Effectiveness of Technology-Enhanced Learning to Improve Periodontics Educational Outcomes: A Systematic Review

Maria C. de C. Berry, Joao M. de M. Neto, Maria Isabel de C. de Souza, Carlos Marcelo da S. Figueredo, Vanessa Reher, Jane L. Evans

Maria C. de C. Berry was a PhD student, Class of 2017, School of Dentistry, Rio de Janeiro State University, Brazil and a visiting Research Fellow at the School of Dentistry and Oral Health, Griffith University, Gold Coast, QLD, Australia, at the time of this study; Joao M. de M. Neto was a Visiting Research Fellow, School of Dentistry and Oral Health, Griffith University, Gold Coast, QLD, Australia, at the time of this study; Maria Isabel de C. de Souza is a Professor of Public Health, School of Dentistry, Rio de Janeiro State University, Brazil; Carlos Marcelo da S. Figueredo is Associate Professor of Periodontology, School of Dentistry and Oral Health, Griffith University, Gold Coast, QLD, Australia; Vanessa Reher is a Senior Lecture in General Dental Practice, School of Dentistry and Oral Health, Griffith University, Gold Coast, QLD, Australia; Jane L. Evans is Associate Professor of Dental Technology and Deputy Head of School (Learning and Teaching), School of Dentistry and Oral Health, Griffith University, Gold Coast, QLD, Australia. Direct correspondence to A/Prof. Jane L Evans, Griffith Health Centre, School of Dentistry and Oral Health, Griffith University, Parklands Drive, Gold Coast, QLD, 4222, Australia; j.evans@griffith.edu.au.

Effectiveness of Technology-Enhanced Learning to Improve Periodontics

Educational Outcomes: A Systematic Review

Abstract:

Purpose/Objectives: Technology-enhanced learning (TEL) has been suggested as a suitable learner-centred pedagogical approach in dental education. However, the results of TEL effectiveness in periodontics education are controversial. Therefore, this systematic review aimed to evaluate the effectiveness of TEL to improve educational outcomes in the periodontics field compared to traditional learning methods. **Methods:** The search, comprised randomised controlled trials (RCTs) and crossover studies that were related to periodontics education from the following databases: MedLine, PsycINFO, Eric, Scopus, EMBASE, and Web of Science. Two authors independently performed study selection, data extraction, and assessed risk of bias. Kirkpatrick's four-level evaluation model was used to evaluate educational outcomes. **Results:** From 1642 studies, after applying inclusion criteria, seven studies remained for analysis. On level 1 (Reaction), undergraduate dental students reported positive attitudes related to TEL. On level 2 (Learning), three studies found that TEL improved knowledge gain compared to traditional learning methods. Three other studies did not show any difference between TEL and conventional learning methods, and one found that traditional learning methods presented superior results. On level 3 (Behaviour), one study found that TEL application improved students' performance. On level 4 (Results), five studies suggested that the implementation of TEL would improve educational outcomes in periodontics education if combined with traditional learning methods. **Conclusion:** The findings showed that the exclusive use of TEL does not significantly improve periodontics educational outcomes when compared to traditional learning methods. However, the combination of TEL and traditional learning methods can be the key to enhancing periodontics education.

Keywords: dental education; educational technology; periodontics; systematic review; technology-enhanced learning (TEL)

INTRODUCTION

New technologies have led to the implementation of innovative learning and teaching methods in dental education away from traditional educational pedagogies.¹⁻³ Among different types of technologies, technology-enhanced learning (TEL) is the application of information and communication technologies in the delivery of education.^{4,5} In this systematic review, the concept of TEL was adopted to describe any learning methods that implement computers, mobile devices, software, virtual reality, virtual learning environment and videos as educational tools. In dental education, Park-Howell⁶ suggested the use of TEL as a learner-

centred pedagogical instrument and, Cooper's⁷ highlighted that the adoption of TEL in the dental curriculum has the potential to enhance students competences.

Although TEL has been applied in dental education, there are variations in the result of its effectiveness among dental disciplines. Clunie et al. concluded in their systematic review that there was not enough methodological power to measure TEL effectiveness in anatomy education.⁸ Whereas, in endodontic education, Negendrababu et al. found in their systematic review that TEL had the same effect as traditional learning methods in educational outcomes.⁹ Contrary, Wong et al. reported that the application of video in anesthesiology was effective in teaching psychomotor skills in the administration of local anesthetics for undergraduate dental students.¹⁰ Besides, in a randomised control trial in Prosthetics by Liu and colleagues, they found that the use of video improved the performance of undergraduate dental students in ceramic crown preparation.¹¹ Equally, videos have been suggested as a TEL potentially educational tool in periodontics education.¹²⁻¹⁴

Among the variety of TEL available, videos, computer-assisted learning and virtual learning environments are more frequently used in periodontics education. However, differences between the effectiveness of each application are not apparent. Levine et al. published the first study comparing TEL and traditional learning methods in periodontics education in 1987.¹⁵ In their study, the authors compared computer-assisted learning with traditional learning methods and concluded that there was no difference in undergraduate dental students' learning outcomes when comparing TEL to traditional learning methods.¹⁵ However, other studies questioned the capability of conventional learning methods in offering a more in-depth learning experience for students and suggest that more simulation and innovative learning methods would improve educational outcomes in periodontics.¹⁶⁻²⁰ Nonetheless, despite reports about the positive effects of TEL in improving educational outcomes in periodontics education^{13, 21-23}, Ramlogan et al. highlighted that the exclusive use of video as a TEL had some limitations.¹²

Furthermore, corroborating with Levine et al., some authors did not find a difference in TEL application to traditional learning methods in improving educational outcomes of undergraduate dental students' in periodontics.^{24, 25} Thus, results in TEL effectiveness in periodontics educational outcomes remain divergent. Therefore, this systematic review aimed to evaluate the current effectiveness of TEL compared to traditional learning methods in the field of periodontics.

METHODS

This study was a systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)²⁶ and followed the Guideline for Systematic Reviews in Dental Research²⁶. Papers in which the objective was to determine the effectiveness of TEL in educational outcomes compared to traditional learning in periodontics were considered.

The inclusion criteria were based on the PICO criteria²⁷. They comprised, undergraduate dental students (undergraduate dental students), residents (postgraduate students), general dentists, specialists in periodontics and/or university staff (P = Population) in which TEL methods or techniques (I = Intervention) were compared to traditional learning methods (C = Comparator) in educational outcomes (O = outcome). In this study, traditional learning methods are defined as any type of methodology that did not apply technology to teach or deliver periodontics educational contents, a synonymous for conventional lecture.²⁸⁻³⁰ There were no restrictions on language or year of publication. Inclusion criteria contained randomised controlled trials (RCTs) and crossover studies that were related to periodontics education. Reviews, letters to editors, conference readings, editorials, and personal opinions were excluded.

Six databases in the Health and Education field were searched: MedLine and PsycINFO via OVID, Eric via ProQUEST, Scopus, EMBASE, and Web of Science. All searches were

done on September 05, 2019, using keywords (Table 1). The construction of the search strategy, as well as the selection of databases, was performed with a librarian aiming to find the best search strategy and guarantee that all data extraction was efficient and adequate to our search. References were managed, and duplicates were excluded from the EndNote (Clarivate Analytics, PA, USA). Additional manual searches were performed in journals covering the fields of “dental education” and “periodontics” as a single and combined search.

Two of the authors (MB, JM) independently screened the titles and abstracts followed by full-text evaluation of all selected references and crosschecked the information. Disagreements in selection were resolved by a third reviewer (CMF). When necessary, authors of selected studies were contacted by email for missing data.

The same two authors performed data extraction independently, resulting in the following characteristics of the selected papers: first author, year of publication, country of the study, sample size, participants, TEL intervention, and educational outcomes (reaction, learning, behaviour, and results).

The same two authors (MB, JM) independently assessed the Risk of Bias of the included studies, with the resolution of disagreement by a third author (CMF). Cochrane Risk of bias tool was applied for randomised trials and crossover studies (RoB 2.0).³¹

The included studies were classified as “low risk”, “some concern”, or “high risk” based on the risk of bias due to the randomised process, deviations from intended intervention, missing outcome data, measurement of the outcome, selection of the reported result and overall quality. “Low risk” of bias was considered when all the key domains were scored as low risk. A scoring of “some concern” was considered when at least one essential domain had been classified as “some concern”, and if at least one key domain were defined as “high risk” or three or more domains as “some concern”, studies were classified as “high risk”.

Kirkpatrick’s evaluation model was used to evaluate the effectiveness of learning activities in periodontics. The model consists of four levels: reaction, learning, behaviour, and

results, and has been used to evaluate learning and teaching strategies.³² In dentistry, studies have applied this model to evaluate educational outcomes.^{9,33} In this systematic review the four levels of educational outcome are Level 1 (Reaction): measurement based on attitude or students or educators; Level 2 (Learning): measurement based on knowledge attained and/or retained by students; Level 3 (Behavior): measurement based on any change in behaviour assessed by performance in clinical and/or laboratory procedures or diagnostic ability; and Level 4 (Results): measurement based on the return of expectations of a previous intervention.

34

RESULTS

The search strategy identified 2,088 records from the six databases, which was reduced to 1,642 after removing duplicates. In addition to this, three other studies were found by manual search. Although, all the keywords in the search strategy were needed in order to identify as many relevant records as possible, after reading titles and abstracts, most of the studies were not related to our research question.

We found papers related to only technology, periodontics and education for patients, studies without control groups and comparing types of different techniques without educational outcomes. As a result of Consequently, a large number of articles were excluded. Finally, seven articles were selected for the systematic review based on the inclusion criteria (Figure 1), and their characteristics are summarised in Table 2. It was expected that the final number of articles included in the study would be limited due to the research question been specific to the periodontics area, and the inclusion of only RCTs and crossover studies. The reasons for exclusions after full-text evaluation are listed in Table 3.

Between the selected articles, five studies were classified as a moderate risk of bias due to inadequacies or absence of information in the randomisation process.^{12,14,15,24,32} Regarding

the measurement of the outcome, one study presented deficiencies. It was classified as a high risk of bias,²³ and only one study,¹³ was classified as a low risk of bias (Figure 2). Most of the studies included in this systematic review were RCTs (71.4%) published in the English peer-reviewed literature in dental or medical journals. The studies were conducted in United Kingdom^{15, 24}, the United States^{13, 14}, Sweden^{23, 35}, and the Bahamas¹² and were published between 1987 and 2019. Sample sizes ranged from twenty-two to 132 participants, all undergraduate dental students, primarily during the first three years of their dentistry program of study.

Different types of TEL were applied in the studies included in this systematic review. Authors utilised video demonstration as a TEL intervention to evaluate improvement in the educational outcome of undergraduate dental students¹²⁻¹⁴. Other types of TEL applied in the remaining studies were: computer-assisted methods^{15,24}, internet-based videoconferencing³², and virtual patient²³. Additionally, three studies investigated TEL effectiveness in the learning and teaching process of periodontal diagnoses, and treatment plan^{14, 15, 23} and four studies investigated TEL effectiveness in the learning and teaching of periodontal screening and examination.^{12, 13, 24, 35} Regarding of the group selection, all seven studies compared the effectiveness of exclusive use of TEL and traditional learning methods, and one study did an extra group using TEL in combination with traditional learning.¹

The four domains of Kirkpatrick's evaluation model were utilised in all seven studies to assess educational outcomes and are described in Table 2. At level 1, six studies measured, via questionnaires, students' reactions to the use of TEL in education. Students' reactions (level 1) consisted of students' perception, attitudes, satisfaction, and acceptability of the intervention. All six studies reported that students had a positive reaction regarding TEL application in their learning.^{12-15, 24, 35} Within this group, two studies found that students favoured a combination of TEL with the traditional learning methods¹²⁻¹⁴. However, two other

studies concluded that, although students had a positive reaction to TEL, they still preferred the traditional learning methodology.¹⁵⁻³²

All seven studies assessed knowledge gain at level 2 (learning); however, educational tools differed among the studies. Two studies applied practical exams^{13, 23}; two applied multiple-choice questions (MCQ)^{14, 15}, one applied writing test,¹² and two applied educational tools combinations.^{24, 35} As a result of knowledge gain in periodontics education, four studies did not find improvements when TEL was compared to traditional learning methods.^{15, 24, 32, 12} Contrary, two studies concluded that the application of TEL improved students' knowledge gain^{13, 23}, and one found that the combination of the methods improved the knowledge gain of undergraduate dental students.¹⁴ A narrative summary of the findings at level 2 is described in Table 4.

Three studies assessed the level 3 (behaviour) applying different educational tools, such as confidence log with pre and post practical test²⁴, 6-point performance scale²³, and checklist.¹² Two studies concluded that there was no significant difference in students' behaviour when Computer-assisted methods or Video demonstration was applied.^{12, 24, 12} However, one study showed a significant difference in students' behaviour ($p < 0.01$) when Virtual patient was applied.²³

The expectations of TEL interventions were evaluated at level 4 (results). Five studies suggested that TEL should be integrated into the periodontics curriculum instead of replacing traditional methods.^{12, 13, 15, 23, 24} Additionally, one study concluded that combining both methods was effective in improving educational outcomes for periodontal diagnosis and treatment planning.¹⁴ Moreover, three studies emphasised that students still value face-to-face interactions.^{15, 24, 32}

A meta-analysis was not performed at any domain due to the high heterogeneity among the studies and differences in evaluation methods.

DISCUSSION

Even though technology-enhanced learning (TEL) has been used to overcome limitations of traditional learning methods,³⁶⁻³⁹ our systematic review found that the effectiveness of TEL, when compared to traditional learning methods, may not necessarily lead to improving educational outcomes in periodontics education. This result corroborates other systematic reviews of TEL effectiveness in improving educational outcomes when compared to traditional learning methods in the oral radiology,⁴⁰ orthodontics,⁴¹ and endodontic fields.⁹

In this systematic review, to minimise confounding factors between studies, the measures of educational outcomes were based on Kirkpatrick's 4-levels evaluation model (reaction, learning, behaviour, results) and each level was analysed separately. Level 1 (reaction) was assessed through questionnaires by six of the seven included studies. Our results show a positive attitude related to TEL application in periodontics education, which was also emphasised by other studies in dental education.^{2, 42-44} This finding might suggest that TEL implementation in undergraduate dental courses motivate students through their learning process. The application of a questionnaire to assess students' attitudes was highlighted by Shoiab et al. as an essential tool in evaluating impacts on educational outcomes, especially in a learner-center approach.⁴⁵

All seven studies included in this systematic review evaluated level 2 (learning). However, each one used a different evaluation tool to analyse the knowledge gain of TEL when compared to traditional learning methods. In this context, it was not possible to compare the results. Nevertheless, parameters of the p-value (p), sample size (N) and risk of bias, suggest that TEL had the same effect as traditional learning methods in knowledge gain on the delivery of periodontics education, consequently, not leading to improvements.

Regarding level 3 (behaviour), only three of the included studies evaluated participants' ability to transfer skills into the workplace. Due to the heterogeneity between evaluation tools, the results of TEL in improving students' performance, when compared to traditional learning methods, were unclear. Recently, Evans et al. published a valid and reliable instrument to test

students' perception of transferable skill requirements⁴³, which might be an optional tool to evaluate TEL effectiveness in transferable skills in periodontics education.

At level 4 (results), which summarised the expectations of TEL application in periodontics educational outcomes when compared to traditional learning methods. This data was identified by five authors^{12, 13, 15, 23, 24}, who suggested that the implementation of TEL, in combination with traditional learning methods, would improve educational outcomes in periodontics education. Furthermore, a study from Lee & Kim concluded that the combination between TEL and traditional learning methods was successful in improving educational outcomes in periodontology when compared to traditional learning method by itself.¹⁴ This combined learning method, as known as blended learning, was also described in a systematic review by Gianoni-Capenakas et al. as an effective and engaging learning method in dental education.³³

“The results in the present study should be carefully interpreted in a decision to implement TEL into dental curriculum due to the small sample size among the included studies, variability across the studies and few numbers of included papers. Despite this, some factors corroborate the strength of our study, such as (1) inclusion of a high methodological study, since only randomised controlled studies (RCTs) and crossover were selected; (2) use of a learning assessment model widely used in the scientific dental literature to measure the effectiveness of educational intervention; (3) evaluation of the quality of the studies included through an instrument certified by Cochrane. We encourage more study about benefits and effectiveness between the associations of TEL in traditional learning methods as well as the determination of how and which TEL could be used to improve periodontics education outcome.”

CONCLUSION

Evidence from this review showed that the exclusive use of technology-enhanced learning (TEL) when compared with traditional learning methods, might not lead to educational improvement in periodontics education. However, the addition of TEL can be useful in the delivery of periodontics education for improving students' educational outcomes to complement traditional learning methods.

Acknowledgments: Funds supported this research project from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES); Brazil. The authors would like to express their appreciation to the librarian Ms Bonnie Dixon, Griffith University, for her help with the search strategy.

Disclosure: The authors reported no conflicts of interest.

REFERENCES

1. Schonwetter DJ, Reynolds PA, Eaton KA, De Vries J. Online learning in dentistry: an overview of the future direction for dental education. *J Oral Rehabil* 2010;37(12):927-40.
2. Zheng M, Bender D, Reid L, Milani J. An Interactive Online Approach to Teaching Evidence-Based Dentistry with Web 2.0 Technology. *Journal of dental education* 2017;81(8):995-1003.
3. Establishing New Dental Schools: Lessons Learned and Future Promise. *Journal of dental education* 2018;82(6):547-8.
4. Kirkwood A, Price L. Technology-enhanced learning and teaching in higher education: what is 'enhanced' and how do we know? A critical literature review. *Learning, Media and Technology* 2013;39(1):6-36.
5. Scott KM, Baur L, Barrett J. Evidence-Based Principles for Using Technology-Enhanced Learning in the Continuing Professional Development of Health Professionals. *J Contin Educ Health Prof* 2017;37(1):61-6.
6. Park SE, Howell TH. Implementation of a flipped classroom educational model in a predoctoral dental course. *Journal of dental education* 2015;79(5):563-70.
7. Cooper LF. Digital Technology: Impact and Opportunities in Dental Education. *Journal of dental education* 2019;83(4):379-80.
8. Clunie L, Morris NP, Joynes VCT, Pickering JD. How comprehensive are research studies investigating the efficacy of technology-enhanced learning resources in anatomy education? A systematic review. *Anatomical sciences education* 2018;11(3):303-19.
9. Nagendrababu V, Pulikkotil SJ, Sultan OS, Jayaraman J, Soh JA, Dummer PMH. Effectiveness of technology-enhanced learning in Endodontic education: a systematic review and meta-analysis. *International endodontic journal* 2019;52(2):181-92.
10. Wong G, Apthorpe HC, Ruiz K, Nanayakkara S. An innovative educational approach in using instructional videos to teach dental local anaesthetic skills. *European Journal of*

- dental education: official Journal of the Association for Dental Education in Europe 2019;23(1):28-34.
11. Liu L, Li J, Yuan S, Wang T, Chu F, Lu X, Hu J, Wang C, Yan B, Wang L. Evaluating the effectiveness of a preclinical practice of tooth preparation using digital training system: A randomised controlled trial. *Eur J Dent Educ* 2018;22(4):e679-e86.
 12. Ramlogan S, Raman V, Sweet J. A comparison of two forms of teaching instruction: video vs. live lecture for education in clinical periodontology. *European Journal of dental education: official Journal of the Association for Dental Education in Europe* 2014;18(1):31-8.
 13. Prabhu S, John V, Blanchard S, Eckert GJ, Hamada Y. Assessing Effectiveness of an Audiovisual Educational Tool for Improving Dental Students' Probing Depth Consistency. *J Dent Educ* 2019;83(4):429-36.
 14. Lee C, Kim SW. Effectiveness of a Flipped Classroom in Learning Periodontal Diagnosis and Treatment Planning. *Journal of dental education* 2018;82(6):614-20.
 15. Levine RS, Jones JH, Morgan C. Comparison of computer-assisted learning with tutorial teaching in a group of first-year dental students. *Medical education* 1987;21(4):305-9.
 16. Heym R, Krause S, Hennesen T, Pitchika V, Ern C, Hickel R. A New Model for Training in Periodontal Examinations Using Manikins. *Journal of dental education* 2016;80(12):1422-9.
 17. Steinberg AD, Bashook PG, Drummond J, Ashrafi S, Zefran M. Assessment of faculty perception of content validity of PerioSim, a haptic-3D virtual reality dental training simulator. *Journal of dental education* 2007;71(12):1574-82.
 18. Drucker SD, Prieto LE, Kao DW. Periodontal probing calibration in an academic setting. *Journal of dental education* 2012;76(11):1466-73.
 19. Perry S, Bridges SM, Burrow MF. A review of the use of simulation in dental education. *Simulation in healthcare: Journal of the Society for Simulation in Healthcare* 2015;10(1):31-7.
 20. Inquimbert C, Tramini P, Romieu O, Giraudeau N. Pedagogical Evaluation of Digital Technology to Enhance Dental Student Learning. *European Journal of dentistry* 2019;13(1):53-7.
 21. Fakhry A, Cooper S, Slach N, Krenz S. Video-assisted clinical instruction in dentistry. Overview and applications. *European Journal of dental education: official Journal of the Association for Dental Education in Europe* 2007;11(4):230-7.
 22. Heym R, Krause S, Hennesen T, Pitchika V, Ern C, Hickel R. A Computer-Assisted Training Approach for Performing and Charting Periodontal Examinations: A Retrospective Study. *Journal of dental education* 2018;82(1):76-83.
 23. Schitteck Janda M, Mattheos N, Nattestad A, Wagner A, Nebel D, Farbom C, Le DH, Attstrom R. Simulation of patient encounters using a virtual patient in periodontology instruction of dental students: design, usability, and learning effect in history-taking skills. *European Journal of dental education: official Journal of the Association for Dental Education in Europe* 2004;8(3):111-9.
 24. Bissell V, McKerlie RA, Kinane DF, McHugh S. Teaching periodontal pocket charting to dental students: a comparison of computer-assisted learning and traditional tutorials. *British Dental Journal* 2003;195(6):333-6; discussion 29.
 25. Mattheos N, Schoonheim-Klein M, Walmsley AD, Chapple IL. Innovative educational methods and technologies applicable to continuing professional development in periodontology. *European Journal of dental education: official Journal of the Association for Dental Education in Europe* 2010;14 Suppl 1:43-52.
 26. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 2009;6(7):e1000097.

27. Maia LC, Antonio AG. Systematic reviews in dental research. A guideline. The Journal of clinical pediatric dentistry 2012;37(2):117-24.
28. Montero J, Dib A, Guadilla Y, Flores J, Santos JA, Aguilar RA, Gomez-Polo C. Dental Students' Perceived Clinical Competence in Prosthodontics: Comparison of Traditional and Problem-Based Learning Methodologies. Journal of dental education 2018;82(2):152-62.
29. Atik E, Gorucu-Coskuner H, Taner T. The Effect of Live-Video Demonstration on Dental Students' Orthodontic Bending Performance. Journal of dental education 2019.
30. Godderidge JG, Wall BE, Franklin SA. Creating an Efficient Learning Model: Students' Perceptions and Outcomes of an Active Learning Fixed Prosthodontics Course. Journal of dental education 2019;83(9):1076-80.
31. Sterne JAC, Savovic J, Page MJ, Elbers RG, Blencowe NS, Boutron I, Cates CJ, Cheng HY, Corbett MS, Eldridge SM, Emberson JR, Hernan MA, Hopewell S, Hrobjartsson A, Junqueira DR, Juni P, Kirkham JJ, Lasserson T, Li T, McAleenan A, Reeves BC, Shepperd S, Shrier I, Stewart LA, Tilling K, White IR, Whiting PF, Higgins JPT. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ (Clinical research ed) 2019;366:l4898.
32. Kirkpatrick D, Kirkpatrick J. Evaluation training programm. 3rd edition. Berrett-Koehler Publishers. 2005. 379p.
33. Gianoni-Capenakas S, Lagravere M, Pacheco-Pereira C, Yacyshyn J. Effectiveness and Perceptions of Flipped Learning Model in Dental Education: A Systematic Review. Journal of dental education 2019;83(8):935-45.
34. Paull M, Whitsed C, Girargi A. Applying the Kirkpatrick model: Evaluating an Interaction for Learning Framework curriculum intervention. Educational Research 2016;26(3):490-507.
35. Mattheos N, Nattestad A, Attstrom R. Feasibility of and satisfaction with the use of low-bandwidth videoconferencing for examination of undergraduate students. Journal of telemedicine and telecare 2003;9(5):278-81.
36. Walji MF, Karimbux NY, Spielman AI. Person-Centered Care: Opportunities and Challenges for Academic Dental Institutions and Programs. Journal of dental education 2017;81(11):1265-72.
37. Seymour B, Shick E, Chaffee BW, Benzian H. Going Global: Toward Competency-Based Best Practices for Global Health in Dental Education. Journal of dental education 2017;81(6):707-15.
38. Field JC, Walmsley AD, Paganelli C, McLoughlin J, Szep S, Kavadella A, Manzanares Cespedes MC, Davies JR, DeLap E, Levy G, Gallagher J, Roger-Leroi V, Cowpe JG. The Graduating European Dentist: Contemporaneous Methods of Teaching, Learning and Assessment in Dental Undergraduate Education. European Journal of dental education: official Journal of the Association for Dental Education in Europe 2017;21 Suppl 1:28-35.
39. Al-Madi EM, AlShiddi M, Al-Saleh S, AbdelLatif H. Developing a Dental Curriculum for the 21(st) Century in a New Dental School in Saudi Arabia. Journal of dental education 2018;82(6):591-601.
40. Santos GN, Leite AF, Figueiredo PT, Pimentel NM, Flores-Mir C, de Melo NS, Guerra EN, De Luca Canto G. Effectiveness of E-Learning in Oral Radiology Education: A Systematic Review. Journal of dental education 2016;80(9):1126-39.
41. Al-Jewair TS, Azarpazhooh A, Suri S, Shah PS. Computer-assisted learning in orthodontic education: a systematic review and meta-analysis. Journal of dental education 2009;73(6):730-9.

42. Vuchkova J, Maybury T, Farah CS. Digital interactive learning of oral radiographic anatomy. *European Journal of dental education: official Journal of the Association for Dental Education in Europe* 2012;16(1):e79-87.
43. Sun J, Adegbosin AE, Reher V, Rehbein G, Evans J. Validity and reliability of a self-assessment scale for Dental and Oral Health student's perception of transferable skills in Australia. *Eur J Dent Educ*. 2019;24(1):42-52
44. Sipiyaruk K, Gallagher JE, Hatzipanagos S, Reynolds PA. A rapid review of serious games: From healthcare education to dental education. *European Journal of dental education: official Journal of the Association for Dental Education in Europe* 2018;22(4):243-57.
45. Shoaib LA, Safii SH, Naimie Z, Ahmad NA, Sukumaran P, Yunus RM. Dental students' perceptions on the contribution and impact role of a clinical teacher. *European Journal of dental education: official Journal of the Association for Dental Education in Europe* 2018;22(1):e26-e34.

Table 1. Keywords utilised in searching each database (September /2019)

Database	Keywords and Search Truncation
MedLine (n= 314) ovidsp.tx.ovid.com PsycINFO (n = 78) ovidsp.tx.ovid.com	(periodo* OR gingiv*) AND (learn* OR education OR teach* OR train* OR instruct* OR student* OR skill* OR performance OR perception) AND (“social network*” OR software OR computer* OR web* OR e-learning OR computer-aided OR “computational intelligence” OR program* OR blended OR machine OR online OR technology OR simulation OR “artificial intelligence” OR “virtual reality” OR “mobile phone” OR “cell phone” OR “social media” OR email OR Facebook OR Twitter OR “learning management system” OR blog*)
ERIC (n= 14) proquest.com	(periodo* OR gingiv*) AND (learn* OR education OR teach* OR train* OR instruct* OR student* OR skill* OR performance OR perception) AND (“social network*” OR software OR computer* OR web* OR e-learning OR computer-aided OR “computational intelligence” OR program* OR blended OR machine OR online OR technology OR simulation OR “artificial intelligence” OR “virtual reality” OR “mobile phone” OR “cell phone” OR “social media” OR email OR Facebook OR Twitter OR “learning management system” OR blog*)
Scopus (n= 978) scopus.com	(TITLE-ABS-KEY (<i>periodo* OR gingiv*</i>)) AND (TITLE-ABS-KEY (<i>learn* OR education OR teach* OR train* OR instruct* OR student* OR skill* OR performance OR perception</i>)) AND ((TITLE-ABS-KEY (“ <i>social network*</i> ” OR software OR computer* OR web* OR e-learning OR computer-aided OR “computational intelligence” OR program* OR blended OR machine OR online)) OR (TITLE-ABS-KEY (<i>technology OR simulation OR “artificial intelligence” OR “virtual reality” OR “mobile phone” OR “cell phone” OR “social media” OR email OR Facebook OR Twitter OR “learning management system” OR blog*</i>)))
EMBASE (n= 169) embase.com	(periodo* OR gingiv*) AND (learn* OR education OR teach* OR train* OR instruct* OR student* OR skill* OR performance OR perception) AND (‘social network*’ OR software OR computer* OR web* OR ‘e learning’ OR ‘computer aided’ OR ‘computational intelligence’ OR program* OR blended OR machine OR online OR technology OR simulation OR ‘artificial intelligence’ OR ‘virtual reality’ OR ‘mobile phone’ OR ‘cell phone’ OR ‘social media’ OR email OR Facebook OR Twitter OR ‘learning management system’ OR blog*)
Web of Science (n=535) webofknowledge.com	TOPIC: (periodo* OR gingiv*) AND TOPIC: (learn* OR education OR teach* OR train* OR instruct* OR student* OR skill* OR performance OR perception) AND TOPIC: (“social network*” OR software OR computer* OR web* OR e-learning OR computer-aided OR “computational intelligence” OR program* OR blended OR machine OR online OR technology OR simulation OR “artificial intelligence” OR “virtual reality” OR “mobile phone” OR “cell phone” OR “social media” OR email OR Facebook OR Twitter OR “learning management system” OR blog*)

Table 2. Characteristics of included studies

First author, Year, Country	Sample Size (N)	Participants	TEL Intervention	Educational Outcomes			
				Reaction	Learning	Behavior	Results
Levine 1987 UK	60	1 st year undergraduate student	CA	Attitudes evaluated by questionnaire	Knowledge gain evaluated by MCQ post intervention	NM	CAL may be import in supplying some aspects of teaching, leaving the teacher to teach students individually
Bissell 2003 UK	61	3 rd year undergraduate students	CA	Attitudes evaluated by questionnaire	Knowledge gain evaluated by practical test and writing test	Confidence evaluated by confidence log pre and post practical test	CAL may be ideal for purpose of revision of concepts and should be applied together with practice or use of the skill
Mattheos 2003 Sweden	39	2 nd year undergraduate students	VC	Attitudes evaluated by questionnaire	Knowledge gain evaluated by self-assessments, essay writing, discussion and feedback	NM	IVC can facilitate a complex and highly interactive examination. However, student preferred the classroom assessment
Schitteck 2004 Sweden	39	2 nd year undergraduate students	VP	NM	Knowledge gain evaluated by video-recording, which analyzed: use of time and questions asked by students during the medical-dental history session	6-point performance scale	VP may be used as a supplement to standard instruction in the diagnosis and treatment planning of periodontal disease.

Ramloga n 2013 Bahamas	35	3 rd year undergraduate students	Vi	Attitudes evaluated by questionnaire	Knowledge gain evaluated by pre and post- writing test and compared the difference between well- answered questions.	Clinical exercise evaluated by clinical competency checklist	Vi may not act as a substitute for the traditional method, but show be viewed as a complement or a vehicle for achieve the goals of learning and teaching
Lee 2018 US	132	3 rd year undergraduate students	Vi and PPP	Attitudes evaluated by questionnaire	Knowledge gain evaluated by MCQ pre and post	NM	Providing a short Vi and PPP 48h before in-class session was effectively
Prabhu 2019 US	22	3 rd year undergraduate students	Vi	Attitudes evaluated by questionnaire	Knowledge gain evaluated by practical test, which analyzed: probing depth accuracy comparing it with faculty examiner	NM	Video may serve as an effective adjunct to current teaching methods

Note: CA, computer assisted methods; MCQ, multiple choice question; NM, not mention; IVC, internet-based video conferencing; VP, virtual patient; Vi, video; PPP, power point presentation

Table 3. Studies excluded after full-text evaluation, with reasons

Papers	Reasons for Exclusion
Botticelli AT, Janda MS, Botticelli D, Mattheos N. The Effectiveness of Video Support in the Teaching of Manual Skills Related to Initial Periodontal Therapy Tested on Phantoms. <i>International journal of computerized dentistry</i> 2005;8:117-127.	4
Brown LF, KA, Spencer AJ. Evaluation of a continuing education intervention Periodontics in General Practice. <i>Community dentistry and oral epidemiology</i> 1994;22(6): 441-447.	1
Inquimbert C, Tramini P, Romieu O, Giraudeau N. Pedagogical Evaluation of Digital Technology to Enhance Dental Student Learning. <i>European journal of dentistry</i> 2019;13(1):53-7.	3
Koole S, De Wever B, Aper L, et al. Using online periodontal case-based discussions to synchronize theoretical and clinical undergraduate dental education. <i>European journal of dental education: official journal of the Association for Dental Education in Europe</i> 2012;16(1): 52-58.	2
Koole S, Vervaeke S, Cosyn J, De Bruyn H. Exploring the relation between online case-based discussions and learning outcomes in dental education. <i>European journal of dental education: official journal of the Association for Dental Education in Europe</i> 2014;78(11): 1552-1557.	2
Mattheos N, Nattestad A, Schitteck M, Attström R. A virtual classroom for undergraduate periodontology: a pilot study. <i>European journal of dental education: official journal of the Association for Dental Education in Europe</i> 2001: 5(4): 139-147.	2
Mattheos N, Nattestad A, Christersson C, et al. The effects of an interactive software application on the self-assessment ability of dental students. <i>European journal of dental education: official journal of the Association for Dental Education in Europe</i> 2004;8(3)97-104.	4
Mattheos N, Schoonheim-Klein M, Walmsley AD, Chapple IL. Innovative educational methods and technologies applicable to continuing professional development in periodontology. <i>European journal of dental education: official journal of the Association for Dental Education in Europe</i> 2010;14 Suppl 1:43-52.	5
Rich SK, Keim RG, Shuler CF. Problem-based learning versus a traditional educational methodology: a comparison of preclinical and clinical periodontics performance. <i>Journal of Dental Education</i> 2005;69(6): 649-662.	1
Seo C, Cho AR, Park JC, et al. Dental students' learning attitudes and perceptions of YouTube as a lecture video hosting platform in a flipped classroom in Korea. <i>Journal of educational evaluation for health professions</i> 2018;15.	2

Note: Reasons for exclusion were as follows: 1= studies that did not applied TEL; 2 = Absence of control group; 3 = not applied in Periodontics; 4= control group was not traditional learning; 5 = Not RCTs or Crossover study;

Table 4. Findings of knowledge gain between TEL and traditional methods

First author, Year, Country	TEL Intervention	Assessment	Summary measures	Groups		P value
Levine; 1987 UK	CA	MCQ post	Mean score (%)	C= 85.5	I= 81.3	NS
Bissell; 2003 UK	CA	Practical test	Median score	C= 7	I=7	NS
		Writing test	Median score	C= 6	I=6	NS
Mattheos; 2003 Sweden	IVC	Self-assessments	Median score	C= 8	I= 6	=0.0025*
		Writing Essay	Median score	C=7	I= 7	>0.05
		Discussion	Median score	C=6.5	I=7	>0.05
		feedback	Median score	C=6	I=7	>0.05
Schitteck; 2004 Sweden	VP	Video-recording	Use of time	C=3:43	I=6:39	Time<0.01*
			Questions asked	C=6.61	I=10.06	QCr<0.0001*
			(QCr, Qte, Qti)	C=14.69	I=17.69	Qte>0.05*
				C=15.96	I=26.19	Qti<0.01*
Ramlogan; 2013 Bahamas	Vi	Pre writing test	Mean score (%) + SD	C =49.7 (14.0)	I= 49.1 (13.8)	0.049*
		Post writing test	Mean score (%) + SD	C =74.9 (14.9)	I=68.6 (16.3)	
Lee; 2018 USA	Vi and PPP	MCQ pre MCQ post	Mean score (%) Mean score (%)	C= 54 C = 63	I = 64 I = 78	0.01*
Prabhu; 2019 USA	Vi	PD accuracy	Percentage of	1mm: C= 96	I= 98	1mm=0.18
			sites with	2mm: C= 99	I= 97	2mm= 0.0158
			acceptable PD	3mm: C= 98	I=98	3mm=0.38
			measurement	4mm: C= 75	I= 85	4mm=0.0056*
			compared to	5mm: C=53	I= 54	5mm=0.88
			faculty examiner	6mm: C= 48	I=55	6mm= 0.62
CA, computer-assisted methods; MCQ, multiple-choice questions; C, control group; I, intervention group; NM, not mention; IVC, internet video-conferencing; QCr, critical questions; Qte, total questions excluding follow-up questions; Qti, total questions asked; Vi, video; PD, probing depth; PPP, power point presentation; NS, not significant

Figure 1. Flow diagram of literature search protocol and selection criteria adapted from PRISMA

First author, year	Randomization process	Deviations from intended intervention	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall
Levine (1987)	—	?	+	+	+	!
Bissell (2003)	?	+	+	+	?	!
Mattheos (2003)	?	+	+	+	+	!
Schitteck (2004)	?	+	+	—	+	—
Ramlogan (2013)	?	+	+	+	+	!
Lee (2017)	?	?	+	+	+	!
Prabhu (2019)	+	+	+	+	+	+

Figure 2. Risk of bias summary of included studies showing risk of bias on each factor (Cochrane RoB 2 -2019)