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Development and assessment of an online virtual orthodontic curriculum

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Published in:
Journal of Dental Education

DOI:
[10.1002/jdd.12825](https://doi.org/10.1002/jdd.12825)

Publication date:
2022

Document Version
Peer reviewed version

[Link to publication in Discovery Research Portal](#)

Citation for published version (APA):
Liu, L., Yuan, S., Zhang, W., Wang, Z., Zhao, C., Pan, Y., Yan, B., & Wang, L. (2022). Development and assessment of an online virtual orthodontic curriculum. *Journal of Dental Education*, 86(5), 509-516. <https://doi.org/10.1002/jdd.12825>

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Title: Development and assessment of an online virtual orthodontic curriculum

Abstract

Introduction: Due to break space and time limits, an entirely new online curriculum of orthodontic education with online evaluation system has been structured and developed in the dental school, based on virtual reality simulation.

Curriculum: At Nanjing Medical University, a new online orthodontic curriculum with programmatic assessment process was constructed and implemented based on competency-based education (CBE). It was consisted of the online orthodontic theoretical lectures based on the National Open Online Course “Orthodontics”, the online journal club via the online "flipped classroom", and the online orthodontic pre-clinical training via the Virtual Learning Network Platform. In order to evaluate this curriculum, 94 Year 4 dental students took part to complete the online orthodontic curriculum. The mean total score of all the students was 91.99, and the element scores of the online theoretical lectures, journal club, virtual pre-clinical training and online final examination were respectively 96.83, 79.49, 96.00 and 87.02, which showed a good performance. According to the student feedback towards this curriculum via the online

questionnaire, nearly 98% of the students showed agreement or strong agreement that the online orthodontic curriculum has enhanced their orthodontic theoretical understanding and orthodontic practical ability.

Conclusion: As a student-centered CBE, this online orthodontic curriculum with online evaluation system could provide both orthodontic theory and practice teaching for all the dental students at all times and places based on the online virtual mode, which enriched learners' critical thinking, problem solving and assessment skills.

Keywords

orthodontic education, virtual pre-clinical training, programmatic assessment, competency-based education

Introduction

Compared with medicine, dentistry, particularly orthodontics has highlighted the importance of clinical practice. Thus graduating students must be able to demonstrate skills and abilities to provide safe dental care.¹ The orthodontic clinical practice such as brackets bonding and arch

wire bending, is very important but basic orthodontic practical skills for treating the patients. However, such orthodontic clinical practice is also challenging for the new dental graduates. Since dental graduates are required to be fit for practice, orthodontic education has commonly adopted competency-based assessments or practical outcomes.²

Competency-based education (CBE) is an educational approach based on an organizing framework around students' competencies. It focuses on outcomes that is included in the process of designing, implementing, assessing and evaluating curriculum.³ Based on analyzing patient's social and care needs, CBE has highlighted the graduating practitioners' outcome abilities and competencies to better prepare them for future healthcare practice. Unlike the traditional medical training which emphasizes the importance of building upon years of experience in learning, CBE has shown greater accountability and flexibility using a learner-centered philosophy.⁴ Its teaching philosophy is suitable for the orthodontic education, in particular, focusing on the learning outcome of clinical practical skills.

The competency-based approach has been adopted in medical education which has underscored the key role of a continuous, inclusive and detailed feedback system.⁵ Nevertheless, it is inherently difficult to incorporate assessment methods in dental education given the

complexity of different patient, learner and staff factors.¹ Programmatic assessment, as a longitudinal assessment approach that closely linked with learning outcomes, makes it possible to evaluate student learning and development of their skills and competencies throughout their education.^{6,7} CBE also helps to identify students' individual learning needs of dental education and therefore to make sure they are supported in a learner-centered approach at an early stage. Hence, the orthodontic education with programmatic assessment based on competency has high clinical practical requirements, especially for pre-clinical training.

Since the breakout of the COVID-19 pandemic happened earlier this year, numerous medical students worldwide could not attend the academic course in the classroom due to the universities' facilities closures to prevent cross-infection.⁸ Such challenge is even greater for dental education given the larger surgical component of clinical dentistry. Although it is a challenge for the dental education to ensure students are able to continue their learning journey during the lockdown, it is also an opportunity to innovate, facilitate learning, improve access to education, and optimize the available resources. Some institutions have attempted to transfer a classroom face-to-face teaching to a virtual learning scenario.⁹

As part of the dentistry, orthodontics is an amalgamation of three fundamental

components: theory, laboratory, and clinical practice.⁹ Due to the high requirement of clinical practice, the pre-clinical practice plays a critical role in orthodontic education. It is also the most difficult programme to implement as an online modality. In the last decade, technologies applied in higher education including virtual reality simulators, augmented reality, and computer aided design/computer aided manufacturing (CAD/CAM) systems have facilitated online teaching strategies in orthodontic education, especially for pre-clinical practices.¹⁰

In China, some dental schools have tried to adapt their curriculum to specific needs of their dental learners, based on the stage of their current curriculum, the extent of change required, and the available teaching resource and technologies. An entirely new programme of orthodontic curricula has therefore been structured and developed at the School of Stomatology, Nanjing Medical University. This curriculum adopted competency-based education by applying teaching recourse of the online and virtual reality and programmatic assessment of process and outcome performance.

Curriculum development of orthodontic online education

Based on characteristics of the orthodontic education, the theoretical and practical learning were

of equal importance to the dental students. The online educational process especially the pre-clinical programme with the programmatic assessment was developed and implemented between February and June 2020.

The participants provided informed written consent, and the study followed the Declaration of Helsinki and the guidelines of the Ethics Review Committee of Affiliated Stomatological Hospital of Nanjing Medical University with regard to protocols and ethics (PJ2019-070-001).

◆ **Constructing online orthodontic teaching activities**

The online orthodontic curriculum was consisted of online course system and online evaluation system. The online course system included the online theoretical lectures, journal club, and interactive virtual simulation training (Figure 1). These series of online courses applied various pedagogical models, the instructional and learning strategies, and the online learning technologies.¹¹

- **Online course system**

✧ *Online theoretical lectures*

The online orthodontic theoretical lectures were implemented using the National Open Online Course “Orthodontics” in the MOOC Platform of China Universities (<https://www.icourse163.org/course/NMU-1001753311>). The dental students learned the basic knowledge by this online course, including online instructional videos, unit homework and quizzes, problem based discussion forums.

The unit homework was online assignment for students to complete and submit their work within specified time limit after watching online instructional videos. The MOOC Platform of China Universities randomly assigned several students’ homework to other students in order to evaluate their peer assessment abilities. The unit quizzes, including single/multiple choice questions, essay questions and case reports, were required to be completed in the 10-20 minutes via the MOOC Platform. This online platform provided instant feedback about the unit quizzes results. At the end of the theoretical lectures, the online final test served as one of the summative assessments was provided for evaluating student learning efficacy. The online peer assessment and instant feedback platform may help students increasing their ability of self-assessment/assessment and grasp knowledge points.

This new online teaching via the network platform was delivered using multiple teaching approaches including video demonstration, online quizzes, case reports, small group discussion, peer assessment, instant feedback etc. In the “Classification of malocclusion” unit of the online theoretical lectures, the students learned the online instructional videos, completed unit homework with peer assessment, and group discussion on online forum. Due to above online teaching depending on the self-learning platform, the students were allowed to learn the theoretical essentials without limitation of time and space. Students’ self-learning and self-assessment abilities were improved, as well as the resources of instructors and costs was saved.

✧ *Online journal club*

The online journal club was implemented via the online "flipped classroom" teaching method. The reading list focusing on different orthodontic topics was provided to the students to extending their professional knowledge. In small group discussion, students prepared and presented their interested orthodontic topic to their peers using online meeting software, rather than teachers. The teachers only offered written feedback after class via online platform. This student-centered teaching method could provide the students with as much learning

independence and flexibility as possible, and improve their learning enthusiasm and teamwork skills. This new online teaching could improve student's critical thinking, evidencebased practice, and communication skills/oral presentation skills to address their learning outcomes.

Meanwhile, this online teaching method did not need real classroom. The students and teachers could take part in the online journal club at any time just with the network. The time and space of teaching were free and convenient with a good learning efficiency.

✧ *Online pre-clinical training*

The online orthodontic pre-clinical training was implemented via the Virtual Learning Network Platform (VLNP, Affiliated Stomatological Hospital of Nanjing Medical University, Nanjing, China), such as oral examination and fixed orthodontic appliance bonding (<http://211.139.109.55/virlab/index.html>). VLNP based on the virtual reality simulation was designed and implemented for the pre-clinical dental training by Nanjing Medical University. The virtual reality simulation provided an interactive and virtual learning environment, which various clinical case scenarios were integrated into. The students "enter" into the virtual clinic and "communicate" with the virtual patient to obtain chief complaint and medical history. The

virtual environmental immersion like the real clinic environment could help students playing the role of doctors as soon as possible. With the aid of virtual reality simulation, the students could utilize an interface including a mouse or a keyboard to control virtual operational instruments to accomplish various practical tasks on the “patient”, such as oral examination, impression taking, braces bonding. Meanwhile, it provided augmented visual computerized feedback about a student’s performance compared to an ideal standard—the degree of dental crowding, the correct position of brackets, and the duration of etching. VLNP with instant feedback helped students to understand essential operational procedures and enhance technical skills through the real-time interactive virtual environment.¹²

Students used the VLNP to log into their own student accounts and completed the online interactive virtual simulation training course independently. This course included three components. Firstly, the students were encouraged to read the requirements of the orthodontic practice tasks including the pre-defined criteria. Then, the students were asked to watch videos that demonstrated the stepwise orthodontic practical procedures. Finally, the students used the virtual platform to perform the orthodontic practical procedure in a stepwise manner. In the fixed orthodontic appliance bonding item, for example, the students accomplished tooth

cleaning, etching and drying, adhesive application, bracket placement, and light curing in sequence. The students were provided with opportunities to practice all the procedures with unlimited attempts on the virtual learning environment given their own learning needs.

As a pre-course of offline practical training, this online pre-clinical training was only a part of the whole pre-clinical training, in order to help students grasping the operational essentials and technical skills and improving the efficiency of offline training. Before practicing on the real clinical patients independently, the students need to accomplish the full clinical orthodontic practical training including online pre-clinical training, offline pre-clinical training and clinical practice on the real patients.

- **Online evaluation system**

This online orthodontic curriculum adopted the programmatic assessment process including formative and summative assessments, which improved objectivity and effectiveness of the online evaluation system. In the online orthodontic theoretical lectures, watching online instructional videos, taking unit homework and quizzes, participating in discussion of the problems were parts of the formative assessment. Three tasks were required for students to

complete in the online orthodontic pre-clinical training. These included (i) familiarizing the pre-defined practice criteria, (ii) watching the standard videos and (iii) using the interactive virtual platform to perform orthodontic practical procedure, as part of the formative assessment. The online final tests of the orthodontic theoretical course, online evaluation of the journal club and virtual pre-clinical training test were incorporated into the summative assessment, along with the final examination of the online orthodontic curriculum. This programmatic assessment process with competency-based outcome was tailored in the integrated online orthodontic curriculum, contributing to students having instant feedback and additional support.

◆ **Evaluating online orthodontic teaching activities**

There were 94 Year 4 dental students at the School of Stomatology, Nanjing Medical University, who took part to complete the online orthodontic curriculum. The students aged from 20 to 22 years old with an average age of 21.6. Out of 94 students, 33 were male and 61 were female.

The National Open Online Course “Orthodontics” supplied 49 online instructional videos, 3 unit homework, 13 unit quizzes, 14 problem based discussion forums, and 1 final test. The online journal club provided four general orthodontic topics to the students, including cranial-

maxillofacial growth and development, orthodontic appliance, early orthodontic treatment, and cephalometric analysis. Students were asked to read literature based on the recommended reading list from the online learning platform, and invited to prepare their oral presentation surrounding their interested topic via the online "flipped classroom" teaching method. The instant feedback was provided based on online teachers' advice and evaluation.

In the online orthodontic pre-clinical training, the students logged in the VLNP and completed reading the pre-defined practice criteria, watching the standard videos and performing the practical procedure in a stepwise approach. This gave the flexibility of learning in students' own time. They could spend as much time as possible to learn. This online evaluation system provided the formative and summative assessments of the virtual pre-clinical training. In the end, the final examination and questionnaires evaluating students' experience of attending this online learning were provided online via the MOOC software. The questionnaire was to identify students' opinions about the online orthodontic curriculum based on their own online learning experience.

- **Course assessment**

All the dental students' formative and summative assessments of this online orthodontic curriculum were shown in Table 1. The online total scoring system was consisted of the online orthodontic theoretical lectures score (40%), online journal club score (10%), online virtual pre-clinical training score (20%) and online final examination score (30%). The full score of this online curriculum and element course was 100. The mean total score of all the students was 91.99 with each component scores as for 96.83 for the online theoretical lectures, 79.49 for journal club, 96.00 for virtual pre-clinical training and 87.02 for online final examination.

To examine the impact of the online curriculum on students' educational outcome, we compared the students' scores of 2020 (during COVID19 times) final examination with those of 2019 (pre-COVID19 times) using the independent-samples t test. The level of significance was $p < 0.05$. There were 90 Year 4 dental students participating in the 2019 final examination at the School of Stomatology, Nanjing Medical University. The students' scores of 2020 (91.99) were significantly higher than those of 2019 (83.06) (t-test, $p < 0.05$). The results showed that almost all the dental students have obtained a good performance.

- **Student feedback**

An online questionnaire comprised of five attitudinal items was conducted with all the students after they finished the online orthodontic curriculum (Table 2). Students' experience and attitudes towards this curriculum were collected in order to improve this curriculum. Instead of using the commonly used 5-point Likert Scale, we used a 4-point scale to force dental students to give an opinion about the curriculum. Nearly 98% (n=92) of the students showed agreement or strong agreement that the online orthodontic curriculum had improved the orthodontic theoretical understanding and practical abilities. There were respectively ninety-three (98.9%) and eighty (85.1%) out of 94 students, who strongly agreed or agreed to the statement that the online orthodontic theoretical lectures and online journal club could be conducive to improving their in-depth understanding of the orthodontic theory. There were ninety-one (96.8%) out of 94 students, who agreed or strongly agreed that the online virtual pre-clinical training could be conducive to improving their abilities of the orthodontic practice. Only two (2.1%) and four (4.3%) disagreed and partially disagreed that the online evaluation system with the formative and summative assessments could be conducive to improving the effectiveness of the online orthodontic curriculum and enhancing objective assessment. The results suggested that the dental students approved the effect of this online orthodontic curriculum on the orthodontic

theory and practice.

Discussion

Since orthodontists are required to have good clinical practical capability, orthodontic education is expected to provide the support for the dental students to accommodate their learning needs including assimilating theoretical knowledge and being able to transfer their knowledge into clinical practice. They are required to be able to work independently, to make evidence informed clinical decision, and obtaining manual skills to perform these decisions after their graduation.¹³ Competency-based education (CBE) is thought to realize these requirements and has been therefore recommended in the orthodontic education.¹⁴ CBE has focused on outcome-based learning especially in healthcare education with high requirements of clinical practice. This prepares the graduates to possess a high standard of knowledge, skills, and attitude.^{3, 15} It provides students a seamless transition from undergraduate education to supervised medical or dental practice.¹⁶ Thus, novice students start their training in simulation learning environment to prepare them as a safe beginner with competent clinical abilities and skills for their independent practices.¹⁷

In this study, this novel online orthodontic curriculum based on the competency-based education was constructed via the online platform and virtual simulation, as a novice method including theory learning, clinical training and objective evaluating. The present online orthodontic theoretical lectures based on the National Open Online Course “Orthodontics”, provided the students with online instructional videos, unit homework and quizzes, problem based discussion forums on the MOOC Platform of China Universities. The students could undertake the theory learning in the unlimited time and space. That was same with the online orthodontic pre-clinical training via the VLNP. The students performed the unlimited pre-clinical practice of all the procedures in a stepwise approach through the online interactive virtual platform in their own time. This learner-centered approach offered students flexibility to learn based on their individual learning needs. In the online journal club, the online "flipped classroom" teaching method was implemented in order to improve student’s independent learning, learning effectiveness, presentation skills and problem solving ability.

The purpose of the assessment is threefold: to promote active learning, to facilitate sound decisions making on achievable learning outcomes, and to assess the effect of the curriculum. This online orthodontic curriculum involved an online evaluation system based on

programmatic assessment. It included formative assessment continuously monitoring the students' progress, and summative assessment scoring the students' examination. The rich information available in programmatic assessment provides a solid basis for an elaborative curriculum evaluation.⁷ Individual data points during this assessment programme were maximally informative to the learning process and assisted effective student learning by obtaining constructive feedback in a timely manner.¹⁸ It could supply the students and teachers with more objective, comprehensive and efficient evaluation, in comparison to the single final assessment.

To ensure fairness and justice of tests, we informed students that the tests were closed-book and closed-resources before the task and examination. In order to prevent cheating on examinations, we adopted computer camera and a special examination software recording the whole student' exam process and monitoring whether students consulted other software or recourse on the computer. In addition, to balance the difficulty of each exam, all the questions were obtained from the uniform question bank of Nanjing Medical University. The online evaluation system randomly assigned exam questions based on the difficulty level, question type and so on, in order to ensure the similar difficulty of each exam.

The course scores of all Year 4 dental students attending this online orthodontic curriculum showed that almost all the students acquired a good performance. The mean total score of all the students was 91.99, belonging to an excellent grade. The online questionnaire demonstrating students' experience and attitudes towards this curriculum showed that nearly every student approved this online orthodontic curriculum has improved their orthodontic theoretical understanding and practical ability, including the online virtual pre-clinical training. It implied this online orthodontic curriculum was suitable for the orthodontic education, particularly in the preclinical dental training.

Although the online orthodontic curriculum with programmatic assessment process was established via the virtual simulation in order to avoid unnecessary risk exposure during the COVID-19 pandemic, this new online teaching method had advantages of the improved learning outcomes and instant feedback, objective evaluation, unrestricted training hours and space, as well as better cost-effectiveness for dental schools. Based on a student-centered CBE, it enriched the students' critical thinking, autonomous self-assessment and problem-solving skills. All these skills will further assist students in performing comprehensive practices and developing professionalism for higher quality clinical services. Therefore, this new online

curriculum could also be widely suitable for the orthodontic education in the general teaching.

Conclusion

The new online orthodontic curriculum with online evaluation system was constructed and implemented at the School of Stomatology, Nanjing Medical University. It included three parts: the online orthodontic theoretical lectures based on the National Open Online Course “Orthodontics”, the online journal club via the online "flipped classroom", and the online orthodontic pre-clinical training via the VLNP. Both orthodontic theory and practice teaching could be provided for all the dental students at all times and places based on the online virtual mode. It was suitable for the orthodontic education, particularly the preclinical dental training.

Acknowledgements

We appreciated the help of the National top-level undergraduate program project and the Top-notch Academic Programs Project of Jiangsu Higher Education Institutions (TAPP).

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Tables

Table 1. Students' scores of the online orthodontic curriculum

Learning item	Score	Total (n = 94)		Male (n=33)		Female (n = 61)	
		Mean	SD	Mean	SD	Mean	SD
Instructional videos (10%)	100	97.70	4.05	96.79	5.36	98.19	3.06
Unit homework and quizzes (10%) ^F	100	94.93	7.05	94.48	6.62	95.18	7.32
Problem based discussion forums (10%) ^F	100	98.29	4.53	98.00	5.61	98.50	3.66
Final test (10%) ^S	100	95.95	4.32	94.90	4.31	96.75	4.28

Total	100	96.83	3.74	96.20	4.62	97.17	3.17
Online journal club (10%) ^S	100	79.49	8.95	77.02	10.57	80.84	7.71
Three training tasks (10%) ^F	100	100.00	0	100.00	0	100.00	0
Online pre-clinical training (20%) Virtual training test (10%) ^S	100	92.00	3.87	91.52	4.13	92.26	3.73
Total	100	96.00	1.93	95.76	2.07	96.13	1.86
Online final examination (30%) ^S	100	87.02	5.56	86.43	6.12	87.34	5.26
Online total score (100%)	100	91.99	3.55	91.26	4.03	92.38	3.23

F: formative assessment

S: summative assessment

Table 2. The questionnaire items for the students concerning their opinions on the benefits and drawbacks of using the online orthodontic curriculum.

Item contents	I strongly agree	I agree	I partially disagree	I disagree
1. I have improved orthodontic theoretical understanding and practical ability via the online orthodontic curriculum.	72 (76.6%)	20 (21.3%)	2 (2.1%)	0 (0%)
2. The online orthodontic theoretical lectures can be conducive to improving my in-depth understanding of the orthodontic theory.	52 (55.3%)	41 (43.6%)	1 (1.1%)	0 (0%)
3. The online journal club can be conducive to improving my in-depth understanding of the orthodontic theory.	26 (27.7%)	54 (57.4%)	13 (13.8%)	1 (1.1%)
4. The online virtual pre-clinical training can be conducive to improving my ability of the orthodontic practice.	35 (37.2%)	56 (59.6%)	2 (2.1%)	1 (1.1%)
5. The online evaluation system with the formative	39	49	4	2

and summative assessments can be conducive to (41.5%) (52.1%) (4.3%) (2.1%)
improving the effectiveness of the online
orthodontic curriculum and enhancing objective
assessment.

Figure legends

Figure 1. The online orthodontic curriculum with the online evaluation system.