The Scientific Journal of University of Benghazi

www.sjuob.uob.edu.ly

# Quality of Root Canal Fillings Performed by General Dental Practitioners in Libya: A radiographic assessment

Ibtesam Orafi[1*] and Suha Al Firjani[2],

*1,2. Faculty of Dentistry, University of Benghazi, Benghazi, Libya*

Received: 3/3/2020; accepted: 9/6/2020.

**الملخص**

يعتبر منع اعادة الانتان ضمن منظومة أقنية الجذور والسماح بشفاء الافات حول الذروية هما الهدفان الاساسيان من حشوات الجذور بشكل عام ومن المتفق عليه أن نجاح المعالجة الجذرية مرهون بجودة المادة الحاشية القنيوية من ثلاثة نواحي: طولها , وكثافتها وشكلها المستدق وانجاز ذلك من قبل الممارس العام يعتمد على التدريب الجيد للطبيب في مرحلة ماقبل التخرج اضافة إلى أهمية التعليم الطبي المستمر في اختصاص معالجة الجذور. الهدف من الدراسة تقييم الجودة الشعاعية لحشوات الاقنية الجذرية المنجزة من قبل طبيب الاسنان الممارس العام في ليبيا.

تمت دراسة عينة مكونة من 599 سن معالجة جذريا تحوي 994 جذرا . تم تقييم جودة حشوة الجذور من قبل اثنين من اختصاصي معالجة الجذور بعد توحيد معايير التقييم مسبقا عبر ارتسام الذروة الشعاعية الرقمية لاسنان مختلفة دون تعزيز وضوح المرتسمات ومن ثم تم تصنيف اطوال حشوات الاقنية بحسب علاقتها مع الذروة الشعاعية للجذر كالتالي: مقبولة, قصيرة, زائدة الحشو تم تقييم الكثافة والشكل المستدق لحشوات الجذور بناءا على وجود فجوات ودرجة اتساقية الاستدقاق. تم تصنيف الجودة العامة على انها ملائمة اذا ماكانت جميع المعايير (الطول, الكثافة, والاستدقاق) ملائمة ايضا . النتائج بشكل عام 11.7 % من جميع الاسنان التي تم تقييمها كانت ذات حشوات جذرية مقبولة ذات جودة مقبولة تم تصنيف حشوات جذر مقبولة في 53% من اسنان الفك العلوي و 40.4% من اسنان الفك السفلي في هذه الدراسة كان هناك ايضا فرق جوهري (P<0.001) بين نوع السن وطول الجذر وذلك بنسبة 48.2%, لتلك الملائمة و 11.9% لتلك الزائدة الحشوة و 39.9% لتلك ناقصة الحشو من اسنان الفك السفلي 17.4% من اسنان الفك العلوي و 22.3% تم تصنيف المعالجات الملائمة من حيث الكثافة كان هناك ايضا فرق جوهري (P<0.05) بين نوع السن ودرجة كثافة حشوة الجذر. تم تصنيف حشوات جذر ذات شكل مستدق مقبول في 42% من اسنان الفك العلوي و 33% من اسنان الفك السفلي كان هناك فرقا جوهريا بين نوع السن و درجة ملائمة الشكل المستدق لحشوة الجذر. في الخاتمة وجد في هذه الدراسة أن حشوات الجذور المنجزة من قبل طبيب الاسنان العام كانت دون مستوى المعايير المطلوبة ولذلك فإن هناك حاجة ملحة حاليا لتحسين برنامج التدريب لمرحلة ماقبل التخرج في موضوع حشوات الجذور اضافة الى ضرورة تكثيف برامج التعليم الطبي المستمر في هذا الاختصاص .

**الكلمات المفتاحية:**

الجودة , حشوات الاقنية الجذرية (حشوات الجذور) , طبيب الاسنان الممارس العام , التقييم الشعاعي.

**Abstract**

Aim: to evaluate radiographic quality of root canal fillings performed by General Dental Practitioners (GDPs) in Libya. Methods: A total of 599 endodontically treated teeth with 994 roots were evaluated. Assessment of the quality of root canal fillings was done by tracing digital periapical radiographs for different types of teeth without enhancement by two calibrated endodontists, evaluating length, density and taper. The length of each root canal filling was categorized as acceptable, short or overfilled based on the relationship of the filling with the radiographic apex. Density and taper were evaluated based on presence of voids and uniform tapering of the filling. The overall quality was considered adequate if all three criteria were adequate. Results: Overall 11.7% of all evaluated teeth had an acceptable root canal filling Adequate length of root filling was found in 53% of the maxillary teeth and in 40.4% of mandibular teeth. A significance difference (P<0.001) was found between tooth type and length of root canal filling (48.2%, 11.9% and 39.9% for adequate, over, and short root filling respectively). Adequate density was found in 22.3% of maxillary and 17.4% of mandibular teeth. A significant difference between tooth type and density of root filling (P<0.05) was found. Adequate taper was found also in 42% of maxillary and 33% of mandibular teeth. There was a significant difference (P<0.001) between tooth type and adequacy of root filling taper. Conclusion. The technical radiographic quality of root canal fillings performed by general dental practitioners was found to be substandard. There is an urgent need to improve it.

**Keywords:** quality, root canal filling, general dental practitioners, radiographic.

## 1. INTRODUCTION

The main goal of root canal obturation is to prevent re-infection of root canal system and allow healing of periapical lesion.[1] It is well documented that the success of root canal treatment relays on the quality of root canal filling.[2,3] Previous studies[4-11] reported that poor quality of endodontic treatment can be directly related to apical periodontitis. A recent study carried out by Thampibulet and colleagues[12] reported an increase in the prevalence of post-treatment apical periodontitis owing to the substandard technical quality of root fillings and restorations. Hence, there is an urgent need for the improvement of the quality of root canal treatment in order to minimise the incidence of apical periodontitis.[13]

Root canal treatment is often a challenging area for the general dental practitioners (GDPs) especially the endodontic treatment of posterior teeth.[14] Literature search showed many

*Correspondence:

Dr. Ibtesam Orafi
Faculty of Dentistry, University of Benghazi,
Benghazi, Libya
*ibtesam.orafi@gmail.com*

epidemiological studies focused on the technical quality of root canal filling among the undergraduate students and few of researches were looked at the quality of root canal fillings among general dental practitioners. While, Bjørndal and colleagues[15] reported a satisfactory and excellent quality of endodontic treatment via a self-assessment survey looking at the knowledge and skills of Danish GDPs, other epidemiological studies reported undesirable quality of root canal treatment among either general dental practitioners or undergraduate students. [5,8,16-36]

Modern endodontic courses have focused on the improvement of the technical quality of root canal procedures. It is well documented that there is an association between undergraduate training course and adequate quality of root canal obturation which were performed by general dental practitioners.[37-40] Moradi and Gharechahi[34] highlighted the importance of evaluating the quality of root canal treatment for planning the educational program in Endodontics. Root canal filling is a crucial component in endodontic treatment[41], and an essential criterion for the evaluation of root canal treatment via periapical radiographs which is recommended by the European Society of Endodontology [42] as assessment tool. Those criteria include: preparing a tapered root canal from crown to apex, absence of voids between root canal filling and canal walls and finally the root canal filling preferably terminate within 2mm of periapical region clearly identified. Failure of adequacy in any of the aforementioned criteria can expose the treated tooth to a higher risk of failure and subsequent development or persistent periapical lesion.[43]

The majority of endodontic treatments in Libya are performed by GDPs; therefore, the aim of the current study was to evaluate the technical quality of root canal treatment performed by general dental practitioners at different private dental practice in Libya.

## 2. MATERIALS AND METHODS

A retrospective clinical review was carried out on patients records of endodontic treatment performed by General Dental Practitioners in private dental clinic in Libya. A randomly selected 611 records for patients who had received dental treatment in different private clinics.

**Inclusion criterion:**

- Endodontic treatment should be completed by GDPs.
- Good quality periapical radiograph.

**Exclusion criterion:**

- Root canal treatment with a post-retained core.
- Incomplete endodontic treatment and records without post-operative radiographs.
- Unreadable radiographs due to superimposition of adjacent structures, excessive elongation or foreshortening of the image.
- Teeth had surgical procedure e.g. Apicectomy, cyst enucleation.
- Teeth with endodontic mishaps such as perforation, missed canal or separated instrument.
- Teeth with signs of internal or external root resorption.
- Any retreatment cases.

Twelve unreadable radiographs for patients' records were excluded from the study. The remaining 599 records were fulfilled the inclusion criteria. A total of 994 root canals were evaluated for the quality of root canal fillings.

All radiographs were independently examined by two endodontists. The results of assessment were compared by the two assessors and a final agreement between the assessors was made. In case of disagreement, a third investigator was asked to interpret the radiographs and a final agreement was reached. The latter was the case in only three canals.

Power of agreement was measured using Cohen's kappa (k) values *[K<0 less than chance agreement, 0.01–0.20 slight agreement, 0.21– 0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61– 0.80 substantial agreement, and 0.81–0.99 almost perfect agreement*]. The calculated Kappa value was 0.97, which indicate a perfect agreement. The quality of endodontic treatment was determined by the length of root filling in relation to radiographic apex, the density of the obturation according to the presence of voids and the taper of the root canal fillings (consistent taper from coronal to apical aspect of the root). The following criteria [Table 1] of radiographic interpretation were adapted by Barrieshi-Nusair and colleagues.[44]

**Table 1: Criteria for evaluation of root canal filling.**

| Criteria | Status | Description |
|---|---|---|
| **Length of root canal filling** | Adequate | Root filling ending ≤ 2 mm from the radiographic apex. |
| | Over-filling | Root filling beyond the radiographic apex. |
| | Short filling | Root filling >2 mm short from the radiographic apex |
| **Density of root canal filling** | Inadequate | Voids present in the root filling or between root filling and root canal walls |
| | Adequate | No voids present in the root filling or between root filling and root canal walls |
| **Taper of root canal filling** | Inadequate | No consistent taper from the coronal to apical part |
| | Adequate | Consistent taper from the coronal to apical part |

The overall quality was considered adequate if all variables (length, density and taper) were adequate. Data were analysed using SPSS software version 20 (SPSS Inc, Chicago, IL, USA). Descriptive analysis for each variable was calculated and Chi-square analysis of association at ≤0.05 were performed.

## 3. RESULTS

Five hundred ninety-nine teeth (994 roots filled canals) were investigated in this study. The distribution of examined teeth is shown in Figure 1. Maxillary premolars and mandibular molars represent half of the studied sample (50%). Figure 2 illustrates the distribution of teeth according to group (anterior, premolar and molars). The largest sample composed of premolars teeth..

**Overall quality:**

The overall quality of root canal filling was defined by the combination of all three outcome variables (i.e. length, density, and taper) for both maxillary and mandibular teeth [Figure 3]. Though the percentage of adequate root fillings was 11% in maxillary teeth and 12.8 % in mandibular teeth, the difference between the jaws was not statistically significant [P > 0.05]. Figure 4 illustrate the incidence of inadequate root canal filling

in each tooth type. The inadequate root canal fillings were observed more in maxillary molars (95%) and mandibular molars (91%).

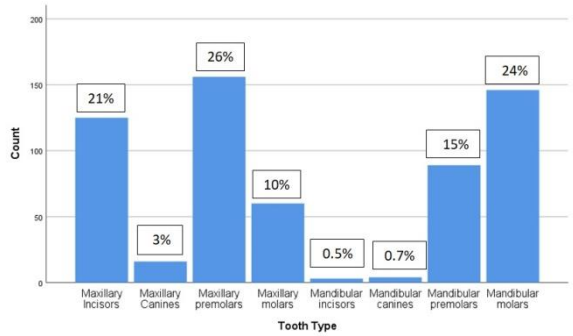



**Figure 1: The distribution of teeth in the maxillary and mandibular arches.**

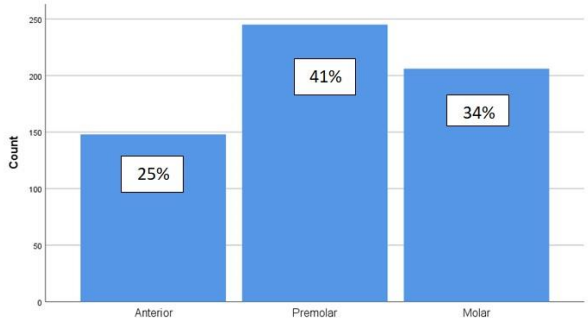



**Figure 2: The distribution of teeth according to groups.**

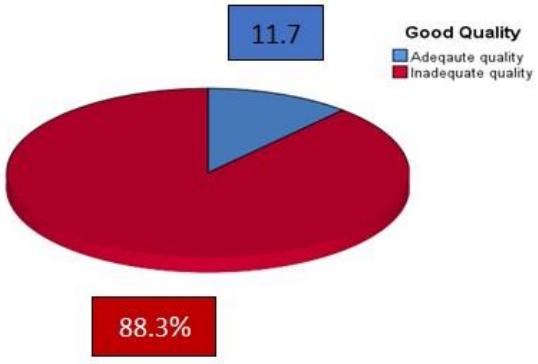



**Figure 3: overall quality of performed root canal treatment.**

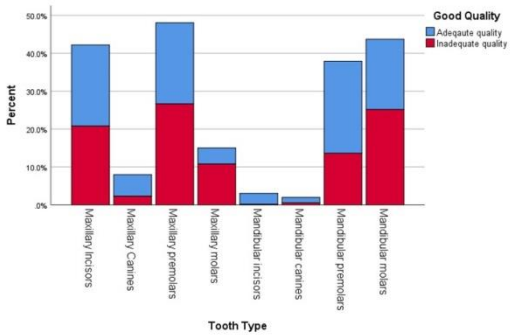



**Figure 4: The overall quality of the root canal filling in each tooth in both arches.**

Figure 5 illustrate the overall quality of different teeth group. The highest incidence of inadequate root canal fillings was observed in molar group compared to other groups. There was no statistically significant difference between groups of teeth and overall quality [P= 0.084].

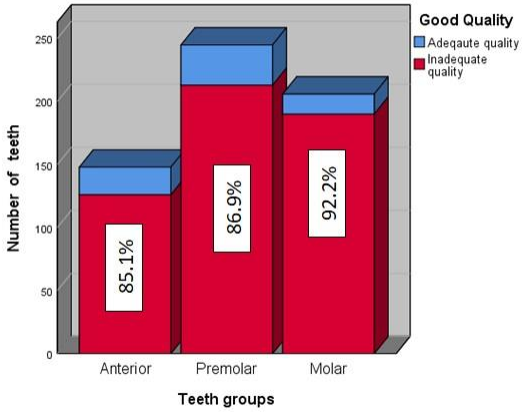



**Figure 5: The quality of root canal fillings according to group of teeth.**

***Length of the roots canal fillings:*** Adequate length of root fillings were observed in 53.3% of maxillary teeth and 40.4% of mandibular teeth. There was a significant difference between both arches [P= 0.008]. The highest percentage of inadequate root canal fillings (*short and over filling*) were observed in mandibular molars (71%) followed by maxillary premolars (59%) and maxillary molars (45%) [Figure 6].

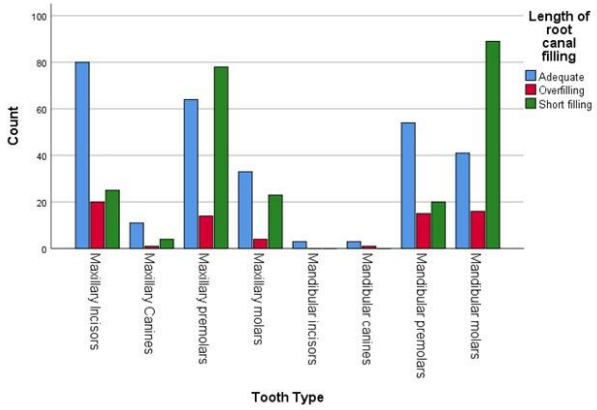



**Figure 6: The relation between tooth type and length of the root fillings**

There was a statistically significant difference between length of root canal fillings and tooth groups [P<0.001] (Table 2) and also length of root canal fillings and number of roots (Table 3) [P<0.001].

**Table 2: The quality of the length of the root canal filling according the group of teeth.**

| Tooth group | Length of root fillings | | |
|---|---|---|---|
| | Adequate | Overfilling | Short filling |
| Anterior | 97 (65.5) | 22 (14.9) | 29 (19.6) |
| premolar | 118 (48.2) | 29 (11.8) | 98 (40) |
| Molar | 74 (35.9) | 20 (9.7) | 112 (54.4) |
| Total | 289 (48.2) | 71(11.9) | 239 (39.9) |
| Values in parentheses are in percentages | | | |

**Table 3: The quality of the length of root canal filling according to the number of roots.**

| Number of roots | Length of root fillings | | |
|---|---|---|---|
| | Adequate | Overfilling | Short filling |
| One root | 163 (61.5) | 40 (15.1) | 62 (23.4) |
| Two roots | 92 (33.7) | 28 (10.3) | 153 (56) |
| Three roots | 34 (55.7) | 3 (4.9) | 24 (39.3) |
| Total | 289 (48.2) | 71(11.9) | 239 (39.9) |
| *Values in parentheses are in percentages | | | |

**Density of root canal fillings:**
The inadequate density of root fillings was observed in 77.7% and 82.6% of maxillary teeth and mandibular teeth respectively. There was no significant difference between both arches [P= 0.154].

***Density and tooth types:*** The inadequate density of root canal fillings was observed more in maxillary molars, mandibular molars and maxillary premolars (88%, 87%, 78% respectively) [Figure 7].

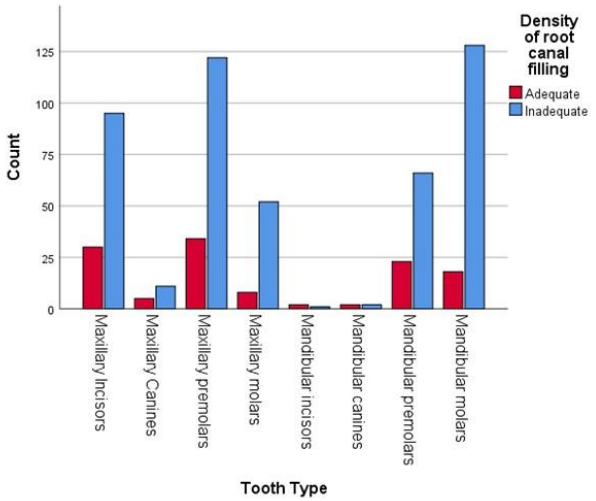



**Figure 7:** The relation between tooth type and density of the root fillings

***Density, tooth groups and the number of the roots:***
Table 4 demonstrate the relation between the density of root canal fillings and teeth groups, and also the density of root canal fillings and the number of roots. There was a statistically significant difference between the teeth groups and density of the root canal fillings [P = 0.002]. There was also a significant difference between the number of the roots and density of the root canal fillings [P=0.02].

**Taper of root canal fillings:**
The inadequate taper of root fillings was observed in 58% and 67% of maxillary and mandibular teeth respectively. There was a significant difference between both arches [P= 0.03].

**Table 4: The relationship between the density of root canal fillings with the groups of teeth and the number of the roots.**

| Density of the root canal filling | Tooth groups | | | | Number of the roots | | | |
|---|---|---|---|---|---|---|---|---|
| | Anteriors | Premolars | Molars | Total | One root | Two roots | Three roots | Total |
| Inadequate | 109 (73.6) | 188(76.7) | 180(87.4) | 477(79.6) | 199(75.1) | 224(82.1) | 54(88.5) | 477(79.6) |
| Adequate | 39 (26.4) | 57(23.3) | 26(12.6) | 122(20.4) | 66(24.9) | 49(17.9) | 7 (11.5) | 122(20.4) |
| Values in parentheses are in percentages | | | | | | | | |

***Taper and tooth type:***
Inadequate taper of root canal fillings was observed more in maxillary (83%) and mandibular molars (75%) [Figure 8].

***Taper, tooth groups and the number of the roots:***
According to tooth groups; Table 5 demonstrates the relation between the taper of root canal fillings with both tooth groups,

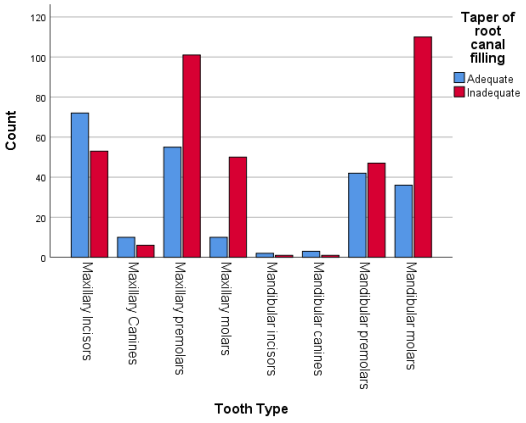


**Figure 8: The relation between the tooth type and the taper of root canal fillings**

and number of roots. There was a statistically significant differences between the tooth groups and the taper of the root canal fillings [P <0.001] and also the number of roots and taper of root canal fillings [P< 0.001].

**Table 5: The relationship between the taper of root canal fillings and tooth groups and number of roots**

| Taper of the root canal filling | Tooth groups | | | | Number of the roots | | | |
|---|---|---|---|---|---|---|---|---|
| | Anterior | Premolar | Molar | Total | One root | Two roots | Three roots | Total |
| Inadequate | 61(41.2) | 148(60.4) | 160(77.7) | 369(61.6) | 127 (47.9) | 191(70) | 51(83.6) | 369(61.6) |
| Adequate | 87(59.8) | 97(39.6) | 46(22.3) | 230(38.4) | 138 (52.1) | 82(30) | 10(16.4) | 230(38.4) |
| Values in parentheses are in percentages | | | | | | | | |

## 4. DISCUSSION

This study was carried out to evaluate the technical quality of root canal treatment performed by GDPs in Libya. In this study, it was decided to include only general dental practitioners graduated from the Faculty of Dentistry, University of Benghazi with clinical experience in endodontics ranged from 5 to 10 years and had not undertaken any postgraduate training in endodontics after graduation. It was believed that would indirectly assess their undergraduate course level in endodontics. The current study utilized data, which comprised of a sample of unenhanced digital radiographs for patients who received root canal treatment by general dental practitioners at the different private clinics in Libya. Patient's panoramic records were excluded from the current study owing to the following: they provide less inter-examiner reliability[45]; difficult to interpret [18] and low Kappa values for intra-observer agreement [46] when compared to periapical radiographs.

The criteria used to assess the quality of root canal fillings were similar to those used in other studies.[4,44,46,48] Literature search showed that most of studies focused on the evaluation of the quality of root canal fillings performed by the undergraduate students which plays an important role in influencing the knowledge and skills of graduates. The quality of endodontic treatment among the GDPs in different countries had been investigated by few researchers; in Poland,[4] Spain[23] and Jordan[26], authors reported the inadequacy of treatment. The latter is in agreement with the current study which reported a disappointing level (12%) of good quality root canal fillings. It could be attributed to the deficiency of undergraduate endodontic training programme,[49] therefore, the quality of endodontic treatment performed by general dental practitioners will be substandard. Qualtrough *et al* [38] believed that more practical experience is needed at the undergraduate level. In the UK, a number of researches [50,51] were interested in the evaluation of the quality of endodontic treatment performed by undergraduate students: authors found that the newly qualified vocational trainees in general practice were not pleased with their undergraduate teaching experience in endodontics. Dummer[52] argued that could be attributed to the limitation of time that has been allocated for endodontic course and also owing to poor staff to student ratio. Furthermore, teaching of endodontics in undergraduate was mostly not given by specialist endodontists.

All the participants in this study graduated from the university of Benghazi and therefore we will focus on the undergraduate programme in the Faculty of Dentistry, University of Benghazi. Previously, the number of teaching hours for theoretical part of endodontic program had been less than allocated for conservative dentistry, and also with fewer laboratory and clinical hours compared to conservative dentistry. Moreover, teaching hours were only allocated to the third and fourth years of a five-year undergraduate program, which is in agreement with other studies carried out in other countries.[4,40,53] The restricted time for endodontic teaching tends to limit student's preclinical training in endodontics with resultant difficulties experienced during clinical practice. Similar teaching problems have been addressed by several investigators who evaluate the undergraduate endodontic teaching programme in the UK. [38,52,54] Interestingly, the time allocated for theoretical program in the Faculty of Dentistry, University of Benghazi is comparable to those programs practiced throughout dental schools in many countries, which also revealed significant shortage in laboratory and clinical sessions.[4,7,40,44]

Recently, in Benghazi Dental School, all efforts have been made to accommodate more clinical and laboratory sessions for the endodontic program to be online with conservative dentistry. In near future program, the students should start training on extracted teeth in the third and fourth year to be illegible for working on patients in intern period. Ideally, the students should work on patients in the final year. However, owing to the large number of students with current facilities and limited number of endodontists in the department may delay this procedure. The undergraduate endodontic program should ideally be delivered to the students by endodontists. The number of endodontic sessions is insufficient to fulfill all the students needs and, consequently, not all students will get the opportunity to perform the endodontic treatment and gain wide experience in endodontics. Other studies have demonstrated similar concerns.[52,40,44] The student: staff ratio is significantly disproportion similar to that reported in other studies. [40,44,55]A recent meta-analysis[36] revealed that the frequency of unacceptable quality of root fillings increased significantly as the tooth position moved further posteriorly. In the current study, molar teeth showed the highest level of inadequate root canal fillings compared with other teeth. The latter was in agreement with other study.[48] This could be attributed to complex anatomy of molar teeth which mainly have narrow and curved canals that considered to be difficult and challenging to treat by GDPs.

Length of the root canal filling is considered as an important factor for the success of endodontic treatment. An improvement of the outcome of RCT were observed when the length of root canal fillings ends 0–2 mm short from radiographic apex. [4,19] In the current study, it was reported that short root fillings were observed in 40% of studied sample compared to only 12% exhibited overfilling. The inadequacy of the length of root canal fillings were observed more in mandibular molars (61%). The latter is in agreement with other studies.[8,44] It could be due to canal curvature and failure to negotiate both mesio-buccal canals. Furthermore, it was also observed that maxillary premolars represent the second most common teeth exhibited short root canal fillings. The latter is in agreement with other

authors.[47,56] Short root canal fillings could be attributed to iatrogenic errors such as short root canal preparation, ledge formation, canal blockage, and root canal transportation that may occur during root canal preparation. Any of these procedural errors may reduce the efficiency of cleaning and shaping, subsequently increase the possibility of underfilling[57] and adversely affects the prognosis of root canal treatment.[58] It is well documented that the sole use of only radiograph in challenging root canal cases might lead to inaccurate working length determination. It is highly recommended to use electronic apex locators as adjunct to radiographs owing to its accurate measurement which reach up to 97%.[31,57]

Other important factor for the long-term success of endodontic treatment is adequate density of root canal fillings.[59,60] It is well documented that one of the causes of the failure of root canal treatment is micro-leakage, which, resulted from inadequate density of root canal fillings.[61] The direct correlation between the incidence of apical periodontitis and inadequate densities were highlighted by Eriksen & Bjertness.[62] The density of the root canal fillings were considered inadequate if there was any voids present between the root canal fillings and root canal walls.[24] In this study, inadequate density of root canal fillings were found to be the most common cause of inadequacy of root canal fillings. This is agreement with a recent meta-analysis carried out by Riberio and colleagues[36] and other authors.[31,63] It was believed that cold lateral condensation technique with gutta percha may produce voids in the root canal which was not well flared.[64] In this study, the overall adequate density of root canal fillings were substandard and inadequate (79%). The latter is alarming as it may jeopardize the treatment outcome. Other studies reported a range of adequate density from 27.6% to 92.6%. [8,28,31,32,44,48,65] There was no significant correlation between maxillary and mandibular teeth with regards to the density of the root canal fillings, which is in agreement with other authors.[44,66]

The third and important factor for the success of endodontic therapy is the taper of root canal fillings. In 2006, the European Society of Endodontology[67] highlights the importance of preparing a taper root canal from the crown to apex and also recommended maintaining the original shape of root canal during and after canal instrumentation. The latter promote healing of periapical area and success of endodontic treatment.[68] Only few studies considered the taper of root canal among the criteria for evaluating the quality of root canal fillings. Although, the assessment of taper of the canal was considered as a subjective criterion,[8] including the taper in this study allowed better following of canal shape and overall evaluation of technical quality of root canal fillings. In the current study, the adequate taper of root canal fillings was observed in only 38% studied sample. This figure is lower than reported in other studies.[8,31,44,69] The latter may be owing to the different instrumentation technique which had been used by GDPs which subsequently affect the outcome of the taper of the canal. The inability of the dental practitioners to keep the original canal shape and proper taper of the root canals may lead to endodontic mishaps such as ledges and perforation. Generally, in order to improve the technical quality of root canal treatment performed by the GDPs, the undergraduate curriculum has to be revised. Improvement in training and focusing on the laboratory and clinic training will definitely improve the standard of endodontic treatment. Moreover, further training courses should be arranged for GDPs who are interested in practicing endodontic therapy. The latter will definitely motivate them and improve their skills which subsequently minimise the procedural errors and increase the success rate.

This study was limited by the fact that the GDPs did not keep complete records of all patient details (e.g. sex, age, etc), and there was no information about the techniques used during canal preparation or obturation. Further research should be conducted such as a prospective study to assess the quality of root canal fillings with standardised instrumentation and obturation techniques.

## 4. CONCLUSION

The results of this study showed a high incidence of unacceptable root canal fillings performed by general dental practitioners in Libya. The low percentage of acceptable root fillings highlight the importance of continuous training course in endodontics. An urgent revision and improvement of undergraduate programme, preclinical and clinical training and also conducting training courses for GDPs under the supervision of specialists or consultants in Endodontics would be beneficial for improving the quality of endodontic treatment.

Acknowledgment: The authors wish to thank all GDPs for their invaluable contribution in this study by providing this research data. Authors have assured that all data will be kept safe and secure in order to protect GDPs confidential information.

## 5. REFERENCES

1. Ng, Y.L., Mann, V., Rahbaran, S., Lewsey, J. and Gulabivala, K., (2008). Outcome of primary root canal treatment: systematic review of the literature–Part 2. Influence of clinical factors. *International endodontic journal*, *41*(1), pp.6-31.

2. Smith, C.S., Setchell, D.J. and Harty, F.J., (1993). Factors influencing the success of conventional root canal therapy—a five-year retrospective study. *International endodontic journal*, *26*(6), pp.321-333.

3. Peak, J.D., Hayes, S.J., Bryant, S.T. and Dummer, P.M.H., (2001). The outcome of root canal treatment. A retrospective study within the armed forces (Royal Air Force). *British dental journal*, *190*(3), pp.140-144.

4. Bołtacz-Rzepkowska, E. and Pawlicka, H., (2003). Radiographic features and outcome of root canal treatment carried out in the Łódź region of Poland. *International endodontic journal*, *36*(1), pp.27-32.

5. Pileggi, R. and Glickman, G.N., (2004). A cost-effective simulation curriculum for preclinical endodontics. *European Journal of Dental Education*, *8*(1), pp.12-17.

6. Kabak, Y. and Abbott, P.V., (2005). Prevalence of apical periodontitis and the quality of endodontic treatment in an adult Belarusian population. *International endodontic journal*, *38*(4), pp.238-245.

7.Lynch, C.D. and Burke, F.M., (2006). Quality of root canal fillings performed by undergraduate dental students on single-rooted teeth. *European Journal of Dental Education*, *10*(2), pp.67-72.

8. Er, O., Sagsen, B., Maden, M., Cinar, S. and Kahraman, Y., (2006). Radiographic technical quality of root fillings performed by dental students in Turkey. *International endodontic journal*, *39*(11), pp.867-872.

9. Kirkevang, L.L., Væth, M., Hörsted-Bindslev, P., Bahrami, G. and Wenzel, A., (2007). Risk factors for developing apical periodontitis in a general population. *International Endodontic Journal*, *40*(4), pp.290-299.

10. Al-Omari, M.A., Hazaa, A. and Haddad, F., (2011). Frequency and distribution of root filled teeth and apical periodontitis in a Jordanian subpopulation. *Oral Surgery, Oral*

*Medicine, Oral Pathology, Oral Radiology, and Endodontology*, *111*(1), pp. e59-e65.
11. Adebayo, E.T., Ahaji, L.E., Nnachetta, R.N., Nwankwo, O., Akabogu-Okpeseyi, N., Yaya, M.O. and Hussain, N.A., (2012). Technical quality of root canal fillings done in a Nigerian general dental clinic. *BMC oral health*, *12*(1), p.42.
12. Thampibul, P., Jantarat, J. and Arayasantiparb, R., (2019). Post-treatment apical periodontitis related to the technical quality of root fillings and restorations in Thai population. *Australian Endodontic Journal*, *45*(2), pp.163-170.
13. Connert, T., Truckenmüller, M., ElAyouti, A., Eggmann, F., Krastl, G., Löst, C. and Weiger, R., (2019). Changes in periapical status, quality of root fillings and estimated endodontic treatment need in a similar urban German population 20 years later. *Clinical oral investigations*, *23*(3), pp.1373-1382.
14. Slaus, G. and Bottenberg, P., (2002). A survey of endodontic practice amongst Flemish dentists. *International endodontic journal*, *35*(9), pp.759-767.
15. Bjørndal, L., Laustsen, M.H. and Reit, C., (2007). Danish practitioners' assessment of factors influencing the outcome of endodontic treatment. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, *103*(4), pp.570-575.
16. Eckerbom, M., Andersson, J.E. and Magnusson, T., (1987). Frequency and technical standard of endodontic treatment in a Swedish population. *Dental Traumatology*, *3*(5), pp.245-248.
17. Imfeld, T.N., (1991). Prevalence and quality of endodontic treatment in an elderly urban population of Switzerland. *Journal of Endodontics*, *17*(12), pp.604-607.
18. Cleen, M.D., Schuurs, A.H.B., Wesselink, P.R. and Wu, M.K., (1993). Periapical status and prevalence of endodontic treatment in an adult Dutch population. *International Endodontic Journal*, *26*(2), pp.112-119.
19. Saunders, W.P., Saunders, E.M., Sadiq, J. and Cruickshank, E., (1997). Technical standard of root canal treatment in an adult Scottish sub-population. *British Dental Journal*, *182*(10), pp.382-386.
20. De Moor, R.J.G., Hommez, G.M.G., De Boever, J.G., Delmé, K.I.M. and Martens, G.E.I., (2000). Periapical health related to the quality of root canal treatment in a Belgian population. *International endodontic journal*, *33*(2), pp.113-120.
21. Boucher, Y., Matossian, L., Rilliard, F. and Machtou, P., (2002). Radiographic evaluation of the prevalence and technical quality of root canal treatment in a French subpopulation. *International endodontic journal*, *35*(3), pp.229-238.
22. Dugas, N., Lawrence, H., Teplitsky, P., Pharoah, M. and Friedman, S., (2003). Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations. *International Endodontic Journal*, *36*(3), pp.181-192.
23. Segura-Egea, J.J., Jiménez-Pinzón, A., Poyato-Ferrera, M., Velasco-Ortega, E. and Ríos-Santos, J.V., (2004). Periapical status and quality of root fillings and coronal restorations in an adult Spanish population. *International Endodontic Journal*, *37*(8), pp.525-530.
24. Eleftheriadis, G.I. and Lambrianidis, T.P., (2005). Technical quality of root canal treatment and detection of iatrogenic errors in an undergraduate dental clinic. *International endodontic journal*, *38*(10), pp.725-734.
25. Loftus, J.J., Keating, A.P. and McCartan, B.E., (2005). Periapical status and quality of endodontic treatment in an adult Irish population. *International endodontic journal*, *38*(2), pp.81-86.
26. Jamani, K.D. and Fayyad, M.A., (2005). A radiographic study of the prevalence of endodontically treated teeth and procedural errors of root canal filling. *Odonto-stomatologietropicale= Tropical dental journal*, *28*(111), pp.29-33.
27. Pettigrew, L.K., Jauhar, S., Lynch, C.D., Savarrio, L., Carrotte, P. and Hannigan, A., (2007). An audit of the quality of root canal treatments performed by undergraduate dental students on single-rooted teeth in Glasgow dental hospital and school. *The European journal of prosthodontics and restorative dentistry*, *15*(2), pp.72-76.
28. Moussa-Badran, S., Roy, B., Bessart du Parc, A.S., Bruyant, M., Lefevre, B. and Maurin, J.C., (2008). Technical quality of root fillings performed by dental students at the dental teaching centre in Reims, France. *International endodontic journal*, *41*(8), pp.679-684.
29.Burke, F.M., Lynch, C.D., NíRíordáin, R. and Hannigan, A., (2009). Technical quality of root canal fillings performed in a dental school and the associated retention of root-filled teeth: a clinical follow-up study over a 5-year period. *Journal of oral rehabilitation*, *36*(7), pp.508-515.
30. Gound, T.G., Sather, J.P., Kong, T.S., Makkawy, H.A. and Marx, D.B., (2009). Graduating dental students' ability to produce quality root canal fillings using single-or multiple-cone obturation techniques. *Journal of dental education*, *73*(6), pp.696-705.
31. Balto, H., Al Khalifah, S.H., Al Mugairin, S., Al Deeb, M. and Al-Madi, E., (2010). Technical quality of root fillings performed by undergraduate students in Saudi Arabia. *International endodontic journal*, *43*(4), pp.292-300
32. Khabbaz, M.G., Protogerou, E. and Douka, E., (2010). Radiographic quality of root fillings performed by undergraduate students. *International Endodontic Journal*, *43*(6), pp.499-508.
33. Unal, G.C., Kececi, A.D., Kaya, B.U. and Tac, A.G., (2011). Quality of root canal fillings performed by undergraduate dental students. *European Journal of Dentistry*, *5*(03), pp.324-330.
34. Moradi, S. and Gharechahi, M., (2014). Quality of root canal obturation performed by senior undergraduate dental students. *Iranian endodontic journal*, *9*(1), p.66.
35. Donnelly, A., Coffey, D. and Duncan, H.F., (2017). A re-audit of the technical quality of undergraduate root canal treatment after the introduction of new technology and teaching practices. *International endodontic journal*, *50*(10), pp.941-950.
36. Ribeiro, D.M., Reus, J.C., Felippe, W.T., Pachêco-Pereira, C., Dutra, K.L., Santos, J.N., Porporatti, A.L. and De Luca Canto, G., (2018). Technical quality of root canal treatment performed by undergraduate students using hand instrumentation: a meta-analysis. *International endodontic journal*, *51*(3), pp.269-283.
37. Buckley, M. and Spangberg, L.S., (1995). The prevalence and technical quality of endodontic treatment in an American subpopulation. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, *79*(1), pp.92-100.
38. Qualtrough, A.J.E., Whitworth, J.M. and Dummer, P.M.H., (1999). Preclinical endodontology: an international comparison. *International endodontic journal*, *32*(5), pp.406-414.

39. Al-Fouzan, K.S., (2010). A survey of root canal treatment of molar teeth by general dental practitioners in private practice in Saudi Arabia. *The Saudi dental journal*, *22*(3), pp.113-117.
40. Elsayed, R.O., Abu-bakr, N.H. and Ibrahim, Y.E., (2011). Quality of root canal treatment performed by undergraduate dental students at the University of Khartoum, Sudan. *Australian Endodontic Journal*, *37*(2), pp.56-60.
41. Friedman, S., (2008). Expected outcomes in the prevention and treatment of apical periodontitis. *Essential endodontology: prevention and treatment of apical periodontitis*, pp.408-469.
42. European Society of Endodontology, (1994). Consensus report of the European Society of Endodontology on quality guidelines for endodontic treatment. *International Endodontic Journal*, *27*(3), pp.115-124.
43. Kapalas, A. and Lambrianidis, T., (2000). Factors associated with root canal ledging during instrumentation. *Dental Traumatology*, *16*(5), pp.229-231.
44. Barrieshi-Nusair, K.M., Al-Omari, M.A. and Al-Hiyasat, A.S., (2004). Radiographic technical quality of root canal treatment performed by dental students at the Dental Teaching Center in Jordan. *Journal of dentistry*, *32*(4), pp.301-307.
45. Gröndahl, H.G., Jönsson, E. and Lindahl, B., (1970). Diagnosis of periapical osteolytic processes with orthopantomography and intraoral full mouth radiography--a comparison. *Svensktandlakaretidskrift. Swedish dental journal*, *63*(10), pp.679-686.
46. Rohlin, M., Kullendorff, B., Ahlqwist, M. and Stenström, B., (1991). Observer performance in the assessment of periapical pathology: a comparison of panoramic with periapical radiography. *Dentomaxillofacial Radiology*, *20*(3), pp.127-131.
47. Lupi-Pegurier, L., Bertrand, M.F., Muller-Bolla, M., Rocca, J.P. and Bolla, M., (2002). Periapical status, prevalence and quality of endodontic treatment in an adult French population. *International endodontic journal*, *35*(8), pp.690-697.
48. Elemam RF, Abdul Majid ZS, Groesbeck M, Azevedo ÁF. Quality of Root Canals Performed by the Inaugural Class of Dental Students at Libyan International Medical University. . 2015, International Journal of Dentistry
49. Jenkins, S.M., Hayes, S.J. and Dummer, P.M.H., (2001). A study of endodontic treatment carried out in dental practice within the UK. *International endodontic journal*, *34*(1), pp.16-22.
50. Brookman, D.J., (1991). Vocational trainees' views of their undergraduate endodontic training and their vocational training experience. *International endodontic journal*, *24*(4), pp.178-186.
51. Benenati, F.W. and Khajotia, S.S., (2002). A radiographic recall evaluation of 894 endodontic cases treated in a dental school setting. *Journal of endodontics*, *28*(5), pp.391-395.
52. Dummer, P.M.H., (1991). Comparison of undergraduate endodontic teaching programme in the United Kingdom and in some dental schools in Europe and the United States. *International endodontic journal*, *24*(4), pp.169-177.
53. Hayes, S.J., Gibson, M., Hammond, M., Bryant, S.T. and Dummer, P.M.H., (2001). An audit of root canal treatment performed by undergraduate students. *International endodontic journal*, *34*(7), pp.501-505.
54. Qualtrough, A.J.E. and Dummer, P.M.H., (1997). Undergraduate endodontic teaching in the United Kingdom: an update. *International endodontic journal*, *30*(4), pp.234-239.
55. Bołtacz-Rzepkowska, E. and Laszkiewicz, J., (2005). Endodontic treatment and periapical health in patients of the Institute of Dentistry in Lódź. *Przegladepidemiologiczny*, *59*(1), pp.107-115.
56. Weiger, R., Hitzler, S., Hermle, G. and Löst, C., (1997). Periapical status, quality of root canal fillings and estimated endodontic treatment needs in an urban German population. *Dental Traumatology*, *13*(2), pp.69-74.
57. Kfir, A., Rosenberg, E., Zuckerman, O., Tamse, A. and Fuss, Z., (2004). Comparison of procedural errors resulting during root canal preparations completed by senior dental students in patients using an '8-step method'versus 'serial step-back technique'. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology*, *97*(6), pp.745-748.
58. Cheung, G.S. and Liu, C.S., (2009). A retrospective study of endodontic treatment outcome between nickel-titanium rotary and stainless-steel hand filing techniques. *Journal of endodontics*, *35*(7), pp.938-943.
59. Cheung, G.S., (2002). Survival of first-time nonsurgical root canal treatment performed in a dental teaching hospital. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology*, *93*(5), pp.596-604.
60. İlgüy, D., İlgüy, M., Fişekçioğlu, E., Ersan, N., Tanalp, J. and Dölekoğlu, S., (2013). Assessment of root canal treatment outcomes performed by Turkish dental students: results after two years. *Journal of dental education*, *77*(4), pp.502-509
61. Kirkevang, L.L., Hörsted-Bindslev, P., Ørstavik, D. and Wenzel, A., (2001). A comparison of the quality of root canal treatment in two Danish subpopulations examined 1974–75 and 1997–98. *International Endodontic Journal*, *34*(8), pp.607-612.
62. Eriksen, H.M. and Bjertness, E., (1991). Prevalence of apical periodontitis and results of endodontic treatment in middle-aged adults in Norway. *Dental Traumatology*, *7*(1), pp.14.
63. Saatchi, M., Mohammadi, G., Sichani, A.V. and Moshkforoush, S., (2018). Technical quality of root canal treatment performed by undergraduate clinical students of Isfahan dental school. *Iranian endodontic journal*, *13*(1), pp.88.
64. Ho, E.S.S., Chang, J.W.W. and Cheung, G.S.P., (2016). Quality of root canal fillings using three gutta-percha obturation techniques. *Restorative dentistry & endodontics*, *41*(1), pp.22-28.
65. Rafeek, R.N., Smith, W.A., Mankee, M.S. and Coldero, L.G., (2012). Radiographic evaluation of the technical quality of root canal fillings performed by dental students. *Australian Endodontic Journal*, *38*(2), pp.64-69.
66. Awooda, E.M., Siddig, R.I., Alturki, R.S. and Sanhouri, N.M., (2016). Radiographic technical quality of root canal treatment performed by undergraduate dental students at the Academy Dental Teaching Hospital, UMST, Sudan. *Journal of International Society of Preventive & Community Dentistry*, *6*(6), pp.554.
67. European Society of Endodontology, (2006). Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. *International Endodontic Journal*, *39*(12), pp.921-930.
68. Gorni, F.G. and Gagliani, M.M., (2004). The outcome of endodontic retreatment: a 2-yr follow-up. *Journal of Endodontics*, *30*(1), pp.1-4.
69.Al Hablain EA, Sadaf D, Ahmad M, Al Qanass BS., (2018). Quality of Root Canal Therapy (RCT) Performed by the Undergraduate Students at the Qassim University, Kingdom of Saudi Arabia (KSA). *Med Forum*;29(6), pp. 80-88.