Effectiveness of technology-enhanced learning in Endodontic education: a systematic review and meta-analysis

Abstract

The aim of the present systematic review was to evaluate the effectiveness of technology-enhanced learning (TEL) in the field of Endodontics to improve educational outcomes compared to traditional learning methods. Randomized controlled studies published in English were identified from two electronic databases (PubMed and Scopus) up to May 2018. Two authors independently performed study selection, data extraction and assessed the risk of bias (ROB). Any teaching method using TEL was considered as the intervention, and this was compared to traditional methods. The outcome measuring the effectiveness of learning activities were evaluated by Kirkpatrick's four-level training evaluation model. The four levels of training outcomes are: Reaction, Learning, Behaviour and Results. A meta-analysis was performed to estimate the standardized mean difference by the random effects model. In total, 13 studies were included in the systematic review. Only three studies were assessed as "low" ROB. A meta-analysis could not be performed in the domains of Reaction and Behaviour. No significant difference was observed in knowledge gain (Learning domain) between TEL and traditional methods (SMD, 0.14 (95% CI -0.10 to 0.39) I2= 62.7%). Similarly, no difference was observed in performance (Behaviour domain). A variable response was found in attitude (Reaction domain). From the available evidence, it can be concluded that TEL is equally as effective as traditional learning methods.

Keywords: Endodontics; education; meta-analysis; systematic review; Technology-enhanced learning.

Introduction

The use of information and communication (digital) technology in the delivery of education is referred to as "technology-enhanced learning (TEL)" (Kirkwood & Price 2014). TEL uses a wide range of digital technologies to strategically support and enhance learning in what has become commonly known as blended learning (Maresca *et al*. 2014). TEL can include hardware such as computers, tablets and other mobile devices, as well as software such as applications, learning management systems, event capture and discussion boards within education and training programmes (Goodyear & Retalis 2010, Scott *et al*. 2017).

TEL allows users access to a wide range of resource materials and learning tools with flexibility and interactivity that leads to an enhanced constructivist learning environment (Kok 2009). The ease of collaboration and peer learning along with supervised feedback allows the acquisition of knowledge, critical skills and facilitates better decision-making in a non-threatening and safe environment. It has several advantages over other learning methods, for example, it is flexible and allows easier access from multiple locations at any time; it facilitates rapid interaction and conversation; and ultimately it may be more economical as it can replace the need for lecture room space (Kirkwood & Price 2011). In addition, learners can acquire knowledge in privacy, pursue areas of interest in greater depth, skip areas of prior knowledge and pace their learning to suit their needs and thus revise and reinforce their learning as required. TEL also facilitates use of various assessment methods, both formative and summative, that can lead to self-evaluation and achievement of the desired goals (Kirkwood & Price 2011, Nicoll *et al.* 2018).

Technology-enhanced learning has been employed in dental education, including in the field of Endodontics. The first reports in dentistry that evaluated "computer-aided learning" were published in the early 1970s (Sokolow *et al.* 1971, Gaston 1971). As an example, Mullaney *et al*. (1976) compared slide-tape methods and computer-assisted methods using simulated clinical endodontic problems during undergraduate education. They found students in the computer group performed better in selection of diagnostic tests while knowledge on diagnosis and treatment planning was similar in both groups. This general finding was reinforced by Mendel & Scheetz (1982) who reported improvements in the endodontic problem-solving ability of undergraduate dental students using a computer-assisted self-evaluation module. Since then, several other TEL

methods have been evaluated in endodontic training including Video Assisted Clinical Instruction in Dentistry (VACID) (Naseri *et al*. 2016), Haptic Virtual Reality (Suebnukarn *et al*. 2011) and Instructional Multimedia (Naseri *et al*. 2013).

A systematic review (Al-Jewair *et al*. 2010) that evaluated various methodologies such as computer assisted learning computer simulation programmes, computer multimedia programmes, computer assisted self-evaluation (CASE) in Endodontic education concluded that it was efficacious in improving knowledge and was time efficient; however, it failed to demonstrate an improvement in student performance or in the cost-effectiveness of endodontic education. That review concluded there was a need for more studies on various computer assisted learning techniques to be able to better understand the educational outcomes (Al-Jewair *et al*. 2010). Since 2010, several advanced education methods have been evaluated in Endodontics such as online voice-over screen-captured lectures (Schonwetter *et al.* 2016), haptic virtual reality (Suebnukarn *et al*. 2011) and Video-Assisted Clinical Instruction in Dentistry (VACID) (Naseri *et al.* 2016). These educational methods have been reported to improve the quality of endodontic knowledge and skills acquired by learners. Given the current focus on both postgraduate and undergraduate education and training in Endodontics (European Society of Endodontology 2010, De Moor *et al*. 2013) and the increased emphasis on continuing professional development for all dentists and associated professionals. TEL methods are increasingly considered for their effectiveness and ease of access. In this context and due to the advantage and potentiality of the TEL in Endodontic education, a need arises to update the previous review (Al-Jewair *et al.* 2010). Hence, this review aimed to evaluate the effectiveness of TEL compared to traditional learning methods in the field of Endodontics in improving educational outcomes. In this systematic review the term TEL is used to describe learning methods that use computers and specially designed digital programmes. The research question was designed based on the PICOS format: Does technology-enhanced learning (TEL) result in better educational outcomes compared to traditional learning methods in the field of Endodontics from randomised controlled trials?

Methods

The current review was reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher *et al.* 2009). Literature was searched from

inception to May 2018 in two databases; Pubmed and Scopus. The following search terms were used for identification of eligible studies: (e-learning) OR computer-aided learning) OR computer vision system) OR computer assisted learning) OR computational intelligence) OR computer based learning) OR computer based instruction) OR computer based teaching) OR self -instruction programs) OR programmed learning) OR blended learning) OR web based education) OR web based teaching) OR web based learning) OR computer reasoning) OR machine learning) OR online learning) OR technology enhanced learning) OR patient simulation) OR patient simulation) OR educational software) OR virtual reality) OR virtual reality simulation)) AND ((root canal) OR endodontic). Only studies published in English were selected. Reference list from the included studies and previously published reviews were searched to identify appropriate studies. Additional searches were performed in journals covering the fields of Endodontics and dental education. Two reviewers (VN, SP) independently searched and selected studies by screening titles and abstracts followed by full text assessment. Disagreements in selection were resolved by consensus or by a third reviewer (PD). Data extraction was performed independently by two reviewers with disagreements resolved by discussion or by the third reviewer. When necessary, authors of selected studies were contacted by email for missing information.

Inclusion criteria

1. Evaluation of the educational outcomes associated with taught programmes or short courses in Endodontics involving undergraduate dental students (predoctoral), postgraduate students (residents), general dentists, specialist Endodontists and/or university staff (faculty) delivered using TEL techniques or methods and compared with traditional learning methods. The scope of Endodontics included: diagnosis, vital pulp therapies, root canal treatment (including: access cavity preparation, working length determination, cleaning and shaping of canals, canal filling), post-endodontic restorations, endodontic surgery, trauma and regenerative endodontics.
2. Intervention: Technology-enhanced learning included any activity that used computer-assisted learning (CAL), interactive multimedia programs, virtual and simulation learning.
3. Comparison: Traditional methods of instruction through live lectures with or without the use of slides, live clinical or laboratory demonstration, seminars, tutorials, text- or note-based learning, slide-tape methods and no instruction.

4. Study design: Randomized controlled trials.
5. Studies published only in English.

Exclusion criteria

1. Studies in the form of conference proceedings, letters or commentaries.
2. Narrative or systematic reviews.
3. Studies without abstracts.

Data extraction

Customized forms for recording the following information from selected studies were created. Information on author, year, country, subjects, group characteristics, educational outcomes were retrieved independently by two reviewers (VN, SP). Disagreements were resolved by a third reviewer (PD).

Quality assessment

The quality of included studies was appraised by the revised Cochrane risk of bias tool for randomized trials (RoB 2.0) (Higgins *et al.* 2016). Quality assessment was performed by two independent reviewers (SP, VN) with resolution of disagreement by the third reviewer. The included studies were classified as "low", "some concerns" or "high risk" of bias based on the risk of bias due to randomization processes, deviations from intended interventions, missing outcome data, measurement of the outcome, selection of the reported result and overall quality. A study was assessed as having "low risk" of bias if all the key domains were scored as low risk. A scoring of "some concerns" in at least one domain rendered the study as having "some concerns" in quality (ROB). The assessment of at least one domain as "high risk" or three or more domains with "some concerns" resulted in the study being classified as having a "high risk" of bias.

Outcome measures based on Kirkpatrick's evaluation model

The outcomes measuring the effectiveness of learning activities in Endodontics were evaluated by Kirkpatrick's four-level training evaluation model (Kirkpatrick & Kirkpatrick 2009). The four

levels of training outcome are: Reaction (Level 1): Measurement based on attitude of students or educators, Learning (Level 2): Measurement based on knowledge attained and or retained by the students, Behaviour (Level 3): Measurement based on any change in behaviour assessed by performance in clinical and/or laboratory procedures or diagnostic ability, Results (Level 4): Measurement based on the level of success and quality in clinical and/or laboratory procedures over time, audit on success and quality of care. A quantitate analysis was planned if the included studies were considered relatively homogeneous.

Quantitative analysis (meta-analysis)

A meta-analysis was performed to estimate the pooled standardised mean difference (SMD) using a random effects model to account for the heterogeneity among and within studies. SMD is the difference in effectiveness of two education methods in improving the level of knowledge among participants. Heterogeneity in the data was found to be significantly present when the I2statistic was more than 50%. The meta-analysis was performed using STATA 14.1 software (StataCorp, College Station, TX, USA). Publication bias can be assessed visually through generation of funnel plots when ten or more studies are included in a meta-analysis (Sterne *et al.* 2000).

Results

Study selection

The entire search process is shown in Figure 1. The total number of papers for title and abstract screening were 291. A total of 16 studies were identified for full text reading. Following full text reading, three studies (Sandoval *et al.* 1987, Suebnukarn *et al.* 2010, Maresca *et al.* 2014) were excluded, as they were non-randomized controlled trials. Finally, 13 studies (Mullaney *et al.* 1976, Mendel & Scheetz 1982, Puskas *et al*. 1991, Plasschaert *et al*. 1997, Fouad & Burleson 1997, Khayat & Keshtkar 2004, Suebnukarn *et al*. 2011, 2012, Naseri *et al*. 2013, 2017, Moazami *et al*. 2014, Schönwetter *et al*. 2016, Akhlaghi *et al*. 2017) were included for review.

Characteristics of included studies

The characteristics of included studies are shown in Table 1. The various TEL methods used in Endodontic education were computer presentation (interactive), Computer–Assisted Self-Evaluation (CASE), Computer Assisted Learning (CAL), computer stimulation programmes

(ENDO Dx), self-instructional computer programmes, online voice-over screen-captured lectures, haptic virtual reality simulators and Video-Assisted Clinical Instruction in Dentistry (VACID). In this review, the included studies had evaluated learning mostly in undergraduate education with only one study evaluating learning with postgraduate students (Suebnukarn *et al.* 2012). None of the studies involved general dentists, specialist endodontists or professionals allied to dentistry. The technology enhanced learning activities used in endodontic education were for learning on diagnosis, access cavity preparation, endodontic microsurgery and problem solving.

Quality of the included studies

The quality of included studies is provided in Table 2. Among the 13 studies selected, three (Suebnukarn *et al*. 2011, 2012, Moazami *et al*. 2014) were assessed as having a "low" ROB, whereas the rest were considered to have "some concerns" due to inadequacies in the process of allocation concealment and randomization.

Outcome measurements

Three domains of learning based on the Kirkpatrick model were assessed in the included studies and were on reaction (opinion), knowledge and behaviour.

i) Reaction: The opinions of the students towards TEL were evaluated in five studies through questionnaires. Plasschaert *et al*. (1997) reported a positive attitude towards TEL (learning was less repetitive and teaching material more clearly presented) compared to traditional methods, whereas three studies reported no difference in attitudes towards the two methods. Fouad & Burleson (1997) reported that students had varying preferences towards computer simulation programmes or traditional methods in respect of their efficiency and appropriateness for learning. A meta-analysis was not performed in this domain as "opinion" was measured qualitatively in all the studies.

ii) Knowledge: The knowledge gain following the various learning methods were evaluated in 11 studies by pre- and post-multiple choice questions, or only post-multiple choice questions or essay questions (Mullaney *et al*. 1976, Mendel & Scheetz 1982, Puskas *et al*. 1991, Plasschaert *et al*. 1997, Fouad & Burleson 1997, Khayat & Keshtkar 2004, Naseri *et al*. 2013, 2017, Moazami *et al*.

2014, Schönwetter *et al*. 2016, Akhlaghi *et al*. 2017). No difference was observed in knowledge gained between TEL and traditional methods in the majority of the studies (Puskas *et al.* 1991, Plasschaert *et al.* 1997, Khayat & Keshtkar 2004, Naseri *et al.* 2013, 2017, Moazami *et al*. 2014, Schönwetter *et al.* 2016, Akhlaghi *et al.* 2017, whereas one study (Fouad & Burleson 1997) concluded that TEL allowed participants to gain knowledge more effectively than traditional methods. Two studies reported mixed results (Mullaney *et al.* 1976, Mendel & Scheetz 1982). Among the 11 studies, three (Mullaney *et al*. 1976, Mendel & Scheetz 1982, Khayat & Keshtkar 2004) were not included in the quantitative analysis because mean or standard deviation values were missing. Hence, 8 studies were included for quantitative analysis. Quantitative pooling of data from the included studies revealed no significant difference in knowledge gain between TEL and traditional methods (SMD, 0.14 (95% CI -0.10 to 0.39) I2= 62.7%) (Figure 2). Fewer than ten studies were included in the meta-analysis and so no funnel plot was generated for detecting publication bias.

iii) Behaviour: The changes in behaviour or performance following learning were evaluated by a four-point rating scale and competency rating scale modified from the objective structured assessment of technical skills (OSATS). No difference in performance of students was observed between VACID (Naseri *et al*. 2017) and instructional multimedia programmes (Naseri *et al*. 2013) compared to traditional methods. Suebnukarn *et al*. (2011) concluded that there was no difference in performance of endodontic microsurgery with and without using virtual reality simulation. In another study, Suebnukarn *et al.* (2012) also reported similarity in performing access cavity preparations when participants were trained using virtual reality simulation or conventional methods. As the outcomes and the measurements from these studies were heterogeneous, a meta-analysis was not undertaken.

Discussion

Dental education and clinical training is constantly evolving and new methods for learning are being introduced to overcome the limitations of traditional teaching methods and earlier TEL methods. Undergraduate dental students are expected to improve their learning and enhance their clinical and communication skills and hence achieve a level of self-confidence and competence (De Moor *et al*. 2013). The present review categorized the various outcome measures into four,

based on the Kirkpatrick's four-level model of evaluation; reaction (opinion on the learning method), learning (knowledge gain), behaviour (performance) and results (change in health outcomes) (Kirkpatrick & Kirkpatrick 2009). Traditional methods such as live lectures and demonstrations have been identified as having limitations in terms of learning (Maresca *et al.* 2014). Such methods usually involve large numbers of students, and there is an inherent difficulty if the teaching has to be repeated and/or reinforced There is also limited interaction between the teacher and participant that leads to a passive approach to learning. It must be noted, however, that traditional lectures are being supplemented with flipped lectures and classrooms which have been reported in dental education to lead to improved learning and performance compared to traditional methods (Chutinan *et al*. 2017, Lee & Kim 2018). A recent meta-analysis (Hew & Lo 2018) concluded that the flipped classroom method in the education of health professionals improved student learning significantly compared to traditional methods.

TEL methods can overcome some or many of the limitations of traditional teaching methods. TEL allows access to learning at any time, multiple times and can incorporate interactivity that enhances student performance and delivery of care (Kirkwood & Price 2011, Nicoll *et al*. 2018). Various reviews on the effectiveness of new learning approaches under the broad umbrella of TEL have been published in dentistry. In Oral Radiology education, students exposed to e-learning or traditional methods had similar levels of knowledge gain (Santos *et al.* 2016). However, another review (Al-Jewari *et al.* 2009) found that CAL led to increased knowledge gain compared to traditional methods in Orthodontic learning. Al-Jewari *et al.* (2010) went on to report that CAL and traditional method were similar in terms of Endodontic learning. Since 2010, various learning methods under the definition of TEL such as live demonstrations with instructional multimedia, virtual learning, online voice-over screen-captured lecture and VACID have been evaluated in Endodontic education. Hence an update review was required to determine the effectiveness of TEL in Endodontic education.

Reaction (opinion)

Plasschaert *et al.* (1997) observed a positive attitude in students towards TEL whereas Puskas *et al*. (1991) and Khayat & Keshtkar (2004) reported similar preference for TEL and traditional methods. Mullaney *et al.* (1976) and Fouad & Burleson (1997) reported divided and mixed

responses among students on their opinion towards TEL and other methods. A meta-analysis could not be performed in this domain due to the qualitative nature of the outcome data. Reviews in Orthodontics (Al-Jewari *et al*. 2009) and Oral Radiology (Santos *et al.* 2016) education concluded that students had a positive attitude towards CAL and E-learning respectively. In the present review, attitudes among students towards TEL in Endodontic education varied and were similar to a previous review on CAL in Endodontics (Al-Jewari *et al.* 2010). Hence no conclusion could be drawn on attitudes of students towards TEL in Endodontic education. Clearly, further studies are needed to explore this topic.

Knowledge

Most of the included studies concluded that TEL made no difference to knowledge gain compared to traditional methods. Fouad & Burleson (1997) reported that TEL was better than traditional methods while Mullaney *et al.* (1976) and Mendel *et al.* (1982) reported mixed results as CAL did have a positive impact on some parameters, such as data gathering and selection of diagnostic tests, but not on others, such as diagnostic skills, problem solving and treatment planning. Schönwetter *et al*. (2016) measured cognitive engagement through knowledge retention and recognition. Recognition test items assess comprehension and application of knowledge and hence this data was used in the present meta-analysis and not knowledge recall. The time period from educational intervention and post-test evaluation varied in the included studies. In the study by Moazami *et al*. (2014), the post-test data at two months was used for the meta-analysis. From the meta-analysis on the knowledge domain, no difference was observed in knowledge gain between TEL and traditional methods. A previous review on Endodontic education (Al-Jewari *et al.* 2010) did not summarize the results through meta-analysis due to heterogeneity in study methods and reporting of results. However, that review concluded qualitatively that knowledge gain was similar between CAL and traditional learning methods. Another review in Oral Radiology education (Santos *et al.* 2016) came to the same conclusion through qualitative analysis, but again no meta-analysis was performed in that review. A meta-analysis on Orthodontic education (Al-Jewair *et al.* 2009) reported that CAL was superior in terms of knowledge gain compared to other traditional methods.

Behaviour

In recent years, the use of Virtual Reality (VR) and VACID have been used in dental education, including Endodontics. Suebnukarn *et al.* (2011) reported that haptic VR training reduced errors and the time taken to prepare access cavities compared to conventional phantom head training. However, the differences between the two methods were not significant. In another study, Suebnukarn *et.al* (2012) reported that pre-surgical training using a VR simulator led to better performance in endodontic microsurgery and osteotomy. Among endodontic postgraduate students (residents), Naseri *et al.* (2013) reported no difference between conventional demonstrations with or without the use of instructional multimedia in access cavity preparations. In another study, Naseri *et al.* (2016) concluded there was no difference between VACID and conventional demonstration in access cavity preparation. Performance in Oral Radiology was associated with contrasting results (Santos *et al.* 2016). Based on the limited number of included studies, it can be concluded that TEL does not lead to better performance in Endodontic learning compared to traditional methods. However, more studies are needed for a better understanding in this area. A meta-analysis could not be performed for behaviour in the present review due to heterogeneity in the outcomes and its measurement among the studies.

Quality of included studies

In the present systematic review, 10 studies were assessed as having "some concerns", which could be due to bias in randomization processes. Allocation concealment blinds the process of randomization to the personnel involved in recruitment of participants. This concealment is as important as or even more so than randomization as bias gets eliminated by the recruiter, which will further reduce the chance of difference between the groups other than due to chance and the actual effect of intervention. Most studies identified in the review failed to report on the allocation concealment and hence this affected the randomization process. All studies had measured the outcome with objective tests that had been prepared prior to the study and delivered to the participants. This ensured that the outcome measurement was not affected by examiner bias.

The aim of the current systematic review was to assess the effectiveness (knowledge gain, attitude and performance) of technology enhanced learning compared to conventional teaching modalities in the field of Endodontics. Endodontics is a distinctive branch of dentistry and

demands a unique multi-skill learning for the development of tactile and fine motor skills (De Moor *et al*. 2013). In this context, Endodontic education has to be effective to ensure that knowledge and clinical skills are acquired by learners. To combine evaluation of knowledge and skills related to all dental disciplines in the present review would have created a greater chance of introducing significant heterogeneity and could lead to less valid results. Hence, the review aimed to evaluate the effectiveness of TEL related only to Endodontic education and the results being relevant for both undergraduate and postgraduate training programmes. Similarly, several reviews have been published in the specialties of Orthodontics (Al-Jewari et al. 2009) and Oral Radiology (Santos *et al.* 2016).

TEL encompasses a wide range of educational methods such as CASE, CAL, computer stimulation programmes, self-instructional computer programmes, online voice-over screen-captured lectures, haptic virtual reality simulators and VACID. The scope of the present review was to determine the effectiveness of TEL compared to conventional teaching methods. Due to the small number of studies that used individual TEL methods, it was not possible to perform subgroup analysis to evaluate and compare their effectiveness individually. Future studies are required to determine the effectiveness of various TEL method in Endodontic education.

Limitations

The protocol of the present review excluded studies with no abstract, which could be a limitation. Pre-intervention knowledge assessment was not undertaken in some studies (Mullaney *et al*. 1976, Khayat & Keshtkar 2004, Moazami *et al*. 2014, Akhlaghi *et al*. 2017) and this could lead to selection bias as the two groups (test and control) could not be compared at baseline. This could have affected quantitative results on knowledge gain, though the final results did not favour either group. Post-intervention knowledge assessment was done at varying time periods, which could have an impact, as knowledge would vary with time. Significant heterogeneity was observed by the I2 statistic and could reflect the varied test items and different TEL methods used in the selected studies.

Conclusion

Evidence from this review revealed no difference between TEL and traditional learning methods in knowledge gain and performance in Endodontic education among dental students.

Legends

Figure 1: Flow diagram showing the entire search process.

Figure 2: Forest plot of Knowledge gain between TEL and traditional methods.

Table 1: Characteristics of the included studies.

Table 2: Risk of bias of the included studies.

References

Al-Jewair TS, Azarpazhooh A, Suri S, Shah PS (2009) Computer-assisted learning in orthodontic education: a systematic review and meta-analysis. *Journal of Dental Education* **73,** 730-9.

Al-Jewair TS, Qutub AF, Malkhassian G, Dempster LJ (2010) A systematic review of computer-assisted learning in endodontics education. *Journal of Dental Education* **74**, 601-11.

Akhlaghi NM, Khalilak Z, Vatanpour M, Moshari A, Ghaffaric S, Namazikhah MS (2017) Students' Knowledge Comprehension after Implementation of Live Conventional Demonstration, Video Teaching and Video-Assisted Instruction Methods in Endodontic Practice. *Iranian Endodontic Journal* **12**, 201-4.

Chutinan S, Riedy CA, Park SE (2017) Student performance in a flipped classroom dental anatomy course. *European Journal of Dental Education.* Nov 9. doi: 10.1111/eje.12300.

De Moor R, Hülsmann M, Kirkevang LL, Tanalp J, Whitworth J (2013) Undergraduate curriculum guidelines for endodontology. *International Endodontic Journal* **46**, 1105-14.

European Society of Endodontology (2010) Accreditation of postgraduate specialty training programmes in Endodontology. Minimum criteria for training Specialists in Endodontology within Europe. International Endodontic Journal 43, 725-37.

Fouad AF, Burleson JA (1997) Effectiveness of an endodontic diagnosis computer simulation program *Journal of Dental Education* **61**, 289-95.

Gaston GW (1971) Computer assisted instruction in dental education. *Journal of Dental Education* **35,** 283-8.

Goodyear P, Retalis S (2010) Technology-Enhanced Learning. Sense Publishers, Rotterdam, Netherlands.

Hew KF, Lo CK (2018) Flipped classroom improves student learning in health professions education: a meta-analysis. *BMC Medical Education* **18**, 38 – 50.

Higgins JPT, Sterne JAC, Savović J, Page MJ, Hróbjartsson A, Boutron I, Reeves B, Eldridge S. 2016. A revised tool for assessing risk of bias in randomized trials. In: Chandler J, McKenzie J, Boutron I, Welch V.editors. Cochrane Methods. Cochrane Database of Systematic Reviews. **10** (Suppl 1): 29-31.

Khayat A, Keshtkar A (2004) A comparative study of multimedia and conventional education methods in undergraduate training in preclinical endodontics. *Journal of Research in Medical Sciences* **4,** 191-4.

Kok A (2009) Understanding the Technology Enhanced Learning Environments from a Cognitive Perspective. *International Education Studies* ***2***, 3-9.

Kirkwood A, Price L (2011) Enhancing learning and teaching through technology: a guide to evidence-based practice for policy makers. Higher Education Academy, York, UK. http://oro.open.ac.uk/32487/2/2_guide_for_academics.pdf.

Kirkpatrick DL, Kirkpatrick JD (2009) Evaluating Training Programs: the Four Levels. San Francisco, Berrett-Koehler Publishers.

Kirkwood A, Price L (2014) Technology-enhanced learning and teaching in higher education: what is 'enhanced' and how do we know? A critical literature review. *Learning, Media and Technology* **39**, 6-36.

Lee C, Kim SW (2018) Effectiveness of a Flipped Classroom in Learning Periodontal Diagnosis and Treatment Planning. *Journal of Dental Education* **82**, 614-20.

Maresca C, Barrero C, Duggan D, Platin E, Rivera E, Hannum W, Petrola F (2014) Utilization of blended learning to teach preclinical endodontics. *Journal of Dental Education* **78**, 1194-204.

Mendel RW, Scheetz JP (1982) The effect of teaching method on endodontic problem solving. *Journal of Dental Education* **46,** 548-52.

Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of Internal Medicine* **151**, 264–9.

Mullaney TP, Smith TA, Duel RC, Kaplan A (1976) Four-phase study of computer-assisted and slide-tape methods of simulating clinical endodontic problems. *Journal of Dental Education* **40,** 681-7.

Moazami F, Bahrampour E, Reza Azar M, Jahedi F, Moattari M (2014) Comparing two methods of education (virtual versus traditional) on learning of Iranian dental students: A post-test only design study. *BMC Medical Education* **14,** 2-5.

Naseri M, Ahangari Z, Shantiaee Y, Rasekhi J, Kangarlou A (2013) The efficacy of an endodontic instructional multimedia program for enhancing the knowledge and skills of dental students. *Journal of Islamic Dental Association of Iran* **25,** 106-12.

Naseri M, Shantiaee Y, Rasekhi J, Zadsirjan S, Bidabadi MM, Khayat A (2016) Efficacy of Video-Assisted Instruction on Knowledge and Performance of Dental Students in Access Cavity Preparation. *Iranian Endodontic Journal* **11,** 329-31.

Nicoll P, MacRury S, van Woerden HC, Smyth K (2018) Evaluation of Technology-Enhanced Learning Programs for Health Care Professionals: Systematic Review. *Journal of Medical Internet Research* **20***,* e131.

Puskas JC, Fung K, Anderson JA, *et al.* (1991) Comparison of self-instruction methods for teaching diagnostic testing. *Journal of Dental Education* **55**, 316-21.

Plasschaert AJM, Cailleteau JG, Verdonschot EH (1997) The effect of a multi-media interactive tutorial on learning endodontic problem-solving. *European Journal of Dental Education* **1**, 66-9.

Sandoval VA, Dale RA, Hendricson WD, Alexander JB (1987) A comparison of four simulation and instructional methods for endodontic review. *Journal of Dental Education* **51**, 532-8.

Santos GN, Leite AF, Figueiredo PT, *et al.* (2016) Effectiveness of E-Learning in Oral Radiology Education: A Systematic Review. *Journal of Dental Education* **80**, 1126-39.

Scott KM, Baur L, Barrett J (2017) Evidence-Based Principles for Using Technology-Enhanced Learning in the Continuing Professional Development of Health Professionals. *Journal of Continuing Education Health Professions* **37**, 61-6.

Schönwetter DJ, Gareau-Wilson N, Cunha RS, Mello I (2016) Assessing the impact of voice-over screen-captured presentations delivered online on dental students' learning. *Journal of Dental Education* **80,** 141-8.

Suebnukarn S, Haddawy P, Rhienmora P, Gajananan K (2010) Haptic virtual reality for skill acquisition in endodontics. *Journal of Endodontics* **36**, 53-5.

Suebnukarn S, Hataidechadusadee R, Suwannasri N, Suprasert N, Rhienmora P, Haddawy P (2011) Access cavity preparation training using haptic virtual reality and microcomputed tomography tooth models. *International Endodontic Journal* **44**, 983-9.

Suebnukarn S, Rhienmora P, Haddawy P (2012) The use of cone-beam computed tomography and virtual reality simulation for pre-surgical practice in endodontic microsurgery. *International Endodontic Journal* **45,** 627-32.

Sterne JA, Gavaghan D, Egger M (2000) Publication and related bias in meta-analysis: power of statistical tests and prevalence in the literature. *Journal of Clinical Epidemiology* **53**, 1119-29.

Sokolow S, Solberg W (1971) Computer-assisted instruction in dental diagnosis: a product development. *Journal of Dental Education* **35,** 349- 55