Surgical endodontics: are the guidelines being followed? A pilot survey

C. Causey,*[1] J Ban,[2] D. Ramkumar[1] and M. Kaow-Ling Foo[1]

In brief

Raises awareness of the Royal College of Surgeons' guidelines on surgical endodontics.

Highlights that all clinicians are not compliant with the Royal College of Surgeons' guidelines and that there are areas where improvements can be made.

By determining areas of non-compliance with the guidelines it allows for further investigation into the reasons for non-compliance allowing any issues to be addressed.

Introduction Techniques in surgical endodontic treatment are continually evolving and the routine use of magnification and instruments supporting a microsurgical approach have become accepted as the gold standard following the publication of the Royal College of Surgeons' Guidelines for surgical endodontics, 2012. **Method** An electronic survey was emailed to 95 current oral surgery and restorative speciality trainees. The survey audited the techniques and equipment used by the trainees for surgical endodontic procedures. Results were compared with the Royal College of Surgeons' guidelines. **Results** Overall response rate was 54% (61% of oral surgery and 49% of restorative trainees contacted). Compliance with the guidelines was found to vary between both groups of trainees and different aspects of treatment. There were deviations from many aspects of the guidelines including type of equipment and material used, as well as the use of magnification. The use of magnification was most variable with an uptake of 17.4% by oral surgery trainees and 92.9% of restorative trainees. **Conclusion** While a microsurgical technique for surgical endodontics has now been adopted by a substantial number of trainees, uptake of current guidelines is still not complete. An expansive follow-up study may help to further understand compliance with guidelines among a wider range of practitioners who carry out the procedure in both a hospital and practice setting.

Introduction

In recent years surgical endodontic treatment has continued to evolve from traditional gross surgical techniques into the contemporary microsurgical technique[1] which is now considered to be gold standard. The techniques and materials used have continued to be updated and refined in line with current evidence, resulting in improvements to reported success rates.[2]

In particular, advancements in dental loupes and surgical microscope technology, along with a reduction in cost, has led to them being widely adopted for use by the dental profession including for the provision of surgical endodontic treatment.[3] In recent years both the Royal College of Surgeons (RCS)[1] and the American Association of Endodontists[4] have published guidance advocating a microsurgical approach for endodontic procedures and it is current compliance with this guidance that we aim to determine in this study.

Although success rates of 44–95% have been reported[5] for surgical endodontic (SE) procedures, non-surgical retreatment remains, in most cases, the first choice treatment modality in cases where chronic apical periodontitis persists following orthograde root treatment.[6,7] Systematic reviews by Del Fabbro[6] and Torbinejad[7] have shown that while initial success rates for a surgical approach may be more favourable than non-surgical, at four years following treatment there appears to be no significant difference in success. However, surgical endodontic treatment is more likely to be associated with postoperative surgical morbidity[8] and therefore should not usually be considered a first-line approach.

Nevertheless, non-surgical retreatment may not always be possible or indicated. These cases may include teeth with anatomical abnormalities, iatrogenic complications such as a perforation, or instances where non-surgical retreatment has already failed. In these circumstances root-end surgery may need to be undertaken.[1]

The Royal College of Surgeons' guidelines[1] provide guidance on equipment, materials, and techniques that should be used to optimise clinical success. It would be expected that as training units, those institutions providing oral surgery and restorative speciality training would be at the forefront of implementing these best practice guidelines. For this reason our aim was to determine compliance with these guidelines by current oral surgery and restorative trainees. A standard of 100% compliance with guidelines would be expected.

[1]Royal Gwent Hospital, Oral and Maxillofacial Surgery, Cardiff Road, Newport, NP20 2UB; [2]University of Bristol Dental Hospital, Restorative Dentistry Department, Lower Maudlin Street, Bristol, BS1 2LY
*Correspondence to: Christine Causey
Email: mabel87@hotmail.co.uk

Refereed Paper. Accepted 17 October 2017
DOI: 10.1038/sj.bdj.2018.75

Official journal of the British Dental Association.

Table 1 Trainee responses regarding techniques, equipment and materials used by them for surgical endodontic treatment

		Oral surgery trainees	Restorative trainees	Overall trainees (%)
Magnification	None	19	2	39.2
	Loupes	3	7	19.6
	Microscope/endoscope	1	19	41.2
Microsurgical Kit	Yes	6	24	58.8
	No	16	3	37.3
	Other	1	1	3.9
Osteotomy	Fast handpiece	1	3	7.8
	Piezosurgical handpiece	2	4	11.8
	Reverse-air handpiece	0	9	17.6
	Straight surgical handpiece	20	11	60.8
	Other	0	1	2
Root-end preparation	Microsurgical bur	10	6	31.3
	Ultrasonic	13	21	66.7
	Combination	0	1	2
Root-end filling	Amalgam	0	1	2
	Biodentine	1	0	2
	Composite	0	0	0
	Glass ionomer	0	0	0
	MTA	12	21	64.7
	Super EBA	0	0	0
	Reinforced ZnOE	8	0	15.6
	Other	2	0	3.9
	Combination	0	6	11.8
Smear layer removal	Citric acid	0	0	0
	EDTA	2	0	3.9
	None	22	25	92.2
	Other	1	1	3.9
Sutures	Resorbable	19	11	58.8
	Non-resorbable	4	15	37.3
	Combination	0	2	3.9
Post-operative radiograph	Before wound closure	0	10	19.6
	After wound closure	13	14	52.9
	None	8	3	21.6
	Other	2	1	5.9
Antibiotics prescribed	Pre-operatively	1	1	3.9
	Post-operatively	2	3	9.8
	None	19	23	82.4
	Other	1	1	3.9

Method

An online survey, hosted by SurveyMonkey, was emailed to 95 current oral surgery and restorative speciality trainees in January 2016. This included 38 oral surgery and 57 restorative trainees who were contacted through their respective speciality trainee educational groups. The participants were sent a follow-up email two weeks after the initial invitation to complete the questionnaire. Appendix 1 shows the questions the participants were invited to answer relating to the equipment, materials and techniques utilised when carrying out root-end surgery. This aimed to audit the compliance of their current practice with the Royal College of Surgeons' guidelines on surgical endodontics.[1]

Results

A total of 51 trainees completed the questionnaire, consisting of 23 oral surgery and 28 restorative trainees (Table 1). The overall response rate was 54% (61% of oral surgery and 49% of restorative trainees contacted).

Magnification

Overall, 39.2% (20/51) of trainees used no magnification for root-end surgery, 41.2% (21/51) used a microscope and 19.6% (10/51) used loupes.

Osteotomy

For the osteotomy 60.8% (31/51) of the respondents reported they use a straight surgical handpiece for root-end surgery procedures (Fig. 1). A further 17.6% (9/51) use a reverse air handpiece, 11.8% (6/51) a piezosurgical handpiece and 7.8% (4/51) a fast handpiece. One trainee used an alternative unspecified handpiece for their osteotomy.

Root-end preparation

The majority of trainees used an ultrasonic handpiece, 66.7% (34/51), or a microsurgical bur, 29% (16/51), for their root end preparation. One respondent reported using a combination of both handpieces.

Smear layer removal

Smear layer removal was performed routinely by only 7.8% (4/51) of trainees. Two trainees reported using EDTA and the other two respondents using unspecified alternative materials.

Root-end filling material

For the root-end filling material mineral trioxide aggregate (MTA) was used by 64.7%

Official journal of the British Dental Association.

(33/51). A further 15.6% (8/51) reported using reinforced zinc oxide eugenol (ZnOE) and 2% (1/52) amalgam. The remaining 11.8% of respondents used a variety of these materials (MTA, ZnOE or biodentine) depending on the clinical scenario.

Suture material

Wound closure was carried out using non-resorbable sutures by 37.3% (19/51) of respondents in comparison to 58.8% (30/51) who preferred resorbable sutures. The remaining 3.9% (2/51) reported using a combination of both suture types.

Post-operative radiographs

Of the trainees who responded, 19.6% took a radiograph before wound closure, with 52.5% doing so following wound closure. Results showed that 21.6% of trainees took no post-operative radiographic imaging.

Discussion

In recent years surgical endodontics has been greatly influenced by the improved quality and availability of equipment such as surgical microscopes and dental loupes. This has resulted in microsurgical techniques becoming increasingly popular for endodontic procedures. Many studies have therefore focused on the impact of these modern techniques on the outcome of surgical endodontics including two recent meta-analyses studies carried out by Setzer *et al.*[2,9]

The first meta-analysis (2010)[2] compared traditional root-end surgery (TRS) to endodontic microsurgery (EMS) outcomes. With an overall success rate of 59% for TRS (standard surgical bur and instruments, bevelled root-end resection with bur, up to ×4 magnification and an amalgam filling) compared to 94% for EMS (bone cutting bur or piezo, microsurgical instruments, ultrasonic root-end preparation, non-bevelled root resection, high power magnification and a biocompatible filling material), demonstrating a significant improvement in outcome when the EMS technique was used.[2]

The second meta-analysis compared the outcome of EMS when differing degrees of magnification were used. When microsurgical instruments were used with no magnification or magnification of ten times or less, a success rate of 88% was found compared to 94% success rate when microsurgical instruments were used with greater than times ten magnification.[9] These studies have demonstrated that the use of microsurgical techniques and, in particular, magnification can positively influence treatment success. Although the reasons for this were not investigated by the study it may well be due to the enhanced visualisation of anatomical abnormalities or pre-existing root fractures under magnification which would contra-indicate surgical root-end surgical treatment being performed.

Magnification

Our audit found that although magnification is strongly recommended by RCS guidelines the reported use of any form of magnification was just 60.8% (31/51) among all respondents, resulting in the success rates of root-end surgical procedures carried out by the group audited potentially being lower than those that the evidence suggests could be achieved.[9] Interestingly, there was a significant difference in its use between trainee groups with 17.4% (4/23) of oral surgery trainees using magnification compared to 92.9% (26/28) of restorative trainees. There may be several reasons for this difference such as variable availability of equipment or differences in the teaching, however, these were not investigated in our study.

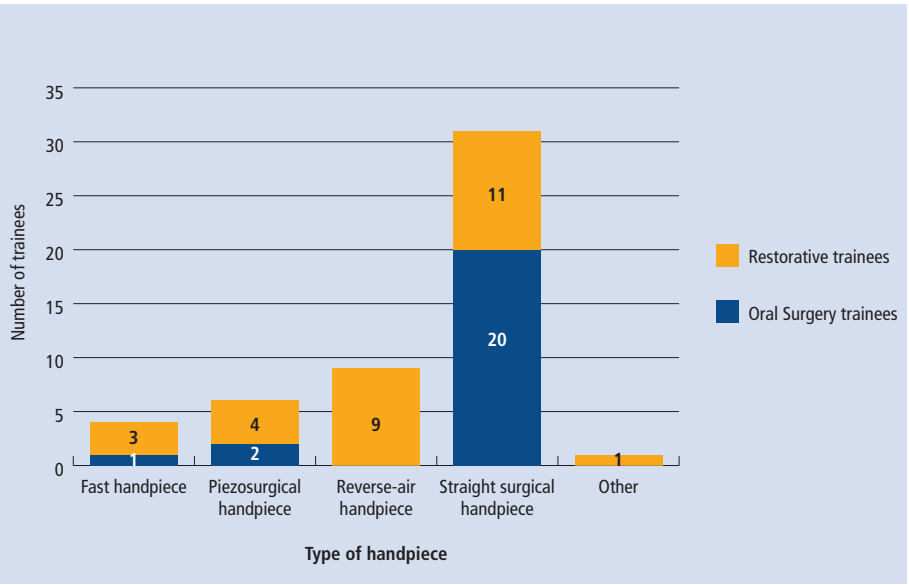
Surgical handpiece

As with any surgical technique there is often variation in the equipment and materials used between operators. This was certainly the case in our study with a variety of methods used for the osteotomy. The RCS guidelines[1] recommend the use of a reverse air handpiece with saline irrigation for osteotomy preparation in root-end surgery, in order to reduce heat production and minimise the size of bony preparation required. Our results show 17.6% (9/51) of the trainees who responded used a reverse air handpiece, of which all were restorative trainees. A straight surgical handpiece was also used by a substantial number of both trainee groups including 87.0% (20/23) of oral surgery and 39.3% (11/28) of restorative trainees.

Air-driven handpieces offer a number of advantages over straight surgical handpieces. They generally tend to have smaller angled heads which allows for better access with the bur to facilitate root-end resection, even with a minimal osteotomy preparation. Although air driven, due to their reverse exhaust design the risk of surgical emphysema is reduced in comparison to a high speed (fast) handpiece.[11] Despite the risk of surgical emphysema being well documented, our study found that four trainees routinely continue to use a high speed handpiece for their osteotomy.[12] Both the guidelines and literature would suggest avoidance of this to prevent potentially serious and unnecessary complications.

The use of piezoelectric handpieces has become increasingly popular in recent times for procedures involving the teeth and jaws including wisdom tooth removal and orthognathic surgery.[10] These handpieces have many benefits over using a traditional bur including increased precision due to well controlled micro-vibrations. This allows for improved tactile sensation as opposed to the less discriminate movement of a bur as well as

Fig. 1 A graph to show types of handpieces used by the trainees for the root-end surgery osteotomy



Official journal of the British Dental Association.

offering relative protection of the surrounding soft tissues.[10] As yet, however, there is limited evidence for its use specifically in endodontic procedures and a recent literature review by Abella concluded further research into its use is required.[10] Our survey found that 11.8% (6/51) of the trainees utilised piezoelectric handpieces routinely for their osteotomy and this number may continue to grow as research and evidence improves.

Root-end resection/preparation

Historically, root-end resection was carried out with a bevel angle in order to improve access to the root tip.[13] With advancements in technology and equipment this is no longer necessary. The RCS guidelines[1] suggest that root-end resection should be as close to 90^{0} to the long axis of the tooth as possible and the root end preparation at least 3 mm deep and along the canal axis. By keeping the root resection perpendicular to the canal axis the number of exposed dentinal tubules is reduced and tooth tissue preserved, therefore helping to reduce leakage of any residual microbial by-products from the tooth into surrounding tissues.

A number of studies including that by Melhaff [14] have investigated the effect of different instruments for root-end preparation. Mehlhaff[14] compared a high-speed bur and ultrasonic tip for root-end preparation and found that when a high speed bur was used for canal preparation, 100% of these preparations deviated from the canal in comparison to deviation in 2.6% of cases where an ultrasonic tip was used.

A further study by Lin *et al.* found that on average there was a 30% reduction in wall thickness when a bur was used in comparison with just 17% with an ultrasonic tip.[15] Over preparation at the apex of teeth should ideally be minimised where possible to prevent unnecessary exposure of dentinal tubules and to reduce the surface area where potential microleakage could occur. These studies suggest the use of an ultrasonic tip offers the advantage of better access and a more accurate preparation.

Although the use of an ultrasonic handpiece has been shown to have some benefits over a bur it has also been reported to have some adverse effects. Studies have shown ultrasonic root-end preparation to be associated with increased cracking at the root end.[16,17,18,19] That said, many of the studies supporting this have been carried out on extracted teeth[17,20] and similar studies carried out on cadavers show no significant increase in root-end cracking. It has been hypothesised that an intact periodontal ligament may act as a shock absorber to dampen vibrations and therefore reduce the impact on the root end.[21]

Our study found that the majority (66.7%) of trainees used an ultrasonic handpiece preferentially for root-end preparation. A large number did, however, continue to routinely use a bur. Both the evidence and guidelines would seem to support that where possible an ultrasonic handpiece should be preferentially used.

Smear layer removal

The need for smear layer removal following root-end preparation remains a debated topic. The RCS guidelines suggest consideration should be given to removal of the smear layer, although the evidence is conflicting. A study by Yildirim[22] found that when the smear layer was removed with ethylenediaminetetraacetic acid (EDTA) and a mineral trioxide aggregate (MTA) root-end filling placed, there was significantly more microleakage than when the smear layer was left intact. Although the majority of trainees surveyed choose not to carry out removal of the smear layer, until further research is carried out to ascertain the effects of its removal on success rates, this remains the clinican's choice.

Obturation material

There are multiple root-end filling materials and the RCS guidelines advocate a number of them, including super ethoxy benzoic acid (EBA), glass ionomer cement, composite resin and reinforced zinc oxide eugenol. MTA is noted specifically as an osteo-and cemento-inductive material associated with a high clinical success rate.[1] Our audit found that 64.7% (33/51) of trainees routinely used MTA for root-end surgery. The remainder used either biodentine, reinforced zinc oxide eugenol or a combination of these materials. One respondent reported routinely using amalgam which is considered unsuitable in the RCS guidelines. The type of material used may well reflect the materials available to the trainees rather than trainee preference.

Bates *et al.* carried out a study on extracted teeth randomly allocated with EBA, MTA or amalgam root end fillings.[23] Results indicated that MTA and EBA had similar levels of microleakage. However, both had significantly less microleakage when compared to amalgam. Amalgam has also been shown to elicit an increased inflammatory response in apical tissues in comparison to MTA.[24, 25] Although this study shows EBA has a similar level of microleakage to MTA, the osteo- and cemento-inductive properties of MTA may be advantageous in terms of healing, however, the clinical situation will dictate final decision on the choice of an appropriate material.

Radiographs

Overall, 27.5% of trainees reported they did not routinely carry out radiographs at the time of surgery. Of the remaining trainees 19.6% of respondents took a radiograph before wound closure and 52.9% following wound closure. This study has shown that although the majority of trainees do carry out a radiograph post-operatively, only a small proportion do so before wound closure and therefore compliance with guidelines remains low, as the RCS guidelines advocate taking a post-operative radiograph before wound closure where possible. Any radiograph taken at this stage will allow for verification of the quality of the root-end filling and any appropriate steps to rectify any deficiencies can be taken, in addition to acting as a baseline radiograph for any future comparisons. It is generally accepted that treatment success is measured using a combination of clinical and radiographic findings such as those suggested by Rud *et al.* and Molven *et al.*[26–28]

Wound closure

For closure of the wound RCS' guidelines[1] recommend the use of synthetic monofilament sutures in order to minimise microbial colonisation and reduce the inflammatory response associated with the sutures.[32] Much of the evidence suggests that sutures should be removed as soon as healing has taken place in order to limit bacterial ingress into the wound.[33] The guidelines recommend removal between 48 and 96 hours post-surgery.[1] Our survey found that, 58.8% of trainees used resorbable sutures which are not recommended by the guidelines. When analysed further, 83% (19/23) of oral surgery trainees routinely use resorbable sutures in comparison to 39.2% (11/28) of restorative trainees.

This study provides an overview of compliance by oral surgery and restorative trainees with the RCS' guidelines on surgical endodontics. It is, however, important to note that as with any audit there are limitations and these must be taken into account when interpreting the results. Although our sample size was relatively small it has highlighted the different

Official journal of the British Dental Association.

clinical practices adopted by clinicians of diverse speciality backgrounds. While a more detailed method to ascertain the various techniques utilised in surgical endodontics may involve auditing individual patient records, this approach would present a logistical challenge. Should future more expansive audits be carried out, the current audit may act as a pilot, upon which these larger scale audits could be based.

The seniority of the trainees and availability of equipment were not investigated as part of this audit. Although this was not the primary aim of the study these factors could impact on compliance with the guidelines and therefore may be relevant to the outcome. In addition to this endodontic speciality, trainees and qualified specialists were not audited due to issues with identifying the contact details of these groups, however, we would recommend any future work that is based on this pilot study should be expanded to include these groups to ascertain the clinic practice of a broader spectrum of practising dentists.

Conclusion

While our study has shown that a microsurgical approach has now been adopted by a substantial number of trainees for surgical endodontics, this is being carried out without the use of magnification in a number of cases and there has not been complete uptake by all clinicians. The reasons for this are outside the scope of this audit, although the process of highlighting the results of this audit may result in improvements to the adoption of the surgical endodontic guidelines. Further work is, however, needed to ascertain the reasons for use of equipment and techniques that are outside the best practice guidelines, in order to address this on a local and national level, as well as an assessment of whether patient outcomes are being adversely affected by this overall lack of compliance.

1. Evans G, Bishop K, Renton T. Royal College of Surgeons: Guidelines for Surgical Endodontics. 2012. Available at https://www.rcseng.ac.uk/dental-faculties/fds/publications-guidelines/clinical-guidelines/ (accessed November 2015).
2. Setzer F C, Shah S B, Kohli M R, Karabucak B, Kim S. Outcome of Endodontic Surgery: A Meta-analysis of the Literature – Part 1: Comparison of Traditional Root-end Surgery and Endodontic Microsurgery. *J Endod* 2010; **36:** 1757–1765.
3. Alzebiani N, Alotaibi S, Bogari D *et al.* Awareness and attitude toward using dental magnification among dental students and residents at King Abdulaziz University, Faculty of Dentistry. *BMC Oral Health* 2017; **17**: 21. Available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4950692/ (accessed February 2017).
4. American Association of Endodontists. Endodontics colleagues for excellence: contemporary endodontic microsurgery: procedural advancement treatment planning considerations. 2010. Available at: https://www.

Appendix 1 Apicectomy techniques questionnaire

1. What is your current role?
- Oral surgery registrar
- Restorative/endodontic registrar
- Other

2. Do you routinely use any form of magnification when you carry out an apicectomy?
- Microscope
- Loupes
- None
- Other

3. Do you routinely use a microsurgical kit to carry out apicectomies?
- Yes
- No

4. What method are you currently using for the osteotomy?
- Fast handpiece
- Piezosurgical handpiece
- Reverse-air handpiece
- Straight surgical handpiece
- Other

5. What method do you currently use for the root end preparation?
- Microsurgical bur
- Ultrasonic handpiece
- Other

6. What material do you currently use for root-end obturation?
- Amalgam
- Biodentine
- Composite
- Glass ionomer
- Mineral trioxide aggregate (MTA)
- Reinforced zinc oxide eugenol
- Super ethoxy benzoic acid (Super EBA)
- Other

7. Do you remove the smear layer following root-end resection? If yes, what material do you use?
- Citric acid
- Ethylenediaminetetraacetic acid (EDTA)
- No smear layer removal
- Other

8. What type of suture material are you currently using to close the wound? Please comment on whether or not you routinely remove the sutures at follow-up appointment.
- Resorbable
- Non-resorbable

9. Do you take a post-operative radiograph? If yes, when?
- Before wound closure
- After wound closure
- No post-operative radiograph taken

10. Do you prescribe antibiotics? If yes, when?
- No antibiotics
- Pre-operatively
- Post-operatively

Official journal of the British Dental Association.

aae.org/specialty/wp-content/uploads/sites/2/2017/07/ecfefall2010final.pdf (accessed November 2016).
5. Rahbaran S, Gilthorpe M S, Harrison S D, Gulabivala K. Comparison of clinical outcome of periapical surgery in endodontic and oral surgery units of a teaching hospital: A retrospective study. *Oral Surg Oral Med Oral Path* 2001; **91:** 700–709.
6. Del Fabbro, M Taschieri, Testori T. Surgical vs non-surgical endodontic re-treatment for peri radicular lesions. *Cochrane database Sys Rev* 2007; **18:** CD005511.
7. Torabinejad M, Corr R, Handysides R, Shabahang S. Outcomes of non-surgical retreatment and endodontic surgery: a systematic review. *J Endod* 2009; **35:** 930-937.
8. Del Fabbro M, Corbella S, Sequeira-Byron P *et al.* Endodontic procedures for retreatment of periapical lesions. *Cochrane Database Syst Rev* 2016; **19:** CD005511.
9. Setzer F C, Kohli M R, Shah S B, Karabucak B, Kim S. Outcome of Endodontic Surgery: A Meta-analysis of the Literature – Part 2: Comparison of Endodontic Microsurgical Techniques with and without the Use of Higher Magnification. *J Endod* 2012; **38:** 1–10.
10. Abella F, de Ribot J, Doria G, Duran-Sindreu F, Roig M. Applications of piezoelectric surgery in endodontic surgery: a literature review. *J Endod* 2014; **40:** 325–332.
11. McKenzie W S, Rosenberg M. Iatrogenic subcutaneous emphysema of dental and surgical origin: a literature review. *J Oral Maxillofac Surg* 2009; **67:** 1265–1268.
12. Smatt Y, Browaeys H, Genay A, Raoul G, Ferri J. Iatrogenic pneumomediastinum and facial emphysema after endodontic treatment. *Br J Oral Maxillofac Surg* 2004; **42:** 160-162.
13. Kim S. Endodontic microsurgery. *In* Cohen S, Burns R E, (editors) *Pathways of the Pulp*. 8th Edition. p. 705. St Louis, MO: Mosby; 2002.
14. Mehlhaff D S, Marshall G, Craig J, Baumgartner C. Comparison of ultrasonic and high-speed-bur root-end preparations using bilaterally matched teeth. *J Endod* 1997; **23:** 448–452.
15. Lin C P, Chou H G, Kuo J C, Lan W H. The quality to ultrasonic root end preparation: a quantitative study. *J Endod* 1998; **24:** 666–670.
16. Tawil PZ. Periapical microsurgery: can ultrasonic root end preparation clinically create or propagate dentinal defects. *J Endod* 2016; **42:** 1–4.
17. Saunders W P, Saunders E M, Gutmann J L. Ultrasonic root end preparation. Part 2. Microleakage of root end fillings. *Int Endod J* 1994; **27:** 325–329.
18. Abedi H R, Van Mierlo B L, Wilder-Smith P, Torabinejad M. Effects of ultra-sonic root end cavity preparation on the root apex. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1995; **80:** 207–213.
19. Kim S, Kratchman S. Modern endodontic surgery concepts and practice: a review. *J Endod* 2006; **32:** 601–623.
20. Gondim E Jr, Figuereido Almeida de Gomes B P, Ferraz C C, Texeira FB, de Souza-Filho FJ. Effect of sonic and ultrasonic retrograde cavity preparation on the integrity of root apices of freshly extracted human teeth: scanning electron microscopyanalysis. *J Endod* 2016; **28:** 646–650.
21. Eliyas S, Vere J, Ali Z, Harris I. Micro-surgical endodontics. *Br Dent J* 2014; **216:** 169–177.
22. Yildirim T, Oruçoğlu H, Cobankara F K. Long term evaluation of the influence of smear layer on the apical sealing ability of MTA. *J Endod* 2008; **34:** 1534–1540.
23. Bates C F, Carnes D L, del Rio C E. Longitudinal sealing ability of mineral trioxide aggregate as a root-end filling material. *J Endod* 1996; **22:** 575–578.
24. Baek S, Hanns Plenk H, Kim S. Periapical Tissue Responses and Cementum Regeneration with Amalgam, SuperEBA, and MTA as Root-End Filling Materials. *J Endod* 2005; **31:** 444–449.
25. Fogel H M, Peikoff M D. Microleakage of root-end filling materials. *J Endod* 2007; **27:** 456–458.
26. Zuolo M L, Ferreira M O, Gutmann J L. Prognosis in periradicular surgery: a clinical prospective study. *Int Endod J* 2000; **33:** 91–98.
27. Rud J, Andreasen J O, Möller Jensen J E. Radiographic criteria for the assessment of healing after endodontic surgery. *Int J Oral Surg* 1972; **1:** 195–214.
28. Molven O, Halse A, Grung B. Observer strategy and the radiographic classification of healing after endodontic surgery. *Int J Oral Maxillofac Surg* 1987; **16:** 432–439.
29. Jesslen P, Zetterqvist L, Heimdahl A. Long-term results of amalgam versus glass ionomer cement as apical sealant after apicoectomy. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*1995; **79:** 101–103.
30. Yazdi P M, Schou S, Jensen S S, Stoltze K, Kenrad B, Sewerin I. Dentine-bonded resin composite (Retroplast) for root-end filling: a prospective clinical and radiographic study with a mean follow-up period of 8 years. *Int Endod J* 2007; **40:** 493–503.
31. Von Arx T. Apical surgery: A review of current techniques and outcome. *Saudi Dent J* 2011; **23:** 9–15.
32. Selvig K A, Biagiotti G R, Leknes K N, Wikesjö U M. Oral tissue reactions to suture material. *Int J Periodontics Restorative Dent* 1998; **18:** 474–487.
33. Gutmann J L, Harrison J W. Closure of the surgical site and postsur-gical management. *In* Gutmann J L, Harrison JW (editors) *Surgical endodontics*. pp. 278–299. St. Louis: Ishiyaku EuroAmerica, 1994.

Official journal of the British Dental Association.