

Digital Dental Patient Study Concept: Improved Approach for High Quality Dental Education Within the Conditions of War or Sanitary Restrictions

Myroslav Goncharuk-Khomyn¹, Svitlana Kostenko², Volodymyr Melnyk³, Liubov Bilyschuk³, Anatoliy Foros², Stepan Sheveria⁴, Yuriy Bun², Ivan Bohdan², Oleksandr Bilynskyi¹

1. Department of Restorative Dentistry, Uzhhorod National University, Uzhhorod, Ukraine.
2. Department of Prosthetic Dentistry, Uzhhorod National University, Uzhhorod, Ukraine.
3. Department of Pediatric Dentistry, Uzhhorod National University, Uzhhorod, Ukraine.
4. Department of Postgraduate Dental Education, Uzhhorod National University, Uzhhorod, Ukraine.

Abstract

Objective of study was to present originally-developed approach of digital dental patient study concept and assess student-oriented satisfaction with it, while also evaluate its effectiveness for keeping high-quality dental education level at the conditions of war or sanitary restrictions.

Digital dental patient study concept was originally developed for the Department of Restorative Dentistry, adapted to its' educational needs and primarily included further obligatory components: 1) intraoral scans; 2) various types of X-ray examination results (periapical radiographs, orthopantomograms, CBCT scans); 3) online periodontal charts; 4) adapted charts for the annotation of clinical findings. Survey among students was held in the form of online-questionnaire designed within Google-form. Implementation of digital dental patient study concept helps to compensate to some manner deficiency of clinical practice caused by the war-related limitations, since students satisfaction with the quality of obtained practical skills (including such needed for the clinical practice and such related to the interaction with digital dental technologies) reached 4.48 ± 0.67 , and was statistically higher than during online-education mode with no additionally proposed improvements ($p < 0.05$).

Implementation of digital dental patient study concept did not impact students satisfaction with environment safety and comfort ($p > 0.05$) and students' satisfaction with the support provided from the teaching staff, attending staff and education managers ($p > 0.05$), which in general were rated more than "good". Proposed digital dental patient study concept may serve as an effective solution to keep high quality of dental education within online study mode under circumstances of providing it at the ongoing war conditions or sanitary restrictions.

Digitalization of dental education aimed at strengthening clinically-oriented study process, enhancing students awareness with modern digital technologies and deepening understanding of clinical aspects on the simulation models.

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Introduction

Implementation of digital dentistry advances and new computerized informational approaches into the pre-graduate study process of future dental specialists have been reported previously as effective instrument to enhance

quality of provided education.^{1, 2, 3} Such innovations within educational workflow support development of clinical thinking among students, while also improve understanding of complex solutions during problem-based study and at the same time involve pre-graduates into the deeper knowledge of advanced digital know-hows within dental practice in general.^{4, 5, 6, 7} Nevertheless, it should be noted that due to the available literature implementation of digital dentistry novelties within pre-graduate dental education was provided just within specifically-targeted courses, at the limited aspects of several complex study program, or within try-

*Corresponding author:

Myroslav Goncharuk-Khomyn
Department of Restorative Dentistry, Uzhhorod National University, Uzhhorod, Ukraine.
E-mail: myroslav.goncharuk-khomyn@uzhnu.edu.ua

in/experimental mode. In all above-mentioned cases digital dental advances were aimed at coupling and boosting clinically-oriented dental education.^{4, 5, 6, 7, 8}

COVID-19 sanitary restrictions changed profile of dental education in general and made it face with all the advantages, but also limitations of fully online study mode.^{9, 10, 11, 12, 13} In post pandemic period considering unique possibilities of online-teaching instruments and platforms they have been blended together with off-line study mode resulting into maximum effect of hybrid form of dental education. Moreover recent advances of immersive technologies, such as virtual reality, augmented reality and mixed reality forming a new paradigm within concept of digital dental education at the post-COVID era.^{14, 15} But the end of COVID-19 sanitary restrictions in Ukraine overlapped with Russian war invasion, which formed new challenges for Ukrainian education system.¹⁶ Considering that life, health and well-being of students are the primary goals of any education system, many of Ukrainian universities continue to provide online or hybrid (online-offline) modes of study to minimize any potential risks for the students being harmed in present wartime conditions.¹⁶ Due to the already present experience of online education Ukrainian institutions has adapted to the war-linked limitations and continue to provide high quality education to the possible manner, while also improving it using novel teaching instruments.¹⁶

The remaining problem of dental pre-graduate education in Ukraine within present war conditions is that it should include clinical part as an obligatory component of the study program, but realization of such is limited due to the risks both for the student and for the patient.¹⁶ Based on the data available at the alerts.in.ua website between February 24 of 2022 and October 31 of 2023 more than 28139 air raid alerts were registered over the territory of Ukraine, each of which is associated with direct risk of missile attack.

Considering such conditions there is a need for novel solution of dental education improvements, which can cover clinical components of dental education, while also will not compromise safety of students during the provisions of complex pre-graduate dental education during ongoing war.

Objective

Objective of study was to present originally-developed approach of digital dental patient study concept and assess student-oriented satisfaction with it, while also evaluate its effectiveness for keeping high-quality dental education level at the conditions of war or sanitary restrictions.

Materials and Methods

Present study included two separate phases: 1) development of digital dental patient study concept with its corresponding structure adapted to 90 minutes class; 2) assessment of digital dental patients study concept's perception by the students as indirect indicator of quality of provided dental education.

Digital Dental Patient Study Concept

Digital dental patient study concept was originally developed by the first author (M. G.-K.), and elements of such were implemented by other authors into the study process among different departments of Faculty of Dentistry at Uzhhorod National University (Ukraine).

Digital dental patient study concept was originally developed for the Department of Restorative Dentistry at Faculty of Dentistry (Uzhhorod National University, Ukraine), adapted to its' educational needs and primarily included further obligatory components: 1) intraoral scans (IOS); 2) various types of X-ray examination results (periapical radiographs, orthopantomograms, CBCT scans); 3) online periodontal charts; 4) adapted charts for the annotation of clinical findings (Fig. 1).

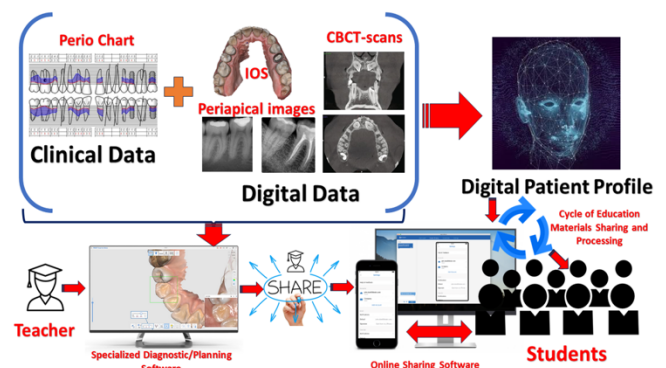


Figure 1. Schematic layout of digital dental patient study concept

Data of IOS, X-ray examination results and online periodontal charts were coupled

together to create complex of digital patient, while in some cases those components were used separately to address different educational aspects. Intraoral scans were used for improving teaching of topics related to caries, recessions and dentition in general, while CBCT scans and peri-apical radiographs were used for the endodontic-related topics of classes. Online periodontal charts were coupled with IOS for classes dedicated to the periodontal status changes (condition of gingiva, recessions, interproximal papilla condition).

All the clinical data was gathered from the clinical database of University Dental Clinic (Faculty of Dentistry, Uzhhorod National University, Ukraine), and prior to the use within the study process it was correspondingly anonymized. Above-mentioned data available within University Dental Clinic's database was used for the educational purposes only under condition if patient previously has signed informational consent form regarding potential use of his/her anonymized dental information for the research or educational objective with no disclosure of any of their personal information or identity.

Intraoral scanner (Medit I500, MEDIT Corp., Seoul, Republic of Korea), 3D printer (Raise3D Pro 2, Raise 3D Technologies Inc., Rotterdam, Netherlands), milling machine (Lyra Mill, LYRA etk, Sallanches, France), supportive software licenses and associated consumables supplies, which all were used for the formulation of digital dental patient study concept were provided for the Department of Restorative Dentistry (Uzhhorod National University, Uzhhorod, Ukraine) by the LYRA etk company (Sallanches, France) within the educational humanitarian mission «Support Department of Restorative Dentistry», which was originally initiated by the Digital Dentistry Society.¹⁷

Algorithm of clinically-oriented digital dental patient study concept was originally designed for 90 minutes class:

- 1) theoretical part of the class with provision of basic study material in the form of mini-lecture (20 minutes);
- 2) demonstration of caries/endodontic/periodontal lesions by sharing the screen with active diagnostic software (15 minutes);
- 3) explanation of used diagnostic software functioning for the targeted reason,

possibilities to manipulate with the data and how couple it with other diagnostic findings (15 minutes);

- 4) share access to the active diagnostic software on the teacher's computer by using online collaboration mode of Team Viewer (TeamViewer, Goppingen, Germany) or other analogical software to give students possibilities for trying in its' functioning features (20 minutes);
- 5) setting condition for clinically-oriented home-task and explanation the aspects of its realization (20 minutes) (following materials were sent to students' emails: link for the targeted software (if license of such is free) or for the viewer software, set of the materials that needed to be annotated (screenshots, IOS, CBCT-scans, radiographs), link for the image processing software in which annotation over screenshot could be provided, adapted annotation form in spreadsheet software).¹⁸

The following software were used for the realization of digital dental patient study concept's elements: Medit Link (MEDIT Corp., Seoul, Republic of Korea) – for the analysis of intraoral scans, Exocad view (exocad GmbH, Darmstadt, Germany) – for the analysis of 3D objects (intraoral scans in various file formats, lite *.stl, *.ply, *.obj), Paint.NET (dotPDN LLC, Seattle, Washington, USA) – for the analysis of screenshot made in other software and graphical annotation of targeted aspects, Planmeca Romexis® Viewer (Planmeca OY, Helsinki, Finland) – for the analysis of CBCT scans, Periodontal Chart Online (<https://www.periodontalchart-online.com/uk/>) – for the periodontal parameters registration, ideaMaker 4.3.3 (Raise 3D Technologies, Inc., Shanghai, China) – for visualization of 3D printing process, Goole Meet (Google, California, United States) – for the online-classes and lectures, Team Viewer (TeamViewer, Goppingen, Germany) – for share access over different diagnostic software to manipulate with available data and parameters, Microsoft Excel 2019 (Microsoft Office 2019, Microsoft Corp., USA) – for providing annotation within adapted form designed in spreadsheet software.

Assessment of Students Satisfaction with Provided Dental Education Quality

Survey among students was held in the form of online-questionnaire designed within

Google-form. Only students with active university-linked emails, registered at the domain of uzhnu.edu.ua, could take part within survey. Link-request for the survey participation was sent to the emails of 80 students of the 3rd course. Questionnaire consisted of three parts: introduction, rating part and comparative parts. Introduction part of questionnaire included description where students should mentioned their course of studying and study subject, which was modified by the elements of digital dental patient study concept. Rating part of the questionnaire was formed in the closed-end formant of multiple choice questions, so students just needed to choose one of the proposed answers.¹⁶ Rating part of questionnaire included 10 questions (Q1-Q10) formulated to assess student's satisfaction with provided quality of dental study while taking into account improvements provided by digital dental patient study concept.

Rating part of the questionnaire was formulated analogically to the design described within the previous research,¹⁶ and adapted to the objective of present study with the inclusion of the following questions:

- Q1: Rate your satisfaction with provided theoretical information quality considering its' clinical orientation;
- Q2: Rate your satisfaction with the quality of obtained practical skills (including such needed for the clinical practice and such related to the interaction with digital dental technologies);
- Q3: Rate your satisfaction with the quality of conducted lessons in general;
- Q4: Rate your satisfaction with the quality of provided technological support and digital dental advances during on-line classes;
- Q5: Rate your satisfaction with the quality of provided technological support and digital dental advances while doing homework;
- Q6: Rate your satisfaction with study course content;
- Q7: Rate your satisfaction with teaching materials' quality, availability and relevance;
- Q8: Rate your satisfaction with environment safety and comfort;
- Q9: Rate your satisfaction with provided collaborative learning;
- Q10: Rate your satisfaction with the support provided from the teaching staff, attending staff and education managers.

Comparative part of the questionnaire was analogical to the rating part regarding quantity of questions and their formulation, but all the requested questions were repeated with the additive comment "if improvements of digital dental patient study concept would not be provided (education held in conventional online-study mode)" (Q11-Q20). Students were asked to answer questions Q1-20 by using five-point Likert scale, as follows: 1 – poor, 2 – weak, 3 – satisfactory, 4 – good, 5 – excellent.¹⁶

Survey could not be completed if answers for some questions were missed, thus guaranteeing the maximization of data volume for the further analytical processing and statistical analysis.

Statistical Analysis

Google-forms' data was converted into the xls-spreadsheet with its further processing within Microsoft Excel 2019 software (Microsoft Office 2019, Microsoft Corp., USA). Statistical add-in XLSTAT (Addinsoft Inc., Long Island, NY, USA) was used for inferential statistics procedures within Microsoft Excel 2019 software. Grouped results of ratings obtained in the rating and comparative parts of questionnaire were presented with the use of mean values and standard deviations. Differences in ratings obtained after questionnaire responds analysis was assessed with the use of Student's t-tests, considering verified pattern of data distribution. Significance of established differences was validated only under condition of $p < 0.05$.

Ethical aspects

Design of present study and its conformity with relevant ethical standards was approved by Institutional Review Board of Faculty of Dentistry at Uzhhorod National University (Ukraine). Provided research is a part of complex scientific research work of the Department of Restorative Dentistry at Uzhhorod National University (Ukraine). Students did not disclose their name or any other personal information except year of study in any part of questionnaire, so none of the collected information could link any individual response with participants' identity, thus realizing principle of anonymity during provided survey.

Results

69 out of 80 students, who have obtained request to take part in the survey, completed it, given 86.25% response rate. Implementation of digital dental patient study concept supported

higher students' satisfaction with provided theoretical material compared to the conventional online education mode ($p < 0.05$), even though it was no principal differences within theoretical information content used for the classes. Also students responded with higher satisfaction level regarding teaching materials' quality, availability and relevance during the realization of digital dental patient study concept ($p < 0.05$). These differences were noticed on the background that satisfaction with course content in general was analogical either with or without implementation of digital dental patient study concept elements ($p > 0.05$). Considering such outcome it could be theoretically hypothesized that even if basic theoretical course content remains the same usage of digital dental advances during the teaching enhances dental students perception regarding quality of provided material and its relevance.

Implementation of digital dental patient study concept did not impact students satisfaction with environment safety and comfort ($p > 0.05$) and students' satisfaction with the support provided from the teaching staff, attending staff and education managers ($p > 0.05$), which in general were rated more than "good".

Implementation of digital dental patient study concept helps to compensate to some manner deficiency of clinical practice caused by the war-related limitations, since students satisfaction with the quality of obtained practical skills (including such needed for the clinical practice and such related to the interaction with digital dental technologies) reached 4.48 ± 0.67 , and was statistically higher than during online-education mode with no additionally proposed improvements ($p < 0.05$). Moreover, usage of digital dental advances supported higher values of satisfaction with collaborative learning (up to 4.58 ± 0.37), which has dropped during conventional online classes (3.45 ± 1.49).

The same trend was noted regarding satisfaction with the quality of provided technological support and digital dental advances during online-classes and while doing homework, which was higher with the implementation of digital dental patient study concept's elements ($p < 0.05$) (Table 1).

Satisfaction criteria	Education with the implementation of digital dental patient study concept's elements		Education without the implementation of digital dental patient study concept's elements		p-value
	Mean value	Std.dev.	Mean value	Std.dev.	
Satisfaction with provided theoretical information quality considering its' clinical orientation	4.56	0.74	3.84	1.10	$p < 0.05$
Satisfaction with the quality of obtained practical skills (including such needed for the clinical practice and such related to the interaction with digital dental technologies)	4.48	0.67	3.52	0.96	$p < 0.05$
Satisfaction with the quality of conducted lessons in general	4.52	0.71	3.99	1.08	$p < 0.05$
Satisfaction with the quality of provided technological support and digital dental advances during online classes	4.62	0.57	4.07	0.49	$p < 0.05$
Satisfaction with the quality of provided technological support and digital dental advances while doing homework	4.49	0.54	3.89	0.78	$p < 0.05$
Satisfaction with study course content	4.55	0.63	4.13	0.55	$p > 0.05$
Satisfaction with teaching materials quality, availability and relevance	4.79	0.47	4.02	0.87	$p < 0.05$
Satisfaction with environment safety and comfort	4.43	0.46	4.40	0.75	$p > 0.05$
Satisfaction with provided collaborative learning	4.58	0.37	3.45	1.49	$p < 0.05$
Satisfaction with the support provided from the teaching staff, attending staff and education managers	4.37	0.56	4.18	0.79	$p > 0.05$
General satisfaction	4.53	0.57	3.95	0.89	$p < 0.05$

Table 1. Comparison of students' satisfaction with provided education quality with and without the implementation of digital dental patient study concept's elements.

Std.dev. – standard deviation, p-value - probability value, $p < 0.05$ is considered statistically significant.

Registered differences of students' satisfaction rates while implementing elements of digital dental patient study concept and without such supported the outcome that general satisfaction with quality of provided dental education reached out level of 4.53 ± 0.57 if education mode was improved by the proposed digital dentistry advances; such level outreach results calculated for the conventional online study mode without incorporation of any elements from proposed digital dental patient study concept in statistically significant manner ($p < 0.05$).

Discussion

Online education mode has arisen worldwide as an effective solution for the continuation of study process within COVID-19 sanitary restrictions conditions, nevertheless, such approach still considered problematic for the different medical specialties, for which clinically-oriented study and interaction between dental student and patients are ones of the primary goals.^{10, 11, 13} On the other hand online-approach has several unique advantages, which universities still using even after COVID era within blended (hybrid) mode of study, to incorporate immersive learning into the education process.^{12, 13} Such approach seems to be highly relevant for the dental education considering arise of modern digital dental technologies and its close adherence to the advances in virtual reality, augmented reality, artificial intelligence and machine learning, computerized manufacturing and computer-aided designing.^{19, 20, 21} Nevertheless nationwide survey provided in China revealed that there is still a need for improvements of teaching strategies and pedagogical means within online dental education to «boost informatization» of the study process.²² Even though online study mode has proven its efficiency and validity, researches highlighted demand of controlling and adequate structuring of online courses' design, necessity to provide individual progress tracking with adapting the course flow considering specific topics' claims, need for prompt responded professional support and technical monitoring, while also for targeted assessment.²²

Present study represented digital dental patient study concept, which on one hand was developed taking into account recent advances in digital dentistry and previous experience of online learning, while on the other hand it was formed based on the practical need to provide high quality dental education for the students under conditions of ongoing war while not compromising health safety and life risk issues. All over the world education institutions underwent transition from COVID-19 caused online study mode to the blended mode of offline-online education, while in Ukraine this transition was interrupted by Russian war aggression, which compromised quality of education system in general.¹⁶ Previously it was established that already present experience of effective online

education during 2020-2022 supported retention of high quality education even during the war-ongoing conditions due to the provided effort of teaching personnel, prepared quality of study material and corresponding quality of technical support.¹⁶ Nevertheless, quality of acquired practical skills and collaborative learning was graded by students themselves as the lowest ones during COVID period, since realization of such remain problematic due to the inability to provide real time clinical-based study process and direct interaction between students and patients.¹⁶ In present study we have discovered that implementation of digital dental patient study concept helped to compensate to some manner deficiency of clinical practice caused by the war-related limitations, since students have rated satisfaction with the quality of obtained practical skills (including such needed for the clinical practice and such related to the interaction with digital dental technologies) with mean of 4.48 ± 0.67 , which was statistically higher than during online-education mode with no additionally proposed improvements. Potentially such outcome was reached due to the "boosting effect" caused by students having possibility to interact with digital dental technologies directly while having no previous experience among such.

Worldwide analysis shown that both professors and students struggle with implementing digital technologies into the education process during COVID-19 pandemic.²³ That is why it is incredibly important to proposed well-structured algorithm and provide previous trainings for teaching personnel before incorporating digital dentistry advance into study process. Digital dental patient study concept includes time-differentiated class structure, while design of such concept is rather adaptive to the education needs and may vary depending on the specific topics.

Usage of digital dental scans, models and simulations during dental education have been previously described in number of targeted studies, demonstrating its effectiveness and positive impact on the quality of education process.^{1, 2, 3, 4, 24} However, such were used for the specific education needs or within context of specific education topic, while in present study we propose complex digital dental patient education concept, which potentially may cover most of the aspects within dental education curriculum. Proposed education approach also

helps to involve students into the modern dental technologies, given them possibilities to manipulate with intraoral scans, observe process of 3D printing, being involved into the virtual modeling of restoration, taking part within complex treatment planning, observe advantages of CBCT data analysis, while also understand process of digital dental documentation work-flow on the example of online perio-charts. Previous survey demonstrated that motivation of using modern digital technologies among students based on the knowledge of such and perspective of implementation in their own future clinical practice.⁷ Considering this it may be hypothesized that digital dental patient education concept provide promotion of digital dental technologies among future dentists thus forming an impact on the future dental practice in Ukraine.

Previously systematic review has revealed that different educational technologies may improve problem-based health science education by implementing following pedagogical approaches into the study process: 1) structurization of theoretical knowledge and skills; 2) realization of articulation, collaboration and reflections interactions among students; 3) establishment of clinical thinking strategies.²⁶ Study concept of digital dental patient presented in our research in full manner following principles of all above mentioned approaches, since it helps to create virtual platform of clinical patient based on which students may realize clinical discussion, personal interaction, practical approbation of theoretical knowledge during diagnostics process and treatment planning stage. Basically digital dental patient study concept is a try to realize blending learning educational features, while considering all the war-related limitations. Obtained students satisfaction rate with digital dental patient study concept was higher than of conventional online education while both were realized over the same study programs of restorative dentistry. Such outcomes fully corresponds to the results of previous meta-analysis, which also established that blended learning supports more positive impact on knowledge insights when compared with traditional learning within the health education field.²⁷ Moreover, it was found that usage of digital dental patient study concept enhance students satisfaction with provided theoretical material quality even though basic theoretical course content remained the same for different

study modes; potentially such outcome may be argued by changes within students' perception after having ability to not only observe, but to be involve in manipulations with intraoral scans, 3D objects, CBCT results and other digital educational materials.

Recent systematic review revealed that modern technologies including computer-assisted learning (C-AL), augmented reality-assisted learning (AR-AL), and virtual reality-assisted learning (VR-AL) may be categorized as effective replacement of traditional preclinical instructions,²⁸ but there is still ongoing discussion if such may to some manner compensate clinical component of education. Even though students appreciated digital dental patient study concept, only few of them considered such approach as full replacement of offline face-to-face study mode. Most of the students tends to demonstrate the willing to interact with the patients in real life conditions, and interpret digital dental patient study concept as only temporary solution for the wartime period. The same results were obtained in previous study of Hattar et al. (2021),²⁹ where students-respondents were satisfied with online education mode, but they did not interpret it as full-manner substitute of clinical practice, since latter was categorized as the most negatively affected aspect of dental education during COVID-related restrictions.

Digitalization complex for medical and dental education was proposed in Finland as nationwide project, objective of such was to incorporate digital teaching, learning and assessment methods to reach harmonization of education curriculums at the national level.³⁰ In present study we do not interpret digital dental patient study concept as an only available solution to improve dental education at the background of war, but aspects of such methodology may be easily implemented within part of education program at different universities, thus directing dental education system in Ukraine towards principal consolidation.

Limitations of present study associated with the fact of providing survey among students who previously experienced online mode of education only, but not with students who previously undergone conventional pattern of offline real-life clinically-oriented dental education. Such limitation adhere to the phenomenon of war-associated limitations overlapping over COVID-19 sanitary restrictions. Nevertheless, on

the other hand it helped to established specific tendency regarding improvements of dental online education by implementing digital dental patient concept into it. Other limitation is associated with labile design of digital dental patient study concept, since such can be modified in needed directions based on the specific education topic requirements, so there is no strict framework which need to be followed, but rather just a general course of incorporating digital analogues of clinical data into the study process based on digital scans, clinical videos and intraoral photos, digital radiographs and perio-charts. Above mentioned features limits possibilities to apply the same assessment approach for validating effectiveness of digital dental patient study concept during different courses, and forming conditions where each study topic or at least series of related topics needs to be evaluated separately while comparing proposed educational approach with conventional online study mode.

Both COVID-associated restrictions and war-linked limitations are the challenges for dental education, causing the need for improvements and reorganization within curricula with involvement of modern teaching technologies to compensate deficiency of clinical trainings.^{16, 31} Usage of different study platforms should be grounded on objective educational needs and possibilities to expand their functional potential with use of modern digital dentistry advances. Today's technological accelerations related with adoption of artificial intelligence models into the study process may in great manner improve dental and medical education after proper trainings of teaching personnel regarding its correct and controlled application into the teaching practices, while also legal and ethical aspects should be taken into consideration while incorporating AI into education practice.^{32, 33}

Conclusions

Proposed digital dental patient study concept may serve as an effective solution to keep high quality of dental education within online study mode under circumstances of providing it at the ongoing war conditions or sanitary restrictions. Digitalization of dental education aimed at strengthening clinically-oriented study process, enhancing students

awareness with modern digital technologies and deepening understanding of clinical aspects on the simulation models. Nevertheless it should be mentioned that digital dental patient concept even considering its advantages could not replace real-time clinically-based study mode, so usage of such should be interpreted as efficient but temporary resolution for problems arising at limited access to educational facilities due to the threaten for life or health of the students under war-related or pandemic-associated conditions.

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Declaration of interest

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