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A Report on the Clinical and Radiographic Outcomes of 38 Cases of Apexification with Mineral Trioxide Aggregate.

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Abstract - *The aim of the study was to report on the clinical and radiographic assessment of 38 cases of apexification using MTA over a three year period. Thirty-eight cases of incompletely developed teeth requiring endodontic therapy were treated using MTA to achieve an apical barrier prior to obturation with gutta-percha. The teeth were clinically and radiographically assessed. The findings indicate that apexification using MTA is a predictable procedure. In particular, the number of visits and the total time taken to achieve an apical barrier was markedly less than conventional techniques using calcium hydroxide. The presence of a preoperative periapical radiolucency had no effect on the outcome or the treatment protocol. MTA shows promise as a viable alternative to calcium hydroxide to achieve root-end closure and using MTA, the number of visits to achieve a successful apical barrier may be markedly reduced.*

KEY WORDS: Apexification, mineral trioxide aggregate, apical plug.

INTRODUCTION

Endodontic management of the non-vital permanent tooth with an incompletely formed apex is a significant clinical challenge. Before the introduction of apical closure techniques, the common approach to this problem was surgery[1]. Although this approach may provide a successful outcome, the mechanical and psychological problems that need to be overcome are often significant[1]. For example, the thin, fragile dentinal walls associated with a large open apex make it difficult to achieve an apical seal and the reduction of the root length if an apicectomy is also carried out leads to a further compromise in the crown to root ratio. In addition, since it is often a child who requires treatment, a surgical approach is often more difficult and will often require a general anaesthesia[1].

Apexification is a technique aimed at inducing apical repair with a hard tissue barrier across an open apex[2]. Historically, this has been achieved with the use of calcium hydroxide, although several other methods and materials have been advocated[2]. Calcium hydroxide has also been used in combination with a number of other materials including sterile water, saline, local anaesthetic, camphorated parachlorophenol, methylcellulose base, zinc oxide paste with cresol and iodoform, polyantibiotic paste and tricalcium phosphate[3]. However, using calcium hydroxide to achieve an apical barrier can involve a protracted treatment time and has been associated with an increased risk of tooth fracture[3-11].

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In 1993, Lee and colleagues described the use of MTA for the repair of root perforations *in vitro*[12]. The material was developed by Professor Torabinejad and his associates at the Loma Linda University[13-24]. It has been used clinically for several years and was approved for human use by the FDA in 1998[25].

MTA is primarily marketed as a root canal repair material but its use has also been advocated for apexification, retrograde root filling, perforation repairs, internal resorption, root fracture, dens invaginatus prophylaxis and pulp capping. It is available in the UK as a grey or white powder consisting of fine hydrophilic particles that sets in the presence of moisture and its properties have been well documented[12-36].

The potential advantages of using MTA in apexification procedures are its biocompatibility and opportunity to form an 'immediate' apical barrier. This has resonance with the one-step apexification which has been suggested in the past using various materials[37-40]. The rationale of this technique is to establish an apical stop, which would then enable the root canal to be obturated almost immediately[41,42]. The use of MTA in apexification procedures has been advocated and has already been reported but these are primarily case reports[25, 30, 41-43]. Recently Simon *et al.* reported on a radiographic follow up of teeth with immature apices treated with MTA[44].

The Department of Restorative Dentistry in Morriston Hospital Swansea, because of its regional trauma remit sees a large number of young patients with traumatised incompletely developed teeth. These had historically been treated using a calcium hydroxide based regime with treatment often taking many visits over a prolonged time period. This had significant resource implications and this, together with the reported properties of MTA meant that this material became the material of choice from 2000 for patients with immature teeth requiring root canal therapy.

The material was first introduced into the Department in 1998 and used in conjunction with conventional apexification techniques until 2000.

The aim of this paper is to evaluate 38 cases of teeth with incomplete apical closure requiring endodontic therapy but treated over a three year period using MTA to achieve root end closure. A clinical and radiographic assessment was carried out and the number of visits and the period of time taken for treatment were evaluated as was the outcome of any pre-operative apical radiolucent areas.

MATERIALS AND METHODS

Between 2000 and 2003, 38 individuals with incompletely developed non-vital teeth were treated within the Department using MTA (ProRoot MTA Original, Denstply, Weybridge, UK). This involved 43 teeth with 5 patients having 2 teeth treated. Six of the 38 patients (total of 6 teeth) had commenced apexification using calcium hydroxide before 2000, but had their treatment completed using MTA. Treatment was considered if the tooth was restorable, necessary for function and the patient could be treated under local anaesthetic in an out patient environment.

The treatments were carried out by 4 experienced hospital based clinicians. The regimen utilised in the Department consisted of chemo-mechanical cleaning of the root canal system using hand files, sodium hypochlorite solution (5%) and ultrasonics under microscopic magnification, rubber dam isolation and local anaesthesia. Depending on whether the canal was dry or not, the choice was made to use MTA or to dress with an intra-appointment non-setting calcium hydroxide paste (Hypocal, Ellman, NY, USA) respectively. The access cavity was sealed with an interim filling material (Coltosol, Coltene, Whaledent, Switzerland). At a subsequent visit, if the tooth remained asymptomatic, there were no signs of infection and the canal was dry, MTA was used to seal the apical area. If these criteria were not met the canal was re-prepared and the tooth dressed with a non-setting calcium hydroxide for a week. Infection was considered to be present if a swelling or sinus was evident or if the tooth was tender to percussion or mobile in the absence of any possible occlusal cause.

The technique of MTA placement involved the following: after radiographic and paper point working length determination the MTA was mixed according to the manufacturers instructions[45] and then introduced into the canal in a pellet form using a straight root end filling amalgam carrier with the working length recorded using a rubber stop. The broadest paper point which fitted the canal at the working length was then used to pack the MTA in the apical region. A confirmation radiograph was obtained to confirm the quality and length of the apical filling with the objective of achieving an apical fill of at least 3mm. At this stage, a moist cotton pellet was introduced into the root canal system and the access cavity restored using an interim filling material. The patient was reviewed approximately one week later and the root canal backfilled with thermoplasticised gutta-percha after lining with an endodontic sealer (Pulp Canal Sealer EWT, Kerr Italia S.r.l, Salerno, Italy). The radicular section was then sealed with a glass ionomer restoration lining up to the CEJ and the coronal section was restored with a dentine/enamel bonded composite. Arrangements were then made to review the patient one week later. Subsequently the patient was seen at three and six months after completion of treatment and then yearly.

Data Collection

For each patient treated, information was recorded using standardised data collection forms pre and post operatively. At the review in 2003, the data were updated for the 38 patients who had undergone apexification procedure. The clinical and radiographic assessment was carried out using the European Society of Endodontology guidelines[47]. The data collected included:

General

Date of birth, date of initial examination, details of the tooth treated, date of commencement and completion of treatment, and the number of visits required to complete treatment

Clinical

a. Presence or absence of a sinus tract, and its location
b. Presence or absence of tenderness to percussion (the affected tooth was gently tapped along the long axis and laterally using a mouth mirror handle and the response compared with the adjacent teeth and the contra-lateral tooth).
c. Nature and extent of any periodontal pocketing > 3mm around the treated tooth (a graduated periodontal probe was walked around the affected tooth and the greatest depth measured).
d. Presence or absence of mobility of the treated tooth and any mobility graded according to modified Miller's Index[48,49].

Radiographic

An intra-oral periapical radiograph film was obtained at the start and completion of treatment as well as at the annual reviews using a long cone paralleling technique and a commercial beam aiming and film holding device.

The radiographs were examined using a desktop viewing box, which had been modified to eliminate excess light. This was achieved by using black card from which a rectangular section had been removed to allow the radiograph to be inserted[50]. All the radiographs in this review were examined by one of the authors; however, no attempt was made to assess intra-examiner reliability.

The presence or absence of any periapical radiolucency was recorded (a radiolucent area was present if the widening of the periodontal ligament was greater than 1mm)[50]. If present, the lesion was measured using a graticule incorporated into a 4X magnifying eyepiece. This eyepiece graticule had an overall length of 10 mm with 100 subdivisions of 0.1 mm. The maximum extent of the periapical lesion was assessed and the widest diameter of the lesion recorded (Figure 1).

The review was carried out as an observational study designed to review certain parameters which were simple to collect and relevant to clinical practice. Consequently, no statistical analysis was carried out.

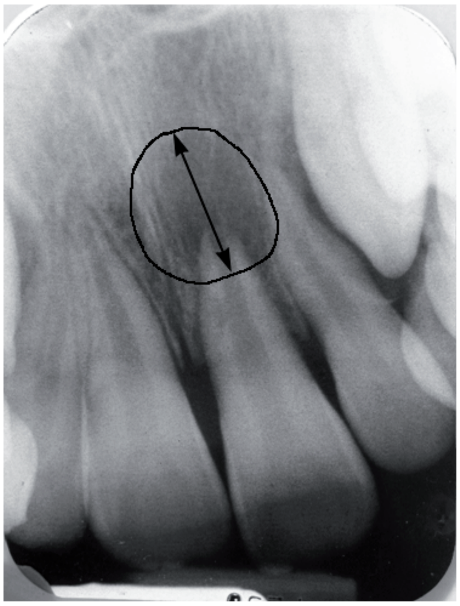

Figure 1. *Intraoral periapical radiograph of tooth with incomplete root end closure and associated radiolucency.*

RESULTS

General

Age

The mean age of the 38 patients was 19 years with a range of 8 to 58 years. Eighty percent of the patients were below the mean age (Figure 2).

Follow up period

The mean follow-up period was 10.67 months with a range of 1 – 28 months. No teeth were lost during the period of evaluation.

Tooth details

Thirty six of the 43 teeth treated were maxillary central incisors and the remainder (7) maxillary lateral incisors.

Treatment time (Figure 3)

The mean treatment time from first appointment to MTA filling was 20 weeks with a range of 1 – 84 weeks. When those patients (6) who had started their treatment with calcium hydroxide before 2000 but had been completed with MTA were excluded, the mean treatment time was 12 weeks with a range of 1 – 40 weeks.

Number of visits (Figure 4)

The mean number of visits required to complete the apexification procedure was 3 with a range of 1 – 8. When the calcium hydroxide group (6) was excluded then this figure reduced to 2 with a range of 1 – 5 visits.

Clinical Findings

Preoperatively, 32 teeth had one or more clinical signs of infection. At the time of reassessment only 6 teeth had any signs, none of which were associated with any radiographic changes (Figure 5). Of these:

- Four teeth had grade I mobility of which one had grade I mobility preoperatively.
- One tooth had a 5mm pocket, grade II mobility and evidence of external root resorption. This tooth had grade I mobility preoperatively and no pocketing >3mm.
- One tooth had a 6mm pocket on its labial aspect. This tooth had no pocketing >3mm pre-operatively.

Radiographic Findings

Nineteen of the 43 teeth had evidence of an apical radiolucency at the start of treatment with the largest being 16.5mm at its widest dimension and the smallest 3mm. The mean post-operative follow up period for the 19 teeth was 10.2 months and in 2003, 11 (mean follow up period 11.8 months) of the 19 teeth had complete resolution of the periapical radiolucency. Of the 8 teeth (mean follow up period 8 months) with an apical radiolucency on review, all showed a reduction in the size of the lesion (Figure 6).

DISCUSSION

Comparing findings from this study with others is difficult due to the limited availability of similar studies in similar groups. Recently, Simon *et al.* reported results from a study of the radiographic changes associated with teeth with immature apical development treated using a one-visit MTA technique[45]. However, this study included teeth other than maxillary incisors but did not differentiate the findings by tooth type. In our report the majority of teeth were maxillary incisors since these are the most common ones encountered with immature apices, probably as result of their risk of trauma in young patients[51, 52]. Thus comparison with Simon *et al.*'s study is difficult even though the mean age of patients treated in both studies was comparable[45].

Both clinical and radiographic factors were evaluated in the study reported in this paper in line with the ESE Guideline[47], whilst Simon *et al.* only reported radiographic findings. In the study by Simon *et al.* a single operator provided the care[45], whilst the nature of the Department of Restorative Dentistry meant that the results from 4 experienced hospital clinicians were recorded.

The technique used for MTA apical barrier restoration in this study is based on standard endodontic procedures and the manufacturer's instructions and is comparable to that described in Simon *et al.*'s paper[45].

Of the 6 (15%) teeth that showed clinical signs of infection, 4 showed some overall improvement and it is possible that these may improve further with a longer follow-up[53,54]. There appeared to be an increase in the number of teeth showing Grade I mobility following treatment (period of examination range: 3 – 6 weeks). This may be either due to the short postoperative period or due to examiner variability. These teeth may also have persistent inflammation either from the original pathology or as result of the treatment. However, none of these teeth had any radiographic evidence of deterioration and were functional.

Among the cohort of teeth that were being assessed, a number had large apical radiolucencies at preoperative assessment. It was not considered appropriate to use the

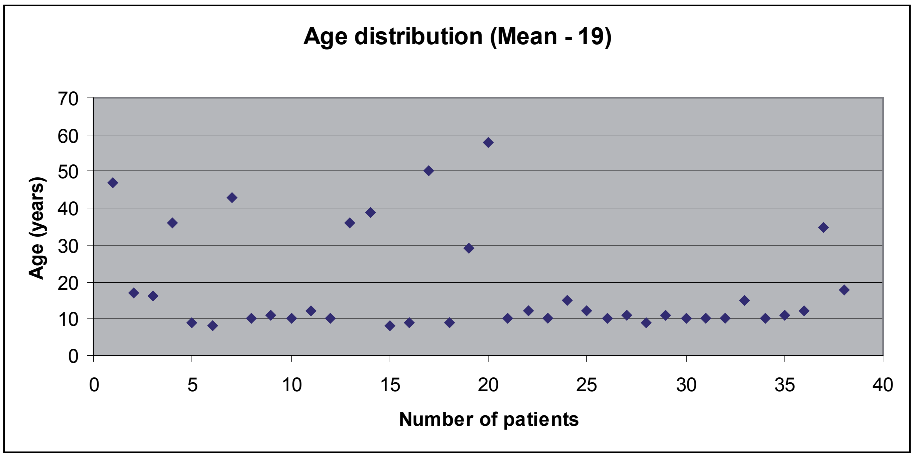

Figure 2. *Graph illustrating age distribution of 38 cases treated*

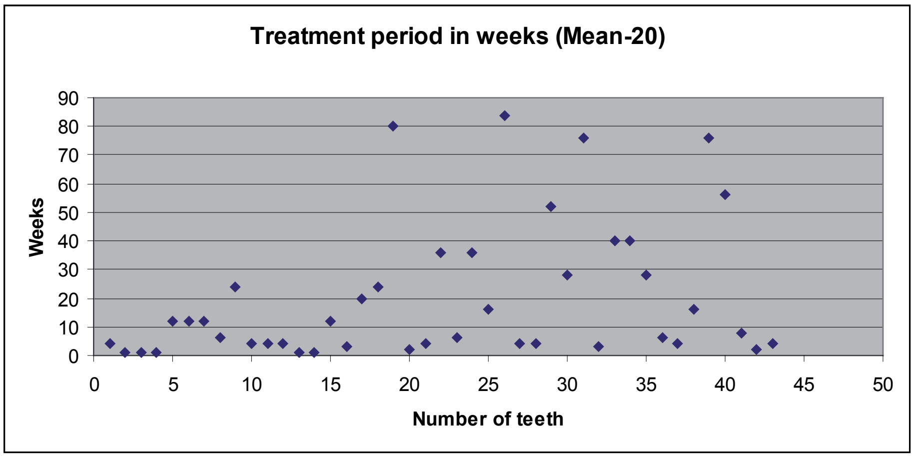

Figure 3. *Graph illustrating total time taken to treat each of the 43 teeth.*

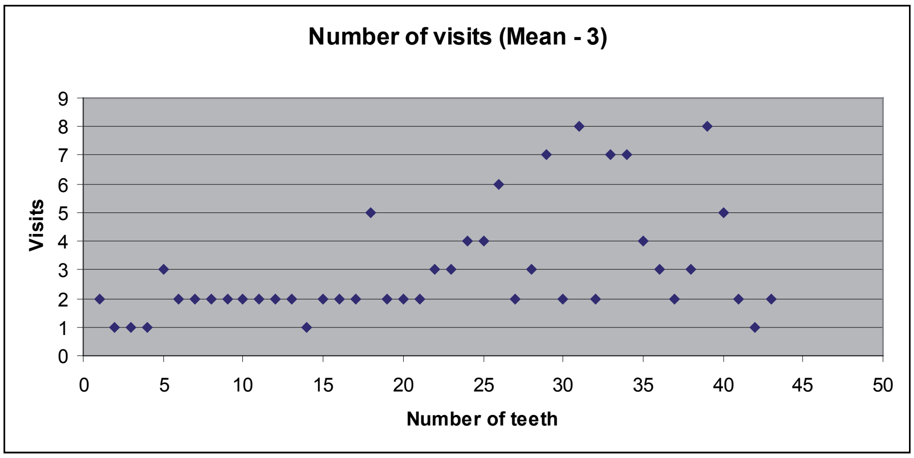

Figure 4. *Graph illustrating total number of visits to treat each of the 43 teeth.*

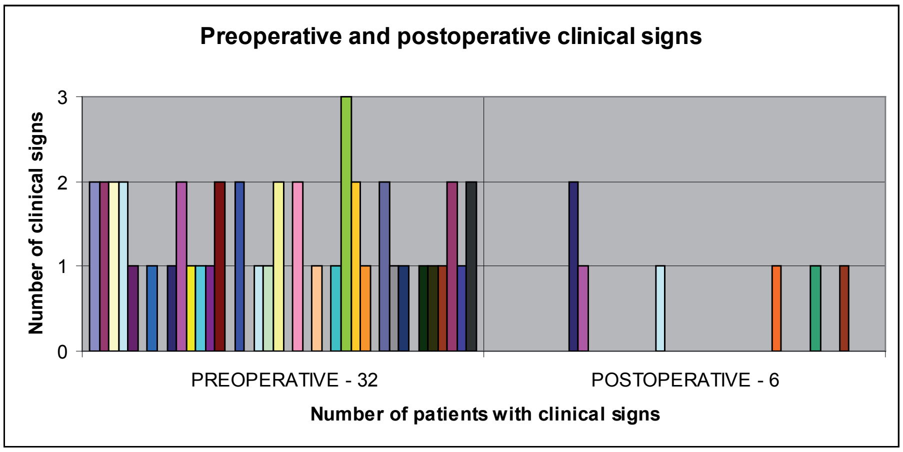

Figure 5. *Graph illustrating change in number of clinical signs of infection pre and postoperatively.*

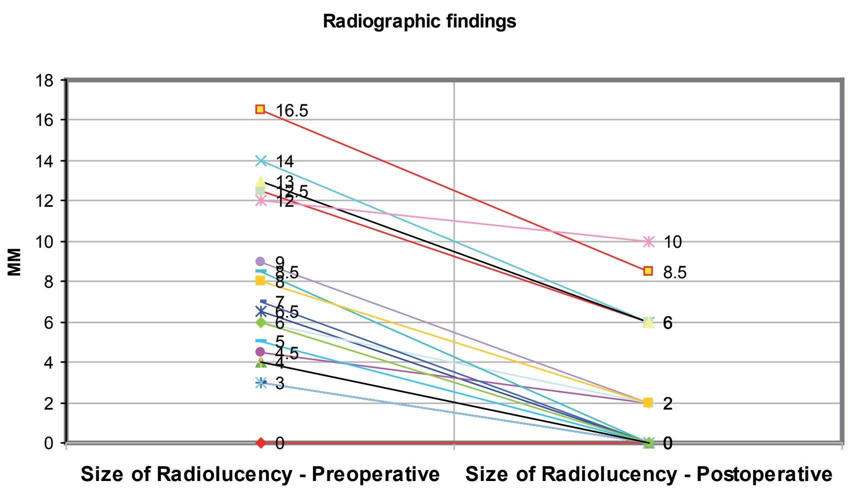

Figure 6. *Graph illustrating change in size of periapical radiolucencies pre and postoperatively.*

periapical index (PAI) proposed by Ørstavik *et al.* in this study to evaluate the apical radiolucencies[55]. This was due to the dissimilarity in the potential radiographic reference points associated with the different degree of apical development. It was decided instead that the simplest method to assess the periapical status would be to measure the size of the periapical radiolucency and plot it as continuous data. In this study 57% of preoperative periapical lesions showed complete healing (absolute success) at review whilst the relative success rate (healed lesions and lesions in process of healing) was 100%.

Simon *et al.* (2007)[45] reported a higher absolute radiographic success rate but a comparable relative figure to that observed in this report. The difference in absolute success could be accounted for by the longer mean follow up time reported by Simon *et al.* (2007)[45] since studies have concluded that a longer observation time is associated with increased radiographic improvement[53,56]. Other factors such as the different radiographic assessment procedures and the fact that Simon *et al.* included teeth other than incisors may also contribute to the observed differences[45].

Apexification with calcium hydroxide is carried out with replacement of the medicament every three months with a clinical check being made for hard tissue formation apically on each occasion[57]. Once an apical barrier has been confirmed, final obturation is usually carried out. As such, the time required for apical barrier formation with calcium hydroxide can be protracted with a range of between 5 to 75 months being reported[3-10]. In a recent study, it was reported that a mean time of 12.19 months was required for apical formation to occur using calcium hydroxide[58]. This obviously has resource and patient compliance implications[3-10].

To overcome the problem of the need for multiple visits, techniques have been described to establish an immediate apical stop using various materials. This would then enable the root canal to be obturated at the same or subsequent visit[37-40, 42]. The reasons for these techniques as quoted in the studies are: lengthy treatment times are fraught with problems of non-completion, difficulty in creating a leak-proof temporary restoration for the duration of treatment, difficulty in protecting the thin root from fracture, unpredictability of the result – all of which can lead to ultimate failure of the case.

One of the potential advantages of using MTA for apexification is the reduction in time to obtain an apical barrier[41, 42]. In this study of those patients treated solely with MTA, the mean barrier formation time was just under 3 months (Range: 1 to 10 months). This compares favourably with when calcium hydroxide is used[10, 59]. This result is also based on a cautious approach to treatment.

Previous studies using calcium hydroxide have not recorded the number of visits required to achieve barrier formation[3-10]. However, an indication of the number can be deduced if it is assumed that, following recommended guidelines, the calcium hydroxide was changed at least once every three months[57]. If this is the case, then by simply dividing the treatment times (in months) recorded in the studies by three, an approximate figure for the probable number of visits can be obtained. The studies which have recorded the treatment time, report durations of between 5 and 75 months[4, 6, 60, 61]. This would suggest that between 2 and 25 visits were necessary to form an apical barrier in these studies.

The findings from this report indicate that the comparable figure for treatment with MTA was 3, which is a notable difference when compared to calcium hydroxide. The number of visits could be further reduced if backfill had occurred at the same visit rather than on a subsequent visit. This protocol was followed in this study due to the prolonged setting time associated with the MTA used and the fact that a cautious approach was taken during this period with the expansion of use of the material within the Department.

Shortened treatment times have obvious resource benefits and also overcome problems of patient compliance. In addition, the risk of delaying apexification due to repeated re-entries into the root canal system would also be negated[6, 62]. Andreasen *et al.* also highlighted the decreased fracture resistance of teeth treated over a 30 day period with calcium hydroxide compared to those ultimately obturated with MTA[11]. Although in this study MTA was not used to completely fill the root canal, a prolonged treatment time with calcium hydroxide retained within the root canal was obviated. This may have an effect in the long-term in reducing the number of cervical fractures reported by Cvek in endodontically treated teeth with immature root development[63].

In their study, Simon *et al.* used a single visit procedure irrespective of the initial clinical findings[45]. Their absolute success figure (complete healing – 65%) was greater than that reported in this study (57%) which would suggest that the more cautious approach may not be necessary, particularly as the relative success of both studies appears similar. However, they did not report any associated clinical findings[45].

One of the reasons why historically the use of MTA may be limited is its cost. However, when considering this as a factor, the reduced number of visits required when using this material compared with calcium hydroxide must also be considered. In such circumstances, MTA may in fact be a more cost effective material to use although a more detailed cost-benefit analysis would be necessary to make any firm conclusions.

Clinical review of a new material should ideally be carried out in a standardised manner to assess its efficacy and success rates. This review was an observational study consisting of both retrospective and prospective elements where a simple descriptive analysis demonstrates the effect of the material.

CONCLUSION

This paper evaluates the clinical and radiographic outcome of 38 cases of apexification carried out with MTA. The findings confirm the potential benefit of this material when used in this manner, in particular the notable reduction in the number of visits required to complete treatment and the favourable response when used in teeth with pre-operative apical radiolucencies.

MANUFACTURER'S DETAILS

- ProRoot MTA Original, Dentsply, Weybridge, UK
- Rubber stop, Union Broach, York, PA, USA
- Obtura II, QED, Peterborough, UK
- Pulp Canal Sealer EWT, Kerr Italia S.r.l, Salerno, Italy
- Glass Ionomer Cement, Fuji II, GC corporation, Tokyo, Japan
- Composite, Herculite, Kerr Italia, Scafati, Italy
- RINN, Dentsply, Weybridge, England
- Graticules MAG 6 Measuring Magnifier, Graticules Ltd, Tonbridge, UK
- MTA-Angelus, Quality Endodontic Distributors Ltd, Peterborough, England

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