# Preclinical endodontic teaching

## *A survey of Saudi dental schools*

***Udaya Narayanaraopeta,*** *BDS, MDS,* ***Emad AlShwaimi,*** *FRCD(C), DMSc.*


## ABSTRACT

**الأهداف:** هذه الدراسة تعطي نظرة شمولية لتدريس مقرر علاج جذور واعصاب الأسنان في المرحلة ماقبل السريرية والذي يدرس في أعرق 6 كليات طب أسنان بالمملكة العربية السعودية.

**الطريقة:** تم اختيار كليات طب الأسنان والتي خرجت على الأقل دفعتين من طلاب كلية الأسنان. وقد شملت الدراسة كليتين من منطقة الرياض (الوسطى)، كلية من منطقة مكة المكرمة (الغربية) ، كلية من منطقة أبها (الجنوبية) ، كلية من منطقة القصيم (الوسطى) وكلية من المنطقة الشرقية. تم إرسال استبيان إلكتروني للمشرفين على المقررات في 6 كليات في المناطق المذكورة. تكونت الأسئلة من 20 سؤالا شملت نواحي عديدة من مقرر علاج جذور واعصاب الاسنان في المرحلة ماقبل السريرية.

**النتائج:** أوضحت وجود عدد كبير من أعضاء هيئة التدريس من حملة الدكتوراة (ن=21) بينما حملة الماجستير كانوا اقل (ن=15 ) ومن ثم حملة البورد السعودي لعلاج الجذور والأعصاب (ن=8). وكذلك تم تحديد نسبة المدرسين للطلبة وتتراوح من 1:2 إلى 1:8.ولوحظ ان 5 من أصل ست كليات استخدمت مبارد النيكل تايتانيوم في تحضير القنوات.كل الكليات استخدمت الأشعة كطريقة أساسية لتحديد طول القنوات وحسب النتائج فإن كليتين فقط تستخدم الأشعة الالكترونية في تدريس المقرر.

**الخاتمة:** اتضح من هذه الدراسة أن المنهج المدرس لمقرر علاج جذورٍ وأعصاب الأسنان في المملكة العربية السعودية مقارب جداً لنفس المقرر المدرس معظم في الدول الأوروبية. نحتاج دراسة تفصيلية أكثر لتغطية جميع كليات طب الأسنان في السعودية وتكون قادرة على وضع تصور لأفضل مقرر يتم تدريس

**Objectives:** To provide an overview of the general curricula in preclinical endodontic training from 6 established dental schools in Saudi Arabia.

**Methods:** This study was conducted in January 2014 including only schools that had more than 2 groups of student graduates prior to the study. We included 2 dental schools from the Central region, one from Qassim region, one from the Makkah region (west), one from Abha region (south west), and one from the eastern region. An internet-based questionnaire was sent to the course directors of preclinical endodontics department of the 6 schools. The survey comprised 20 questions that examined various aspects of preclinical endodontics.

**Results:** It was demonstrated that a significant number of faculty members had Doctor of Philosophy (PhD) degrees (n=21), Master's degrees (n=15), and Saudi board certifications (n=8). We determined that the faculty to student ratio varied from 2:1 to 8: 1 among the colleges. The participating dental schools were found to teach the Step Back, as well as the Step Down techniques for root canal preparation. Five of the 6 schools implemented the use of nickel titanium rotary instruments. All dental schools predominantly used radiographs as the means of the working length determination.

**Conclusion:** The curriculum for preclinical endodontics in Saudi Arabia is comparable to that followed in most European countries. A more comprehensive survey is needed that would involve more schools to formulate generalized guidelines for preclinical endodontic training in Saudi Arabia.


***Saudi Med J 2015; Vol. 36 (1): 94-100***
***doi: 10.15537/smj.2015.1.9336***

*From the Department of Restorative Dental Sciences, College of Dentistry, University of Dammam, Dammam, Kingdom of Saudi Arabia.*

*Received 19th May 2014. Accepted 17th November 2014.*

*Address correspondence and reprint request to: Dr. Emad AlShwaimi, Department of Restorative Dental Sciences, College of Dentistry, University of Dammam, PO Box 1982, Dammam 31441, Kingdom of Saudi Arabia. Tel. +966 (13) 3331404. Fax. +966 (13) 8572624. E-mail: ealshwaimi@uod.edu.sa*

Endodontic treatment is performed in a major portion of dental emergencies worldwide, and there is an increasing need to educate and train dental students in this specialty, such that they are prepared to perform better and predict treatment outcomes. Several studies particularly in Europe have demonstrated that the standard of endodontic treatment provided by the general dentists is not high.[1-4] Although many factors might be responsible for this inadequacy, a major contribution is attributed to the deficiencies in endodontic training provided to dental graduates of most universities.[5] To overcome the shortcomings in the curricula of various universities in Europe, the European Society of Endodontology published guidelines for the undergraduate curriculum in exndodontology in 1992 and 2001, to ensure a minimum level of competence in endodontics before graduation.[6] A revised guideline was published in 2013 in response to various studies that continued to show a decreased standard endodontic treatment in the European populations.[7-10] Dentistry as an art and science has always relied on comprehensive and effective training of dental students at the preclinical, as well as the clinical levels. A competent preclinical curriculum affords students with knowledge and skills required to transit comfortably into clinical settings, and to confront the various diagnostic and therapeutic challenges of clinical courses. Various studies have shown that shortcomings in preclinical training affect the clinical treatment provided by dental students.[11-14] Sonntag et al[5] stated that although the European Union has directives and guidelines devised to assure comparable and acceptable standards of dental education and competence from training programs, there is a major difference among countries with respect to the curriculum. The first dental school in the Arabian Gulf region began in Saudi Arabia in the late 1970's, and there are currently 24 dental schools in Saudi Arabia, of which 17 are government-owned, and 7 are run by private organizations serving different regions, or provinces of the kingdom. The curriculum of the dental schools was initially based on that of schools in North America, and lately, many modifications have been implemented to conform to other international standards, as well as to meet the treatment needs of local patients. Newer colleges are inclined toward developing their curricula based on those of more established colleges. As no study has been published regarding the preclinical endodontic curriculum in Saudi Arabia, this paper aims to provide an overview of the general curricula followed by 6 established dental schools in the kingdom, in which endodontics is taught as a separate specialty.

**Disclosure**. Authors have no conflict of interests, and the work was not supported or funded by any drug company.

**Methods.** The survey comprised 20 questions that examined various aspects of preclinical endodontic training in dental schools. Some of the questions were formulated based on the data provided in studies by Sonntag et al[5] in 2008, and Qualtrough et al[15] in 1999. Most of the questions were multiple choices, which options were provided to the respondents, and they were asked to select the most relevant answer. Some of the questions were descriptive, and the respondents were free to write an answer. The respondents were given the opportunity to select more than one answer to the 3 questions. The questionnaire was uploaded onto the internet-based Survey Monkey, and the requests were sent to the course directors of the preclinical endodontics from 6 dental schools in Saudi Arabia. The inclusion criteria were that the government-owned schools should be well-established with more than 2 groups of students having graduated prior to this study. The selection was intended to be representative of the different regions in Saudi Arabia. The sample size was inclusive to all the preclinical endodontic students enrolled at the time of the study. Prior to the survey, the participants were given a briefing regarding the required survey details and the goals to be achieved by this survey. The briefings were conducted by personal telephone calls to the participating course directors. The confidentiality and anonymity of the survey results were of primary consideration, and the evaluators were blind to the data collected from the respondents. To achieve these goals, the names of the participating schools and their respective course directors were not mentioned in the survey. Only the regions of Saudi Arabia, from which the colleges were selected were mentioned. Our study was conducted in January 2014 and included 2 dental schools from Riyadh region (central), one from Qassim region (central), one from the Makah region (west), one from the Abha region (south west) and one from the eastern region.

**Results.** *Student-supervisor ratio and the availability of specialized faculty.* All the participating schools taught the course for a full year during the 4th

year level, except the school in the Eastern Province, which taught the course in one semester. However, it is noteworthy that the total lectures and laboratory hours are equal for all the 6 schools. Regarding the number of students and faculty participating in the preclinical endodontics courses, the ratio between the students and the supervisors varied from a maximum of 2:1 to a minimum of 8:1 (**Table 1**). The most favorable ratio of 2:1 shown by one of the universities was that of fewer students were taking the preclinical course. Regarding the availability of specialized faculty members trained in endodontics, almost 85% of the faculty participating in the courses was comprised of endodontists with various specialized degrees, and 15% were graduates. A good number of faculty members had Doctor of Philosophy (PhD)s (n=21), Master's degrees (n=15) and Saudi board certifications (n=8) among the faculty participating in the preclinical courses in all the 6 dental schools.

***Preclinical laboratory exercises.*** The data collected to evaluate the preclinical exercises (**Table 2**) showed that among the participating schools, 4 schools used extracted, as well as artificial teeth, and the remaining 2 dental schools used only extracted teeth, which were embedded on customized models that could be mounted on the mannequin jaws. Four out of 6 schools used rubber dam isolation for the preclinical training. All the dental schools predominantly used radiographs as one of the means of determination of the working length. Amongst the various types of radiographs regularly used for working length determination (such as conventional, self-processed, semi-digital, and digital radiographs), 3 schools used conventional radiographs; 2 schools used digital radiographs, whereas one school used both conventional and digital radiographs. Along with the use of radiographs, of the 6 schools that participated in the survey, 5 schools also used apex locators for the electronic working length (EWL) determination. All the participating schools teach only the lateral condensation technique for root canal filling. All the participating dental schools teach the step back technique, as well as the step down techniques for the root canal preparation (**Table 2**). Although most of the schools used the step back technique with stainless steel hand files, the students were also introduced to the use of nickel titanium (NiTi) rotary instruments in all, except one school.

**Table 1 -** Comparison of student-supervisor ratio, and qualifications of faculties participating in the preclinical endodontic courses of different dental schools.

| Region | Number of students | Qualification of faculty | | | | Faculty, Total | Students:Supervisor ratio |
|---|---|---|---|---|---|---|---|
| | | PhD/ Doctorates | Master's degree | Saudi Board | Graduates, (demonstrators/ residents) | | |
| Abha | 56 | 10 | 2 | 4 | 3 | 19 | 3:1 |
| Makkah | 42 | 2 | 1 | 2 | 1 | 6 | 7:1 |
| Riyadh 1 | 15 | 3 | 1 | 2 | 2 | 9 | 2:1 |
| Riyadh 2 | 68 | 1 | 5 | 0 | 2 | 8 | 8:1 |
| Qassim | 29 | 3 | 2 | 0 | 0 | 5 | 6:1 |
| Dammam | 32 | 2 | 4 | 0 | 0 | 6 | 5:1 |

PhD - Doctor of Philosophy, Riyadh 1 - first dental school located in Riyadh, Riyadh 2 - second dental school located in Riyadh

**Table 2 -** Preclinical exercises taught in the laboratory among various dental school according to a study in Saudi Arabia.

| Region | Type of teeth | | Rubber dam isolation | Working length determination | | | Instrumentation technique | | Obturation technique | Use of NiTi rotary endodontic instruments |
|---|---|---|---|---|---|---|---|---|---|---|
| | Natural | Artificial | | Conventional radiographs | Digital radiographs | Apex locators | Step back | Step down/ crown down | lateral condensation | |
| Abha | ✓ | ✓ | X | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Makkah | ✓ | X | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ |
| Riyadh 1 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Riyadh 2 | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ |
| Qassim | ✓ | X | X | X | ✓ | X | ✓ | ✓ | ✓ | X |
| Dammam | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ |

**NiTi** - nickel titanium, √ - using, X - not using, Riyadh 1 - first dental school located in Riyadh, Riyadh 2 - second dental school located in Riyadh

**Table 3 -** Comparison of the study materials provided by the faculty to undergraduate students in the preclinical endodontic courses in different schools in Saudi Arabia.

| Region | Study materials | | | |
|---|---|---|---|---|
| | Handouts of the lectures | Handouts of lecture outlines | Copies of chapters from the text books | Ask them to read text books |
| Abha | X | X | ✓ | X |
| Makkah | X | ✓ | ✓ | X |
| Riyadh 1 | X | X | X | ✓ |
| Riyadh 2 | ✓ | X | X | ✓ |
| Qassim | ✓ | X | ✓ | ✓ |
| Dammam | X | ✓ | X | ✓ |

✓ - provided, X - not provided, Riyadh 1 - first dental school located in Riyadh, Riyadh 2 - second dental school located in Riyadh

**Table 4 -** Comparison of different formative assessment methods in the preclinical endodontic courses taught in different schools in Saudi Arabia.

| Region | Formative assessment methods | | | |
|---|---|---|---|---|
| | Orally structured clinical examination | Identification of instruments (Spots) | Submission of assignments | Presentation of completed cases in front of faculty and peers |
| Abha | ✓ | X | X | X |
| Makkah | X | ✓ | ✓ | X |
| Riyadh 1 | ✓ | ✓ | ✓ | X |
| Riyadh 2 | X | ✓ | X | X |
| Qassim | ✓ | X | ✓ | X |
| Dammam | X | ✓ | X | ✓ |

✓ - conducted, X - not conducted, OSCE - orally structured clinical examination, Riyadh 1 - first dental school located in Riyadh, Riyadh 2 - second dental school located in Riyadh

*Didactic and laboratory sessions.* For the preclinical laboratory exercises, the time allotted in each school varied from 3-6 hours per week. There was also a difference in the number of semesters, for which the course was conducted, which was related to the different academic systems followed in annual- and semester-based systems. The didactic sessions varied from one to 2 lectures per week. The students were provided with study materials after the lectures in the form of handouts of the lectures (33.3%), handouts of the lecture outlines (33.3%), and copies of chapters from the text books (50%), and the students are asked to read text books (66.7%) (**Table 3**). Five of the 6 schools provided the students with more than one type of study material; however, one school instructed the students to study from the textbooks without providing additional materials.

*Student assessment methods.* The results showed that in addition to the laboratory requirements and logbooks, the schools had different methods of formative assessment (**Table 4**). The following methods of assessment were included in the 6 schools; the Objective Structured Clinical Examinations (OSCE) were used in 3 schools; the identification of instruments (Spots) assessment was used in 4 schools; submission of assignments was used in 3 schools; and the presentation of completed cases was used in one school. Summative assessment was by practical examinations conducted throughout the course ranging from 1-3 times among the different schools. Written examinations primarily involved multiple choice questions (MCQs) and short answers question. Three of the 6 schools used only MCQ, whereas the other 3 schools used MCQs (75%) and short answer questions (25%).

**Discussion.** The endodontic preclinical curriculum is the foundation and first introduction to endodontic specialty, and it is considered an important step in providing the student with the basic skills required to begin delivering acceptable endodontic treatment to patients.

In this study, we selected dental schools from different regions of Saudi Arabia, to provide an overview of the curriculum followed in those schools. Of the 6 dental

schools that participated in the study, 3 were from the central region (3 from Riyadh and one from Qassim) because the area has the highest population and number of dental colleges in the country. All the selected schools were government-owned, this was intentional to make sure that the resources and the operation system of those schools would be approximate while comparing the curriculum.

One of the most difficult challenges faced during the preclinical training is providing students with models that accurately simulate tooth morphology and the root canal system, as well as the clinical challenges faced by students treating live patients, especially in isolation and infection control. There has been a remarkable transition from the use of human cadaver sections and bovine mandibles[16,17] to sectioned extracted teeth,[18] transparent decalcified teeth,[19] direct visualization through plexirod tubes,[20] curved resin simulated canals,[21] and extracted natural human teeth. Extracted teeth mounted in plaster have been the most commonly used study models in preclinical dentistry. In our study, almost all the schools trained their students on extracted, as well as artificial teeth embedded on customized models that could be mounted on mannequin jaws. This training enhances the students' skills in indirect vision and provides a more realistic clinical simulation, which would help them in their future clinical endodontic courses. The use of mannequin jaws enables the students to practice the use of rubber dam isolation.

Although the use of rubber dams has been strongly recommended by professional organizations including the European Society of Endodontology (1992, 2006) and the American Association of Endodontists (2004),[22] many surveys have shown that dental general practitioners do not commonly use rubber dams. In a survey of UK dentists, only 19% used rubber dams routinely.[23] The rate of rubber dam use in other countries is as follows: 2% in Sudan;[24] 58% in the USA;[25] 7% in Belgium;[26] and 57% in New Zealand.[27] In our survey, we found that only 2 schools did not expose the students to the use of rubber dam isolation during the preclinical endodontic training. One school thought that it was unnecessary for the students to start using rubber dams at the preclinical level, whereas the other school lacked the provision of customized blocks that allowed the placement of rubber dams. It is important that dental educators in Saudi Arabia emphasize the importance of the use of rubber dams at an early stage of dental training so that it will have a long lasting effect on the students' future dental practice.

Most dental schools and most general practitioners routinely use radiographs for the working length determination. This finding was observed in our survey, wherein all the dental schools used radiographs for the working length determination. Qualtrough et al[15] showed that 43% of the dental schools in Western Europe, 38% in Scandinavia, and 36% in North America routinely teach the use of apex locators in preclinical dentistry, whereas 22% of the schools in eastern Europe, and 21% in the UK teach the use of apex locators. Most schools use resin blocks, or extracted teeth mounted in plaster/resin or other media, which allow only the use of radiographs and not EWL determination.[28] Various models have been suggested for use with electronic apex locators in preclinical endodontic training,[28-30] that could be incorporated in dental schools. A combination of the use of radiographs with EWL determination has been recommended for predictive endodontic treatment.[28,31,32] In our study, we have seen that 5 out of 6 schools were adopting this recommendation. It was very encouraging, as the students were introduced to the importance of working length, and the use of more than one technique in the determination of working length, while at the preclinical endodontic settings. This experience would enable them to have a smooth transition to the next clinical endodontic course, thus improving the treatment outcome. From our results, only one dental school classified training in apex locators as relevant for use only in clinical endodontics courses.

The step back technique is the most commonly taught method for root canal preparation. Sonntag et al[5] showed that the 'step back technique is the most commonly taught manual preparation method (70%) in dental schools in Germany. Cailleteau and Mullaney[33] showed that almost 83% of the dental schools in the United States teach the step back technique of instrumentation. In our survey, all the schools (100%) used the step back technique and the step down/crown down technique. Generally, the step down technique is taught in relation to the use of rotary NiTi files. All the schools advocated the use of canal preflaring before the preparation of the apical and the middle third of the canal. Five of the 6 schools (83.3%) encourage the use of rotary NiTi instrumentation in preclinical endodontic training. This percentage is much higher than that reported in dental schools in Germany (63%)[5] Western Europe (27%),[15] Scandinavia (25%),[15] and France (81%).[34] The strongest resistance to the use of NiTi instruments in undergraduate endodontic training has been based on the presumed risk of instrument separation and the cost

of the instruments.[34,35] An appreciable attempt has been made by the dental schools in Saudi Arabia to introduce the use of NiTi rotary instruments at the preclinical level with 5 of 6 schools advocating the use of rotary endodontic instruments by students.

Our study is in agreement with previously published studies such as that of Qualtrough et al[15] which found in their survey that cold lateral condensation was the most frequently used obturation technique, with only one quarter of the participating universities teaching the warm vertical condensation technique. Cailleteau and Mullaney[33] showed that almost 89.6% of the dental schools in the United Sates teach lateral condensation as the primary method of obturation.

The total time for the didactic and practical sessions varied among different schools because some schools followed the annual system and others followed the semester system. The time allotted to the practical sessions ranged from 2.5-6 hours/week, which translated to almost 80-96 hours for the entire preclinical endodontics course. This time span was higher than that reported in Germany (45 hours) and France (78 hours).[5] According to the European guidelines, for demonstration of competency, formative and summative evaluation should be significantly involved.[36] In the schools in this survey, the formative assessment was constituted predominantly by the grades earned by the students for the preclinical laboratory exercises and other methods of assessment, such as OSCE, the identification of instruments, submission of assignments, and presentation of completed cases. Only one of the schools assessed the students on the presentation of completed clinical work. This presentation was conducted in front of the faculty, as well as the entire class, which enabled the students to develop presentation skills, as well as accept peer evaluation and criticism. The summative evaluation was in the form of periodic practical exams, as well as the final written examination. Our study found that a major component of the final written examinations comprised Multiple Choice Questions, which are commonly used because they 'can provide a large number of examination items that encompass many content areas, can be administered in a relatively short period, and can be graded easily.[37]

The faculty to student ratio has a major role in the teaching of technique-sensitive skills to graduate students at educational various levels. Any decrease in this ratio burdens the faculty with more responsibilities, especially in the preclinical courses, in which the grading of student work is always accompanied by feedback from the instructor individually to each student. In this survey, the student to supervisor ratio, on average was found to be more favorable than those reported by Qualtrough et al[15] in an international comparison. Qualtrough et al[15] reported ratios in Western Europe (8:1), Eastern Europe (6:1), Scandinavia (9:1), the United Kingdom (12:1), and North America (9:1). Sontag et al[5] reported a much smaller student to faculty ratio of 16:1 in German dental schools, and a national survey in France (2004) reported a ratio of 18:1.[34] Apart from the student-teacher ratios, the qualification of the faculty plays an important role. Seijo et al[38] stated in their report that 'students place great value on the technical expertise of their instructors'. According to the guidelines of the European Society of Endodontology (1992),[15] undergraduate endodontic training must be provided by faculty members with advanced training in endodontics. Dummer[15,39] stated that "the staff with advanced specialist training invariably provide a higher and more uniform standard of teaching". In this survey, we found that almost 85% of the faculty were endodontists with various specialized degrees, and 15% were graduates. This percentage was quite high, and could be attributed to the fact that endodontics is considered a different specialty, and taught separately in all the universities in Saudi Arabia.

In conclusion, the survey demonstrated that the curriculum for preclinical endodontics followed by schools from different regions of Saudi Arabia is comparable to that followed in most European countries. Although certain schools are much older than others, the curricula followed were generally consistent with international standards. A more comprehensive survey is needed, involving more schools to formulate generalized guidelines for preclinical endodontic training in Saudi Arabia.

## References


1. Stewardson DA. Endodontic standards in general dental practice--a survey in Birmingham, UK, Part 2. ***Eur J Prosthodont Restor Dent*** 2001; 9: 113-116.
2. Saunders WP, Saunders EM, Sadiq J, Cruickshank E. Technical standard of root canal treatment in an adult Scottish sub-population. ***Br Dent J*** 1997; 182: 382-386.
3. Boucher Y, Matossian L, Rilliard F, Machtou P. Radiographic evaluation of the prevalence and technical quality of root canal treatment in a French subpopulation. ***Int Endod J*** 2002; 35: 229-238.
4. Segura-Egea JJ, Jimenez-Pinzon A, Poyato-Ferrera M, Velasco-Ortega E, Rios-Santos JV. Periapical status and quality of root fillings and coronal restorations in an adult Spanish population. ***Int Endod J*** 2004; 37: 525-530.

5. Sonntag D, Barwald R, Hulsmann M, Stachniss V. Pre-clinical endodontics: a survey amongst German dental schools. ***Int Endod J*** 2008; 41: 863-868.
6. Tchorz JP, Ganter PA, Woelber JP, Stampf S, Hellwig E, Altenburger MJ. Evaluation of an improved endodontic teaching model: do preclinical exercises have an influence on the technical quality of root canal treatments? ***Int Endod J*** 2014; 47: 410-415.
7. De Moor R, Hulsmann M, Kirkevang LL, Tanalp J, Whitworth J. Undergraduate curriculum guidelines for endodontology. ***Int Endod J*** 2013; 46: 1105-1114.
8. Eriksen HM, Kirkevang LL, Petersson K. Endodontic epidemiology and treatment outcome: general considerations. ***Endodontic Topics*** 2002; 2: 1-9.
9. Gencoglu N, Pekiner FN, Gumru B, Helvacioglu D. Periapical status and quality of root fillings and coronal restorations in an adult Turkish subpopulation. ***Eur J Dent*** 2010; 4: 17.
10. Peters LB, Lindeboom JA, Elst ME, Wesselink PR. Prevalence of apical periodontitis relative to endodontic treatment in an adult Dutch population: a repeated cross-sectional study. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod*** 2011; 111: 523-528.
11. Schulte A, Pieper K, Charalabidou O, Stoll R, Stachniss V. Prevalence and quality of root canal fillings in a German adult population. ***Clin Oral Investig*** 1998; 2: 67-72.
12. Weiger R, Hitzler S, Hermle G, Löst C. Periapical status, quality of root canal fillings and estimated endodontic treatment needs in an urban German population. ***Endod Dent Traumatol*** 1997; 13: 69-74.
13. Hayes S, Gibson M, Hammond M, Bryant S, Dummer P. An audit of root canal treatment performed by undergraduate students. ***Int Endod J*** 2001; 34: 501-505.
14. Lynch C, Burke F. Quality of root canal fillings performed by undergraduate dental students on single-rooted teeth. ***Eur J Dent Educ*** 2006; 10: 67-72.
15. Qualtrough A, Whitworth J, Dummer P. Preclinical endodontology: an international comparison. ***Int Endod J*** 1999; 32: 406-414.
16. Newton C, Ferguson S, Patterson S. The use of cadaver sections in the preclinical endodontic laboratory. ***J Dent Educ*** 1979; 43: 351-352.
17. Bramante CM, Berbert A, Mondelli J. The use of bovine mandibles for teaching endodontic surgical skills. ***J Endod*** 1981; 7: 282-283.
18. Bence R. Direct visualization of endodontic techniques in extracted teeth. ***J Dent Educ*** 1974; 38: 565.
19. Hasselgren G, Tronstad L. The use of transparent teeth in the teaching of preclinical endodontists. ***J Endod*** 1975; 1: 278-280.
20. Fleisher R, Heintz C. A plastic tube technique for direct vision of endodontic procedures. ***J Dent Educ*** 1977; 41: 630-632.
21. Weine FS, Kelly RF, Lio PJ. The effect of preparation procedures on original canal shape and on apical foramen shape. ***J Endod*** 1975; 1: 255-262.
22. Ibrahim AA, Fadlalla NB, Nory NF, Abu-bakr NH. Difficulties in performing root canal treatment among dental students in Sudan. ***Indian Journal of Dentistry*** 2012; 3: 196-200.
23. Jenkins S, Hayes S, Dummer P. A study of endodontic treatment carried out in dental practice within the UK. ***Int Endod J*** 2001; 34: 16-22.
24. Ahmed M, Elseed A, Ibrahim Y. Root canal treatment in general practice in Sudan. ***Int Endod J*** 2000; 33: 316-319.
25. Hill EE, Rubel BS. Do dental educators need to improve their approach to teaching rubber dam use? ***J Dent Educ*** 2008; 72: 1177-1181.
26. Hommez G, Braem M, De Moor R. Root canal treatment performed by Flemish dentists. Part 1. Cleaning and shaping. ***Int Endod J*** 2003; 36: 166-173.
27. Koshy S, Chandler N. Use of rubber dam and its association with other endodontic procedures in New Zealand. ***N Z Dent J*** 2002; 98: 12-16.
28. Tchorz J, Hellwig E, Altenburger M. An improved model for teaching use of electronic apex locators. ***Int Endod J*** 2012; 45: 307-310.
29. Nikhil V, Srivastava N. A new pre-clinical "endodontic model": Boon to learners. ***Endodontology*** 2009; 21:58-61.
30. Hansen SW, Musanje L, Nguyen T, Kashkouli M. Evaluation of the ModuPRO for In-vitro Measurement of Electronic Length. IADR/AADR/CADR 85th General Session and Exhibition. Oregon Health and Science University, Portland, USA. 2007 March 21-24.
31. Hoer D, Attin T. The accuracy of electronic working length determination. ***Int Endod J*** 2004; 37: 125-131.
32. Kim E, Marmo M, Lee CY, Oh NS, Kim IK. An in vivo comparison of working length determination by only root-ZX apex locator versus combining root-ZX apex locator with radiographs using a new impression technique. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod*** 2008; 105: 79-83.
33. Cailleteau JG, Mullaney TP. Prevalence of teaching apical patency and various instrumentation and obturation techniques in United States dental schools. ***J Endod*** 1997; 23: 394-396.
34. Arbab-Chirani R, Vulcain J. Undergraduate teaching and clinical use of rotary nickel–titanium endodontic instruments: a survey of French dental schools. ***Int Endod J*** 2004; 37: 320-324.
35. Parashos P, Messer HH. The diffusion of innovation in dentistry: a review using rotary nickel-titanium technology as an example. ***Oral Surg Oral Med Oral Pathol Oral Radiol Endod*** 2006; 101: 395-401.
36. Lost C. Undergraduate curriculum guidelines for endodontology. ***Int Endod J*** 2001; 34: 574-80.
37. Cox M, Irby DM, Epstein RM. Assessment in medical education. ***N Engl J Med*** 2007; 356: 387-396.
38. Seijo MO, Ferreira EF, Ribeiro Sobrinho AP, Paiva SM, Martins RC. Learning experience in endodontics: Brazilian students' perceptions. ***J Dent Educ*** 2013; 77: 648-655.
39. Dummer P. Comparison of undergraduate endodontic teaching programmes in the United Kingdom and in some dental schools in Europe and the United States. ***Int Endod J*** 1991; 24: 169-177.