Artificial Intelligence (AI) in dentistry have experienced spectacular development and growth over the past two decades. It took more than a decade for three-dimensional (3D) printing technology to disrupt existing dentistry workflows, which was considered an unprecedently rapid progress [1–3]. AI took less than half of this time to achieve a more significant impact on dentistry's clinical and pedagogical aspects. The coronavirus pandemic has accelerated the adoption of virtual technologies in dental education [4–8]. As the arrival of web 2.0 technologies induced a paradigm shift in e-learning more than a decade ago [9–12], now the new generation of released AI systems like ChatGPT represents a critical turning point in a series of AI release events [13–16].

3D scans with smartphones and applications to support AI diagnostics and therapy of patients are already commonplace in dentistry, but development is still ongoing. For instance, the dental community has expressed interest in using the metaverse. The metaverse is a virtual environment that simulates the natural world and could be used in dental education and telemedicine consultations. The use of the metaverse could also facilitate

the use of blockchain technology and smart contracts in the dental industry [17–19]. The current AI-driven transformation of dental education can be viewed from two aspects:

(1) Impact on theoretical skillset, including soft skills and scientific research.
(2) Impact on practical/clinical skillset for the provision of dental health care.

A recent study by Lin et al. [20] explored the perceptions of high-performing undergraduate (UG) dental students in learning dental materials science. All employed learning strategies, including 'Memorizing and repeating', 'Peer learning', 'Search of resources', 'Study planning', 'Attention in classes', and 'Use of mnemonics' can be nowadays enhanced by modern technologies. Dental schools should ensure that the curriculum is underpinned by fundamental pedagogical theory and that the teaching approaches explicitly align with the student's learning strategies.

In this rapidly changing world, a core curriculum for dental education needs to be revised because health care is fundamentally changing, and teaching and learning methods are undergoing a radical transformation. Indeed, many benefits are foreseeable from the presence of AI in dentistry. For example, adapting the dental AI core curriculum can help increase dentists' AI literacy so that they can critically evaluate and consciously use AI applications [21,22].

Concerning dental education curricula and AI, a recent article by Schwendicke et al. [21] identified four domains of learning outcomes, with most outcomes at the "knowledge" level:

(1) Basic definitions and terms, the reasoning behind AI and the principle of machine learning, the idea of training, validating, and testing models, the definition of reference tests, the contrast between dynamic and static AI, and the problem that AI is a black box and needs to be explained should be known.
(2) Use of case: the types of AI required for them should be taught.
(3) Consideration should be given to assessment measures, their interpretation, the relevant impact of AI on patient or community health, and relevant examples.
(4) Issues of generalizability and representativeness, explainability, autonomy and accountability, and the need for governance should be emphasized [21].

The goal of the Schwendicke team was to define a core curriculum for UG and postgraduate (PG) or graduate programs that established a minimum set of outcomes that learners should acquire when taught about dental AI [21].

The implementation of AI in dentistry is a relatively recent development, and the specific timeline for its adoption depends on the specific AI applications considered. Some possible examples of the use of AI in dentistry include:

(1) The use of machine learning algorithms to automate the interpretation of dental imaging procedures, such as radiographs and CT scans, which have been studied since the 1980s.
(2) The development of AI-powered tools to automatically detect dental caries and other oral diseases has been an active area of research since the 1990s.
(3) The use of AI to support dental diagnosis and treatment planning, which has been explored more recently and is still in the early stages of development.

At this point, the use of AI in dentistry is a rapidly evolving field, and the exact timeframe for its adoption depends on the specific applications, which are difficult to predict accurately, albeit it is inevitable that AI will significantly impact future dental education. The impact will be impossible to ignore and will likely depend on how AI is used and integrated into clinical practice and academic settings. Some potential changes that could result from the use of AI in dentistry include the following:

(1) A shift toward more evidence-based, data-driven dental diagnosis and treatment planning approaches.
(2) The use of digital diagnostic technologies, such as 3D imaging and machine learning algorithms, is greater in dental education.
(3) More emphasis is on training dental students to use and interpret AI-based diagnostic tools.

(4) The development of new educational resources and curricula that address AI and its applications in dentistry.
(5) Integrating AI-powered tools into dental simulations and other hands-on activities for dental students.

AI in dentistry will likely lead to a greater emphasis on technology and data analytics in dental education and a need for dental professionals to master these tools. Research shows that AI in dentistry is primarily used to evaluate digital diagnostic methods, particularly in interpreting oral and maxillofacial radiographs. However, it is also increasingly used in other general dentistry areas. Dental radiology and orthodontics are currently leading the way in implementing AI. This recent AI boom has been growing at an unprecedented rate of about 35% per year since 2017, fueled by the shift to advanced 3D/4D diagnostics and the availability of Big Data, accelerated by the pandemic [23].

It is evident that dental curriculums at universities need to be updated because of the AI paradigm shift. The use of AI in dentistry is an emerging field, and specifics about its incorporation into dental education depend on the availability and effectiveness of AI technology, as well as the willingness of universities to incorporate it. It is also essential to consider the potential ethical implications of using AI in dentistry and the need for dental professionals to be properly trained in its use. Ultimately, any decision to update dental curricula to include AI would need careful consideration and likely require input from experts in the field. Demand from dental students and clinical practice will be critical, as the benefits of AI to patients will be undeniable. Another aspect will be the rapid adaptability of students in implementing AI writing tools, which will force educators to rethink the instruction and student assessment in consideration of AI technology, which could become a gift for student cheaters, a powerful teaching assistant, or a tool for creativity.

Regarding the clinical aspect of dental education, it is currently difficult to define what dental students need to learn, as AI-powered software is just being developed, and application scenarios for AI applications are just being introduced. AI is taking over digital image analysis, growth simulation and prediction, 3D and 4D data segmentation, and even patient management and communication workflows are being fundamentally disrupted. A deep understanding of the role of AI in these systems will be the subject of broader academic discussion, albeit priority will remain on the successful clinical use of these powerful tools. As the clinical use of AI in dentistry is still being explored and is dynamically changing, it will be possible to develop a more detailed notion of curriculum adaptation as current AI software matures.

From the aspect of theoretical education, including soft skills and scientific research and publication, it can be concluded that the AI introduction is poised to have a more substantial impact than the introduction of electricity. Thus, it shall be compulsory to have students understand at least basic principles and terminology regarding AI. There are already some general points that dental students should know about AI:

1. What AI refers to, basic terminology, principles, and application examples.
2. That AI is already used in all specializations in dentistry to help improve diagnosis, treatment planning, and other aspects of dental care.
3. The use of AI in dentistry is still early, and more research is needed to determine its effectiveness, potential risks, and benefits.
4. As future dental professionals using AI in their practice, they shall receive training and be aware of any potential ethical considerations.
5. Using AI in dentistry will lead to more efficient and effective dental care. However, it is crucial to approach it cautiously and consider its potential impact on patients and the dental profession.

1.1. ChatGPT

The world of generative AI is rapidly evolving. On 30 November 2022, the public was given access to the AI-driven ChatGPT on OpenAI's website. ChatGPT was trained on

a sea of digital text from the internet and fine-tuned on top of GPT-3.5 using supervised learning and reinforcement learning.

ChatGPT is an AI model developed by OpenAI that is specifically designed to generate human-like text in response to input. It is based on the Generative Pretrained Transformer 3 (GPT-3) architecture, a type of neural network that uses a large dataset of text to learn the patterns and structures of human speech. ChatGPT is like other AI models in that it uses machine learning algorithms to generate text based on input data. However, it is specifically designed to generate more natural and human-like responses than other AI models. It can also be trained on specific data sets or tasks to generate responses tailored to specific applications, such as chatbots or conversational agents. Compared to other AI models, ChatGPT has the advantage of being able to generate human-like responses that are more natural and fluid. This makes it a valuable tool for applications that require the ability to generate human-like text, such as chatbots or virtual assistants. However, it also has some limitations, such as the need for large amounts of data and computational resources to train and run the model [13].

There is a difference between ChatGPT, a new demonstration of this type of technology, and GPT-3, which has already been in use in various contexts. In terms of performance, ChatGPT is not as powerful as GPT-3, but it is better suited for chatbot applications. It is also generally faster and more efficient than GPT-3, making it a better choice for real-time chatbot systems. ChatGPT and GPT-3 are powerful language models, but they are designed for different purposes and have different strengths and weaknesses [24]. The conversational approach allows the new GPT option to respond to more dynamic interactions and will answer rather than ask. Unlike Chat GPT, which was explicitly trained for this purpose, GPT-3 was previously used by the end user to initiate an interaction. It uses a method known as reinforcement learning from human learning [25].

Various large language models have been introduced to generate texts that appear authentic but are inaccurate. The frequent errors reflect the general concerns of linguists that such artificial language models effectively operate via a trick mirror—learning the form of English without inherent linguistic skills that would demonstrate actual understanding. As the models grow in size and complexity over time, it becomes increasingly difficult to document the details of the data [26,27].

1.2. AI, Academia, and Legal Aspects

The world of generative AI is advancing rapidly. The essay has been at the center of humanistic pedagogy for generations. This age-old tradition is about to be disrupted from the ground up. Neither the engineers developing language technology nor the educators encountering the resulting language are fully prepared for the consequences. Humanities departments judge their students based on their essays. They award doctorates based on the composition of a dissertation. What happens if both processes can be largely automated? Stephen Marche estimates that it will take ten years for academia to come to grips with this new reality: two years for students to become comfortable with the technology, three more years for professors to realize that students are using the technology, and then five years for college administrators to decide what, if anything, to do. Teachers are already among the most overworked and underpaid people in the world. The humanities academic faculty are already dealing with a crisis [28].

Students today use thesauruses, grammar correction tools, or style guides available in all major word processing programs. They are not using someone else; the program is not someone else. The problem is using effective AI tools. Using AI for text generation may raise legal concerns related to plagiarism. Plagiarism occurs when they use someone else's work without proper acknowledgment or permission. In the context of AI texting, this can occur when a user passes off a text generated by a machine learning model as their work without properly citing the source or obtaining permission from the copyright holder. It is only a matter of time before the AI tools steering writing style, and syntax will be integrated into widely used commercial words processors like MS Word or Google Docs.

In general, it is essential to appropriately credit all sources used in a text, including AI-generated texts. This can usually be done by citing or referencing the AI model in the text or a footnote. Depending on the circumstances and laws of the country where the text is used, it may also be necessary to obtain permission from the copyright holder of the AI model before using the generated text. It is also crucial that students are aware of the potential legal implications of using AI for text generation and take steps to properly label and obtain permission for any generated text that is used in any work.

AI is rapidly entering dental education on all fronts, albeit most providers need more knowledge and skills to assess dental AI applications [21,22]. Therefore, the main aim of this paper is to provide information for those seeking information about upgrading the dental education curriculum.

The main purpose of this narrative review was to provide an analysis of the urgency of an "AI update" of the curriculum and a summary with an assessment of the current state of research on the impact of AI on the dental curriculum in universities. Because research on this topic is still in its infancy and there is a lack of high-quality research studies, the goal was to guide academicians considering the urgency and areas of an "AI update" to their current curricula. The introduction of AI will probably significantly impact humanity, potentially even larger than the introduction of electricity. However, it is difficult to predict the exact magnitude and timeframe of this impact.

2. Materials and Methods

Publications dedicated to applications of AI in dental education were reviewed after applying the following search strategy, query, and selection criteria.

- Search strategy:

  Databases: Scopus and Web of Science (WoS).
  Keywords/query: "Artificial intelligence" AND "dental education".

- Inclusion/exclusion criteria:

  Types of studies: Articles, Reviews, Conference Papers, and Notes.
  Languages: Restricted to English.
  Time periods: Publications from 2020 to present.
  Others: Exclusively included papers focused on AI applications in dental education.

A Field-Weighted Citation Impact (FWCI) was chosen for the selected literature to categorize the impact. This indicates how well the scientific community regards this document compared to similar documents. The objective measure is the number of citations the document obtains over time. For instance, a value greater than 1.00 means that the document is cited more often than expected on average. This considers:

- Year of publication
- Type of document, and
- Disciplines associated with the source.

The FWCI is the ratio of all document citations to the average number of citations received by all similar documents over three years. Each discipline contributes equally to this metric, which eliminates differences in citation patterns among researchers.

Except for the literature search, a prompting of a large public language AI model ChatGPT (OpenAI Inc., San Francisco, CA, USA) was used. This large language model was fine-tuned using supervised and reinforced learning techniques and is based on OpenAI's GPT-3.5 language model. The AI was prompted with four questions related to dental education to analyze the factual ambiguity of the ChatGPT responses and a task to rewrite the initially proposed title of this review to reflect its writing ability. The first prompt shown in the results section was entered on 8 December 2022; the same prompt was repeated five days apart on 12 December 2022.

Midjourney was another AI prompted to demonstrate its capacities in the educational process in creating images from textual descriptions. It is similar to OpenAI's DALL-E

and Stable Diffusion. The prompt was entered on 12 December 2022: "*/Imagine Yin yang pie chart similar to brain with one dominant part*". The image was used to visualize parts of dental education coverage with emerging AI skills. Another prompting of this AI with visual outcomes was used to assess the potential of using this image-producing AI system in educational schematic drawings. The prompt was entered on 12 December 2022 as: "*/Imagine Educational schematic drawing of skull anatomy with teeth*".

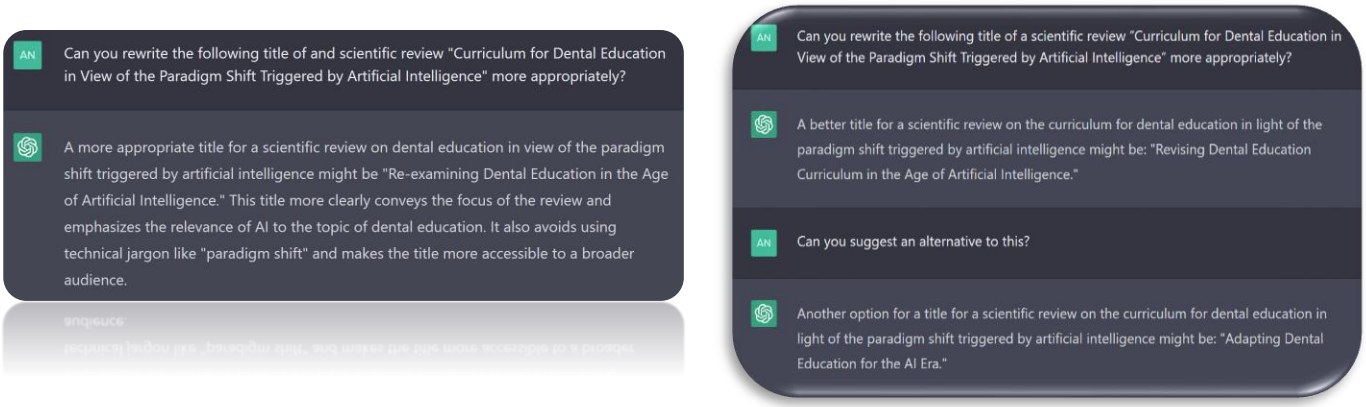
3. Results

ChatGPT was prompted to rewrite the originally intended title for this paper in the context of expectations of a title suitable for narrative review. The original prompt was:

> *Can you rewrite the following title of a scientific review, "Curriculum for Dental Education in View of the Paradigm Shift Triggered by Artificial Intelligence", more appropriately?*

Moreover, the ChatGPT response (Figure 1a) was:

> *A more appropriate title for a scientific review on dental education in view of the paradigm shift triggered by artificial intelligence might be "Re-examining Dental Education in the Age of Artificial Intelligence". This title more clearly conveys the focus of the review and emphasizes the relevance of AI to the topic of dental education. It also avoids using technical jargon like "paradigm shift" and makes the title more accessible to a broader audience.*



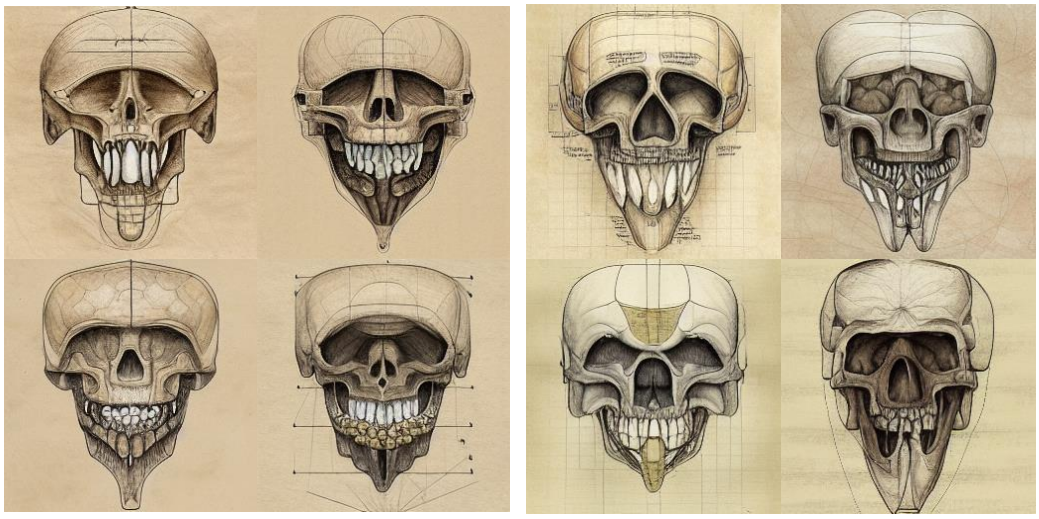
(**a**) (**b**)

Figure 1. The task to rewrite this review's initially proposed title was given to AI ChatGPT to reflect its writing ability: (**a**) Original prompt from 8th of December 2022 returned contextual answer; (**b**) The repetition of dialogue with ChatGPT 5 days after the first prompt returned different and shorter answers.

The dialogue with ChatGPT was repeated five days later with the same prompt and returned different answers. The responses were shorter and suggested a more appropriate title which was partially adopted (Figure 1b).

The Midjourney prompts were utilized to demonstrate potential in the educational process for the production of schematic drawings from textual descriptions. Figure 2 shows variations of anatomically failed comprehension of the prompt "*/Imagine Educational schematic drawing of skull anatomy with teeth*".

Figure 3 shows a rather artistic than schematic interpretation of the prompt: "*/Imagine Yin yang pie chart similar to brain with one dominant part*". The image was augmented for schematic labeling and depicted the main skillset fields identified as relevant for dental education targeting, including emerging AI skills.



(**a**) (**b**)

Figure 2. The prompt was entered on 12 December 2022: "*/Imagine Educational schematic drawing of skull anatomy with teeth*": (**a**) Variations of unsuccessful attempt of AI-generated image of skull end teeth; (**b**) Other failed attempt to AI-create schematic of skull and teeth.

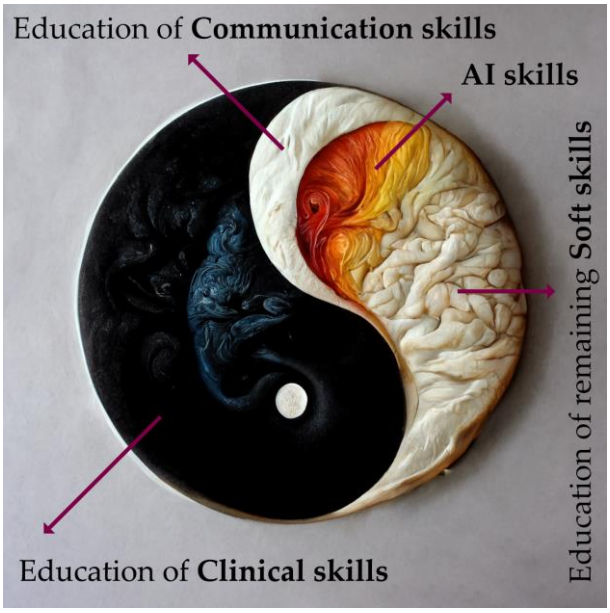


Figure 3. Midjourney AI output for the prompt: "*/Imagine Yin yang pie chart similar to brain with one dominant part*". The image is augmented for schematic labeling of the primary skillsets targeted by dental education, including clinical skills, communication with other soft skills, and emerging AI skills.

Results of the literature analysis that have met the selection criteria are listed in Table 1. Publications registered in Scopus and WoS directly dedicated to AI in dental education are steadily increasing since 2020. Two studies were published in 2020, 5 in 2021, and 8 in 2022 and were indexed as of the 30 November 2022.

Table 1. List of all publications in Scopus and WoS covering the topic of artificial intelligence in dental education.

#	Author	Type	Title	FWCI	Journal	Ref.	Year
1	Schwendicke et al.	Article	Artificial Intelligence in Dentistry: Chances and Challenges . . .	24.02	Journal of Dental Research	[22]	2020
2	Cesur et al.	Article	Quality of information on YouTube about artificial intellige . . . [2]	0.83	Journal of Dental Education	[29]	2020
3	Yüzbaşıoğlu et al.	Article	Attitudes and perceptions of dental students towards artific . . .	2.8	Journal of Dental Education	[30]	2021
4	Tekkesin et al.	Review	A new dawn: The impact of digital technologies in oral and m . . .	Uncited [1]	Journal of Experimental and Clinical Medicine	[31]	2021
5	Maddahi et al.	Article	RoboEthics in COVID-19: A Case Study in Dentistry . . .	0.37	Frontiers in Robotics and AI	[32]	2021
6	Shah et al.	Review	Get smart—Technological innovations in endodontics part 2: . . .	Uncited [1]	Dental Update	[33]	2021
7	Gandedkar et al.	Article	Role of virtual reality (VR), augmented reality (AR) and art . . . [2]	3.06	Seminars in Orthodontics	[34]	2021
8	Siddiqui et al.	Conference Paper	Artificial intelligence in dentistry, orthodontics and Ortho . . .	Uncited [1]	Journal of the Pakistan Medical Association	[35]	2022
9	Tadinada et al.	Article	Utilizing an organizational development framework as a road . . .	Uncited [1]	Journal of Dental Education	[36]	2022
10	Saghiri et al.	Review	Scoping review of artificial intelligence and immersive digi . . .	1.06	Journal of Dental Education	[37]	2022
11	Joda et al.	Review	Personalized workflows in reconstructive dentistry—current p . . .	1.93	Clinical Oral Investigations	[38]	2022
12	Thurzo et al.	Article	Dental Care and Education Facing Highly Transmissible SARS-C . . .	6.41	International Journal of Environmental Research and Public Health	[6]	2022
13	LeResche	Article	Commentary: The Changing Face of Dentistry . . .	2.13	JDR Clinical and Translational Research	[39]	2022
14	Islam et al.	Article	Adopting artificial intelligence in dental education: A mode . . .	Uncited [1]	Journal of Dental Education	[40]	2022
15	Mladenovic et al.	Note	Importance of artificial intelligence in the analysis of chi . . . [2]	Uncited [1]	Journal of Dental Education	[41]	2022

[1] Field-Weighted Citation Impact shows how well is document cited compared to similar documents.[2] Sources identified by WoS as supplementary to the Scopus search.

The ChatGPT prompted with four questions from the field of dentistry from easy to more difficult entered on 8 December 2022 shown on Figure 4, returned the following results:

1. *How many permanent teeth does an adult person normally have*?
   The answer was factually correct.
2. *Why is hypodontia becoming more common*?
   The answer showed a weakness in contextual understanding—a bigger picture.
3. *Which teeth are esthetically the most important for a smile*?
   The answer showed a correct understanding of the context.
4. *Which teeth are not esthetically important for a smile*?

The answer showed proper handling of negative meanings, which is difficult for most of the current AI language models.

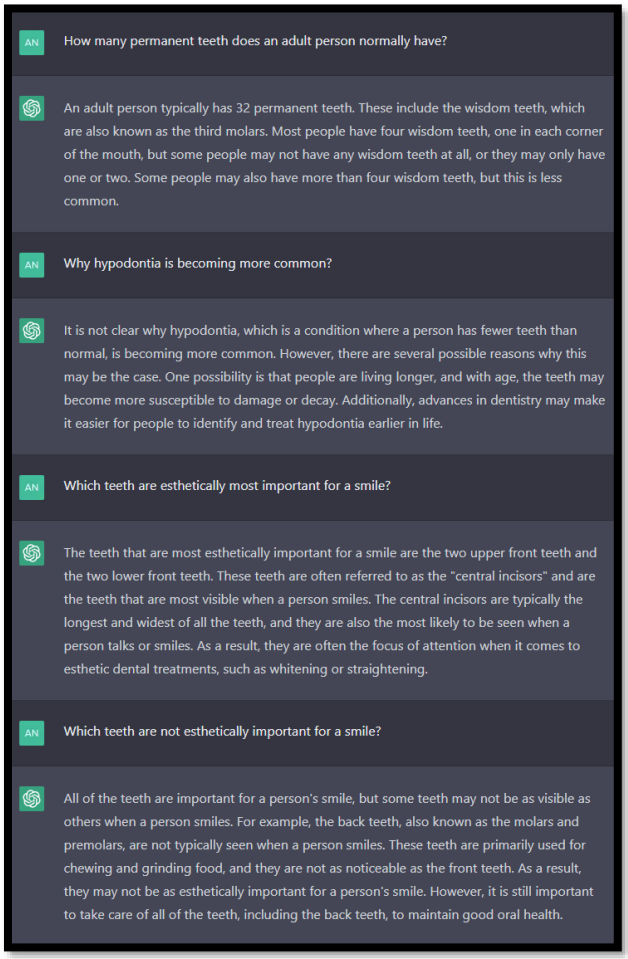


Figure 4. Four questions relevant to dental education were prompted to ChatGPT. The first answer was correct. The second answer showed weakness in contextual understanding of the bigger picture and deeper context of specialized terms. The third answer showed a correct understanding of simple context. The fourth answer showed proper handling of negative meanings which is a difficult task for most of the current AI language models.

4. Discussion

We have not yet fully recovered from the shock that an AI can recognize gender [42] and ethnicity [43] from an X-ray, nor from the fact that no one knows how the AI is capable of doing so, and here we are confronted with the possibility of semi-automatic communication of our office AI telemonitoring systems with the patient in the style and level he or she desires. The same message/treatment instruction can be conveyed to the patient not only in a particular style, "like a cowboy" or "wittier", but also on the level and language desired by a patient, "tell me as if I am 5 years old" or "use only basic English".

The results presented in this paper have confirmed that dialogue with ChatGPT AI is capable of textual communication (paraphrasing text or answering questions) in an unprecedented way. With a possible limitation in the use of medical/technical terms and their contextual "understanding", a powerful language AI model can and will change how we communicate with our patients. This technology will enable better personalization of patient-doctor communication and take over many of the tasks of copywriters by helping them create content for websites and more (Figure 1). Midjourney's AI imaging results have shown that this is not an appropriate way to create detailed educational schemes and drawings, as this AI does not comprehend human anatomy (Figures 2 and 3).

The literature analysis presented in Table 1 showed that AI has the potential to improve dental education in both theoretical and practical areas. In theoretical education, AI is

used to analyze patient data and create plans and simulations. In practical education, AI is used to manage the telemonitoring of patients, provide virtual training environments, and improve student assessment and patient care. However, caution is needed to ensure responsible and ethical use and to avoid biased training data sets.

Two main territories of dental education are being reshaped with AI:

1. Theoretical education with soft skills, research, and publications.
2. Practical/clinical education for direct patient care.

Both areas are experiencing fundamental changes in their traditional workflows. In the first group, for example, a theory for diagnostics faces algorithms that analyze patient data and make a diagnosis without the doctor knowing why. Digital communication can be personalized, and semi-automated, frequently asked questions can be answered in a style and manner typical of the physician or nurse, or rare genetic syndromes can be identified using the patient's 2D face with a face2gene app for enhanced patient evaluation with deep phenotyping [44]. Treatment planning can now be done with Diagnocat or other AI software based on automatically segmented CBCTs. Evidence-based implications of AI analysis of published research will likely change some of the current theoretical dogma. Advanced AI language models, with their ability to create unique texts, will challenge current attitudes toward essay writing and research publication.

In practical/clinical education, we need to become used to a new normal where the patient can be observed before, during, or after treatment with dental monitoring or other telemonitoring applications and where patients provide their data via their cell phones or even wearables and the AI evaluates it and acts accordingly. We, as health providers, set the AI triggers and goals. Practical training will change, and AI will provide realistic virtual training environments. AI will improve student assessment and patient care, where AI will be used not only as a personalized therapist.

There are several ways to integrate AI into the dental education curriculum. Some possible examples include the use of AI-powered simulation tools to provide students with hands-on experience in the diagnosis and treatment of dental disease, the integration of AI-powered decision support systems into clinical education to help students learn to make informed treatment decisions, and the use of AI-powered image analysis and interpretation technologies to improve students' understanding of radiographic images. In addition, AI could improve the efficiency and accuracy of administrative and documentation tasks, such as scheduling appointments and managing patient records. These are just a few examples of how AI could be integrated into the dental education curriculum. The specific way AI is used may vary depending on the goals and needs of the educational institution.

We must expect AI to be misused as well. ChatGPT is a clear wake-up call that AI is superior to humans in some areas. Right now, it needs to be clarified how many students will use AI or whether teachers and professors will find a way to catch them. The ChatGPT bot is currently causing excitement, perhaps even panic, at universities, but soon it will be as mundane a tool as Excel. This is the beginning of the end of the human era in various fields. Many experts believe ChatGPT will force universities to become creative to prevent cheating. With the introduction of ChatGPT, concerns also arose about its potential use in academic settings. Could the chatbot, which provides coherent, witty, and entertaining answers to simple questions, tempt more students to cheat? Students have been able to cheat on assignments over the Internet for decades, so tools now exist to help them check whether their work is original. However, now there are fears that ChatGPT could make these tools obsolete. Experts are unaware of any technology that can tell if an AI has written an essay, but they predict someone will soon build such technology. The best defense against AI essays is for teachers to learn their students' writing styles so they or a future AI can spot a discrepancy in submitted work [45]. Texts generated with AI will lead to a re-valuation of creativity in academic writing. ChatGPT can be used for brainstorming and obtaining new ideas on any topic.

Merriam-webster.com defines "plagiarize" as "to steal and pass off (the ideas or words of another) as one's own: use (another's production) without crediting the source". This

might also fit AI-created content. Students have always found ways to avoid the hard work of actual learning. As long as these shortcuts have existed, however, a large part of education has remained inescapable: writing. Plagiarism aside, students have always been at the point where they stood alone with a blank page, staring at a blinking cursor waiting for the essay to be written. That could be about to change, albeit before redesigning the education system, innovators need to be very cognizant of the legacy of past written and unwritten policies embedded in teachers' practices and beliefs [46,47].

Identifying whether a human or an AI wrote the text can be difficult. Currently, there are attempts by OpenAI to watermark AI-generated texts, which can be used to mark the output of a text statistically. This could be useful to prevent academic plagiarism, mass generation of propaganda, or impersonating someone's writing style to incriminate them [48]. The most effective tools in the fight against AI plagiarism seem to be "AI detectors" such as GPT-2 Output Detector or Writer AI Content Detector.

The main limitation of this paper is that it is not well suited as a narrative overview for such a rapidly changing subject. Some findings are likely to become quickly outdated as new research and developments are published. Another limitation of this paper is the technological overhang present in ChatGPT. The technological overhang refers to the unknown excess capabilities of a new technology that no one has yet explored.

Responsible authorities shall approach both main dental education areas separately as a hypothetical guide for a dental curriculum update. In the field of clinical workflows, AI implementations will storm the current decade and reshape it fundamentally. Here the responsible approach would focus on the general introduction of AI-powered tools in dynamically changing situations. Emphasis on how AI algorithms are implemented in these software tools would allow dental students to choose wisely the AI-powered tools in their practices upon knowledge gained in the university. As tools available a decade from now, they will be impossible to ignore in clinical practice, albeit have not yet been invented or clinically introduced.

Updating the dental curriculum in light of the current capabilities of generative and analytic AI and scenarios in which AI affects methods of communicating with patients or patient management, disseminating knowledge, writing papers, understanding educational or scientific texts, and many other soft skills is far more feasible than training on clinical scenarios that do not yet exist. AI is here to stay. Basic knowledge of it will become an integral part of the theoretical curriculum. Experts also agree on several other points. For example, it will enable more reliable and effective diagnostics and more sustainable oral care. A paper by Ducret et al. discusses the potential use of AI in oral health care with a focus on sustainability and the 2030 Agenda for Sustainable Development. The paper explores the advantages and disadvantages of using AI in oral health care and suggests that systemic impact assessment can promote positive and mitigate adverse effects [49]. Another study by Eschert et al. found that most respondents rated their knowledge of AI as average or below average. However, they believed that AI would improve diagnostics and create uniformity in the field. The survey also raised several concerns about AI, including machine error, data security and privacy issues, and the potential for outsourcing healthcare to technology companies [50].

5. Conclusions

This review has confirmed that the changes in all dental education areas are so extensive that their curriculum needs to be significantly adapted to the many AI uses. AI ChatGPT can facilitate communication between healthcare providers and patients in a personalized and effective manner including problem and sentiment analysis in the messages from the patient. AI-powered language models can help personalize patient-physician communication and take over many of the tasks currently performed by copywriters or office staff. However, the study also found that the AI Midjourney still needs to be developed to produce detailed educational material or diagrams, as it requires an understanding of human anatomy.

AI is fundamentally transforming both main areas of dental education. However, theoretical dental education is much more advanced in AI implementation than practical/clinical education; therefore, it is better suited for curriculum updates. Clinical AI-powered software will reshape the character of oral health care, albeit it will take time to mature, or some use cases have yet to be invented. Currently, the short-term impact of generative AI in dentistry tends to be overestimated, while we strongly underestimate its long-term consequences on all segments of dental education.

AI has the potential to improve the efficiency and effectiveness of dental education significantly. However, caution and knowledge are needed to ensure responsible and ethical use and to avoid biased training data sets. AI plagiarism already exists as is revealed with some AI detectors as new crucial parts of antiplagiarism systems. The discovery that AI can competently perform some human tasks may lead to backward thinking attempts to ban the use of AI by students in universities, rather than adjusting student assessment in more modern ways appropriate to the age of AI.

Finally, this article concludes that the penetration of AI into dentistry and its impact on innovations in education and diagnostic and therapeutic procedures are accelerating in unforeseen ways. Various types of generative AI have already rendered some methods of student education and assessment, including essay writing, obsolete. Indeed, AI has the potential to improve many aspects of dental education significantly. However, we must be concerned about the potential negative consequences of AI, such as AI plagiarism and bias.

Author Contributions: Conceptualization, A.T., M.S., R.U. and K.I.A.; methodology, A.T., M.S., R.U. and K.I.A.; software, A.T.; validation, A.T., M.S., W.U, M.S. and K.I.A.; formal analysis, A.T.; investigation, A.T.; resources, A.T.; data curation, A.T; writing—original draft preparation, A.T., M.S., W.U, M.S., K.I.A. and J.S.; writing—review and editing, A.T., M.S., M.S. and K.I.A.; visualization, A.T.; supervision, J.S.; project administration, A.T.; funding acquisition, A.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by KEGA, grant number 054UK-4/2023.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We acknowledge the technological support of the digital dental lab infrastructure of 3Dent Medical Ltd. company as well as the dental clinic Sangre Azul Ltd. and we would like to express our gratitude to ChatGPT 3.5 model's ability to understand and interpret complex concepts what greatly aided in the final revision and refinement of our research and analysis.

Conflicts of Interest: The authors declare no conflict of interest.

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