Treatment outcomes of single-visit versus multiple-visit non-surgical endodontic therapy: a randomised clinical trial

Amy Wai-Yee Wong1,2, Cissy Sung-Chi Tsang2, Shinan Zhang1, Kar-Yan Li1, Chengfei Zhang1* and Chun-Hung Chu1

Abstract

Background: Clinicians have been providing single-visit and multiple-visit endodontic treatments for their patients. This study aims to compare the success rate, prevalence of postoperative pain and chairside time of single-visit and multiple-visit endodontic treatments.

Method: Patients who required primary endodontic treatment in a university dental clinic were randomly allocated to two general dentists for single-visit or multiple-visit treatments using the same materials and procedures. Ni-Ti rotary files were used to prepare the root canals, which were subsequently obturated with a core-carrier technique. The chairside time was recorded. The treated teeth were followed up every 6 months on clinically signs and symptoms including pain, tenderness to percussion, sinus tract, mobility and abscess. Periapical radiographs were taken to assess periapical pathology. Successful treatments were neither clinical signs/symptoms noted nor radiographic periapical pathology found postoperatively.

Results: A total of 220 teeth from patients aged 46.4 ± 14.1 were followed up for at least 18 months. The mean (±SD) follow-up period was 29.4 ± 9.3 months. The success rates of single-visit and multiple-visit treatments were 88.9 and 87.4 %, respectively (p = 0.729, effect size odds ratio = 1.156). Maxillary teeth had odds ratios of 3.16 (95 % CI: 1.33 to 7.46; p = 0.009) and absence of preoperative apical peridontitis had odds ratios of 4.35 (95 % CI: 1.43 to 13.24; p = 0.010) were identified from logistic regression as having a higher success rate. The average chairside times of single-visit and multiple-visit treatments were 62.0 and 92.9 min, respectively (mean difference = −30.9, 95 % CI: −39.4 to −22.4, p < 0.001, effect size odds ratio = −0.996). Single-visit and multiple-visit treatment had no significant difference in the prevalence of postoperative pain within 7 days (21 and 12 %, p = 0.055, effect size odds ratio = 2.061) and after at least 18 months (0.9 and 1.0 %, p > 0.999, effect size odds ratio = 0.879).

Conclusions: The success rate and prevalence of postoperative pain of single-visit or multiple-visit treatment had no significant difference. The chairside time for single-visit treatment was shorter than multiple-visit treatment.

Trial registration: Clinical Trials (WHO) ChiCTR-IOR-15006117 registered on 20 March 2015.

Keywords: Deferred endodontic treatment, Single visit, Clinical trial, Root canal therapy
Background
Endodontic treatment used to take multiple visits to complete, with one of the main reasons for this being that it requires a considerable amount of time to complete the treatment [1]. Multiple-visit root canal treatment is well accepted as a safe and common therapy. However, the rationales for multiple-visit endodontic treatment are being questioned. A systematic review [1] found no significant differences in antimicrobial efficacies have been reported between single-visit and multiple-visit treatments. In addition, the use of contemporary endodontics techniques and equipment such as magnifying devices, electronic apex locators, engine-driven rotary nickel titanium files and so forth not only increases the success rate of endodontic treatment but also shortens the time needed for the treatment [2]. Endodontic treatment may therefore be completed in a single visit.

Surveys found many general dentists and endodontists preferred to perform root canal treatment in a conventional way, i.e., multiple visits [3–7]. A review found patients undergoing a single visit experienced a higher frequency of swelling and were more likely to take painkillers [8]. However, a meta-analysis found no significant difference in postoperative complications between single-visit and multiple-visit endodontic treatment [1]. There are numerous advantages to completing root canal therapy in a single appointment, such as there is no risk of flare-up induced by leakage of the temporary seal between appointments and materials needed for separate visits are saved [9]. A successful clinical outcome is commonly regarded as absence of signs and symptoms and no radiological evidence of periapical pathology [10–13].

The on-campus University Health Service dental clinic was established to provide dental services to full-time and part-time students, staff and their dependents at the University of Hong Kong [14]. The dental clinic provides comprehensive general dental care, including primary non-surgical endodontic treatment for eligible patients. The quality of dental services is regularly monitored by an annual patient satisfaction survey for continual improvement [15]. The aim of this study was to evaluate the treatment outcomes of non-surgical primary endodontic treatment root canal therapy using either single-visit or multiple-visit endodontic treatment performed by general dentists in the on-campus dental clinic.

Method

Hypotheses tested and outcomes measured
Three null hypotheses were tested in this study. First, there would be no difference between the success rate of single-visit and multiple-visit non-surgical endodontic treatment. Second, there would be no difference between the prevalence of postoperative pain for single-visit and multiple-visit non-surgical endodontic treatment. Third, there would be no difference between the chairside time used for single-visit and multiple-visit non-surgical endodontic treatment. The primary outcome measured was the success of endodontic treatment which is no clinical sign and symptom and no radiographic radiolucency in the follow-up examination. Another outcome measured was the total chairside time spent on completion of endodontic treatment by a single visit and multiple visits. The secondary outcome measured was the prevalence of postoperative pain after 7 days and at the final evaluation (18 to 45 months after treatment) for the single-visit and multiple-visit treatment.

Patient recruitment
The study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU UW 09–303). The clinical trial was registered in the Chinese Clinical Trial Registry of the World Health Organization (ChiCTR-IOR-15006117). The clinical trial was 4 years. Patient recruitment was implemented for the first 30 months so that the participants would be followed up for at least 18 months. Patients after who were generally healthy, required primary non-surgical endodontic treatment and agreed to return for follow-up via the Health Service Dental Clinic of the University of Hong Kong were invited to participate in the study. Furthermore, the participating patients had no history of periodontitis, and the tooth that required primary endodontic treatment was periodontally healthy. Teeth with pulpotomy were not accepted, and at least half of the coronal structure had to be remaining. The protocol of the study was explained to participants and consent was obtained. Patients who had severe acute pulpitis with facial swelling or systemic infection, severe systemic disease, increased stress on the temporomandibular joint musculature or increased psychological stress were excluded from this study (Fig. 1).

Group assignment
The participating patients were randomly assigned by the receptionist for endodontic treatment. The treated teeth were randomly assigned to either single-visit or multiple-visit treatments using the random-number generating function of a calculator. If the patient needed more than one endodontic treatment, the randomised allocation was performed on every tooth required treatment. A number unknown to the operators and the independent assessor was given to each treated tooth for clinical and radiographic assessment, data entry and analysis.

Sample size calculation
For sample size calculation, it has been estimated the success rate of primary non-surgical endodontic treatment was 88 % [12]. A difference in the success rate by at least 10 % between single-visit and multiple-visit endodontic
treatments was considered clinically significant and statistically achievable. The estimated sample size was 102 for each treatment group based on the power of the study set at 80 % ($\beta = 0.20$) and with $\alpha = 0.05$ as the significance level. We estimated the dropout rate would be 20 %, and thus, at least 256 teeth with at least 128 teeth per group were required at the baseline for analysis.

**Clinical procedure**

The two general dentists (A and B) carried out the endodontic treatments. One of them (A) was trained to use a magnifying loupe (2.5x). The two dentists received a calibration workshop prior to this clinical trial to standardise the instrumentation and obturation technique described below. Preoperative periapical radiographs using a parallel...
technique were taken. Local anaesthetic was given and rubber dam was used for isolation. The root canals were
cleaned and shaped using Ni-Ti rotary files (ProTaper NiTi, Dentsply Maillefer, Ballaigues, Switzerland). A 5.25 % sodium hypochlorite was used for irrigation. The prepared tooth was obturated after shaping and cleaning of the canals if it was in the single-visit group. For those teeth assigned to multiple-visit group, non-setting 5 % calcium hydroxide paste (UltraCal XS, Ultradent, South Jordan, UT, USA) was used as inter-appointment medication. The tooth was temporarily restored with resin-modified zinc oxide and eugenol cement (IRM, LD Caulk Dentsply, Milford, CT, USA) until obturation. The next appointment was scheduled in following week. It could be two to three visits depending on the complexity of the treatment. All teeth were obturated using a core-carrier technique (Thermafil, Dentsply Maillefer, Ballaigues, Switzerland). The total chairside time was recorded by the dental assistant. The treated teeth were restored with silver amalgam or composite resin. Patients were recommended to take a dose of paracetamol 500 to 1000 mg every 4 to 6 h if needed. All patients were reviewed 1 week after obturation, and were advised to have indirect extra-coronal restoration (partial or full veneer) to avoid failure due to extra-coronal leakage or tooth fracture.

Evaluation
The patients were reviewed 1 week after obturation. The treated teeth were clinically examined and reason for clinical failure, if any, was recorded. Clinical signs and symptoms including pain, tenderness on percussion, caries (primary or secondary), defective margin of restoration, mobility, periodontal pocket and soft tissue pathology such as abscess or sinus tract were recorded. If the patient experienced pain or discomfort of treated tooth after obturation, they were asked to rate their pain or discomfort using a pain scale score table (Fig. 2). The pain assessment was adopted from our previous study which measured pain on a 10-point Likert scale, ranging from no pain (score 0) to extreme pain (score 10) [16]. The patients were asked to attend regular follow-ups every 6 months after the endodontic treatment. Periapical radiographs were taken using a parallel technique. The method of radiographic assessment was adopted from Chu and his co-workers (2005) [12]. Signs of any internal or external root resorption were recorded and the periapical conditions were classified as 1) normal—normal appearance of the surrounding osseous structure or 2) apical periodontitis—apical radiolucency observed. Multiple-rooted teeth with different periapical statuses at different roots were classified according to the most severe periapical condition. When doubt existed as to whether pathological periapical conditions were present or not, the case was classified as normal. The method of radiographic assessment for the length and density of the root canal filling were recorded for analysis [16]. The length of the root canal filling were recorded as 1) adequate – filling within 2 mm from radiographic apex, 2) overfilling – filling over radiographic apex or 3) underfilling – filling at least 2 mm short from apex. The density of root canal filling were recorded as 1) adequate – filling uniformly packed without visible voids and canal spaces or 2) inadequate – filling with visible voids or canal spaces. The outcome of the endodontic treatment was classified as a success or a failure. Success was graded when there were no clinical signs/symptoms and no radiographic radiolucency found in the periapical radiograph. The reason for the extraction, in particular for those reasons related to endodontic failure, was recorded. To estimate the reliability of the radiographic assessment, duplicated assessment were performed on around 15 % the patients. The intra-observer agreement and inter-observer agreement were measured using the intraclass correlation coefficient (ICC) test. The ICC was calculated for each variable using a two-way random effects model. The ICC values were considered as good for ICC > 0.75, moderate for ICC > 0.40 and poor for ICC < 0.40 [21].
agreement for radiographic assessments (complete healing or failure) were then calculated by Kappa statistics.

**Data analysis**

The collected data was analysed with the IBM® SPSS® Statistics 21.0 program (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) by a statistician (SKYL). The intra-observer agreement and inter-observer agreement for radiographic assessments (complete healing or failure) were calculated by Kappa statistics. For the primary treatment outcome (success or failure), multiple logistic regressions were used to assess the relationship between the primary treatment outcome (success or failure) and the treatment (single-visit or multiple-visit) groups, adjusting for other independent variables. The independent variables included: patients’ gender and age, operators (A or B), use of magnifying loupe, arch (maxillary or mandibular), tooth location (anterior or posterior), number of canals of the endodontically treated tooth (single or multiple), presence of preoperative apical radiolucency, presence of C-shaped canal before treatment, presence of periodontal pocket before treatment ($\geq 4$ mm pocket), vitality before treatment, mobility before treatment, tooth status of the main opposing tooth, tenderness on percussion before treatment, presence of sinus tract before treatment, presence of pain and pain intensity (0 to 10) before treatment. Backward stepwise procedures were used.

**Results**

A total of 228 patients with 256 teeth were recruited, and 34 patients with 36 teeth were lost in the follow-up (Fig. 1). The dropout rate was 14.1 %. A total of 194 patients with 220 teeth from aged 46.38 ± 14.06 were followed up for at least 18 months, and the mean (±SD) review period was 29.4 ± 9.3 months. The reason for dropout was patients failed to return for follow up during the treatment or after completion of treatment. Among them, there were 85 male (38.6 %) patients; 117 teeth (53.2 %) were treated with single-visit endodontic treatment; 49 teeth (22.3 %) were anterior teeth; and 89 teeth (40.5 %) had a single-root canal (Table 1). To estimate the reliability, radiographic assessment in around 16 % of the sample ($n = 36$) was duplicated. Kappa values of the intra-observer agreement for the two observers were both 1.000. Kappa value of the inter-observer agreement was 0.911 (standard error = 0.039).

The success rate of endodontic treatment was 88.2 % ($n = 194$) in this study. The success rates for the single-visit treatment ($n = 104$) and multiple-visit treatment ($n = 90$) were 88.9 and 87.4 %, respectively (Chi-square test: $p = 0.729$, effect size odds ratio = 1.156). The relationship between the primary treatment outcome (success or failure) was not significantly related to the treatment visit, i.e., single visit or multiple visits ($p = 0.764$) in the full model of the multiple logistic regression adjusted for the aforementioned independent variables (Table 2). Results of the final logistic regression after backward elimination showed that maxillary teeth and absence of preoperative apical radiolucency had higher odds ratios of success (Nagelkerke $R^2 = 0.138$). The maxillary teeth had odds ratios of 3.16 (95 % CI: 1.33 to 7.46; $p = 0.009$) with reference to the mandibular teeth. The teeth without apical radiolucency had odds ratios of 4.35 (95 % CI: 1.43 to 13.24; $p = 0.010$) with reference to the teeth with apical radiolucency.

The prevalence of postoperative pain after 1 week of the single-visit and multiple-visit were 21 and 12 % (Chi-square test: $p = 0.055$, effect size odds ratio = 2.061), whereas the prevalence of postoperative pain after at least 18 months were 0.9 and 1.0 %, respectively (Fisher’s exact test: $p > 0.999$, effect size odds ratio = 0.879). There was not significant different on prevalence of postoperative pain after 1 week and after at least 18 months between single-visit and multiple-visit treatment.

The chairside time (mean ± SD) for single-visit and multiple-visit endodontic treatment were 62.0 ± 23.5 min and 92.9 ± 37.8 min, respectively (mean difference = −30.9, 95 % CI: −39.4 to −22.4, effect size $d = −0.996$, $p < 0.001$). Results in the final model of multi-way ANCOVA after
| Variable                      | Category        | All cases (n = 220) | Single visit (n = 117) | Multiple visits (n = 103) | p value |
|-------------------------------|-----------------|---------------------|------------------------|--------------------------|---------|
| Gender                        | Male            | 85 (39 %)           | 60 (51 %)              | 25 (24 %)                | <0.001* |
|                               | Female          | 135 (61 %)          | 57 (49 %)              | 78 (76 %)                |         |
| Operator                      | A               | 112 (51 %)          | 56 (48 %)              | 56 (54 %)                | 0.335   |
|                               | B               | 108 (49 %)          | 61 (52 %)              | 47 (46 %)                |         |
| Use of loupe                  | Yes             | 112 (51 %)          | 56 (48 %)              | 56 (54 %)                | 0.335   |
|                               | No              | 108 (49 %)          | 61 (52 %)              | 47 (46 %)                |         |
| Arch                          | Maxillary       | 140 (64 %)          | 82 (70 %)              | 58 (56 %)                | 0.034*  |
|                               | Mandibular      | 80 (36 %)           | 35 (30 %)              | 45 (44 %)                |         |
| Tooth position                | Anterior        | 49 (22 %)           | 31 (26 %)              | 18 (17 %)                | 0.109   |
|                               | Posterior       | 171 (78 %)          | 86 (74 %)              | 85 (83 %)                |         |
| Number of canal               | Single          | 89 (40 %)           | 55 (47 %)              | 34 (33 %)                | 0.035*  |
|                               | Multiple        | 131 (60 %)          | 62 (53 %)              | 69 (67 %)                |         |
| Apical periodontitis          | Yes             | 129 (59 %)          | 66 (56 %)              | 63 (61 %)                | 0.475   |
|                               | No              | 91 (41 %)           | 51 (44 %)              | 40 (39 %)                |         |
| C-shaped canal                | Yes             | 4 (2 %)             | 2 (2 %)                | 2 (2 %)                  | >0.999a |
|                               | No              | 216 (98 %)          | 115 (98 %)             | 101 (98 %)               |         |
| Periodontal pocket            | Yes             | 32 (15 %)           | 17 (15 %)              | 15 (15 %)                | 0.994   |
|                               | No              | 188 (85 %)          | 100 (85 %)             | 88 (85 %)                |         |
| Tooth vitality                | Vital           | 37 (17 %)           | 20 (17 %)              | 17 (17 %)                | 0.907   |
|                               | Non-vital       | 183 (83 %)          | 97 (83 %)              | 86 (83 %)                |         |
| Tooth mobility                | Yes             | 8 (4 %)             | 2 (2 %)                | 6 (6 %)                  | 0.151a  |
|                               | No              | 212 (96 %)          | 115 (98 %)             | 97 (94 %)                |         |
| Opposing teeth                | Missing         | 6 (3 %)             | 3 (3 %)                | 3 (3 %)                  | 0.367a  |
|                               | Sound           | 153 (70 %)          | 84 (72 %)              | 69 (67 %)                |         |
|                               | Filled          | 43 (19 %)           | 24 (20 %)              | 19 (18 %)                |         |
|                               | Crown           | 18 (8 %)            | 6 (5 %)                | 12 (12 %)                |         |
| Tender to percussion          | Yes             | 109 (50 %)          | 49 (42 %)              | 60 (58 %)                | 0.015*  |
|                               | No              | 111 (50 %)          | 68 (58 %)              | 43 (42 %)                |         |
| Abscess or sinus tract        | Yes             | 42 (19 %)           | 20 (17 %)              | 22 (21 %)                | 0.422   |
|                               | No              | 178 (81 %)          | 97 (83 %)              | 81 (79 %)                |         |
| Preoperative pain             | Yes             | 80 (36 %)           | 33 (28 %)              | 47 (46 %)                | 0.007*  |
|                               | No              | 140 (64 %)          | 84 (72 %)              | 56 (54 %)                |         |
| Length of root canal filling  | Adequate        | 181 (82 %)          | 101 (86 %)             | 80 (78 %)                | 0.115a  |
|                               | Overfilling     | 33 (15 %)           | 15 (13 %)              | 18 (17 %)                |         |
|                               | Underfilling    | 6 (3 %)             | 1 (1 %)                | 5 (5 %)                  |         |
| Density of root canal filling | Adequate        | 203 (92 %)          | 109 (93 %)             | 94 (91 %)                | 0.598   |
|                               | Inadequate      | 17 (8 %)            | 8 (7 %)                | 9 (9 %)                  |         |
| Postoperative restoration     | Intra-coronal   | 70 (32 %)           | 33 (28 %)              | 37 (36 %)                | 0.220   |
|                               | Extra-coronal   | 150 (68 %)          | 84 (72 %)              | 66 (64 %)                |         |
| Treatment outcome             | Success         | 194 (88 %)          | 104 (89 %)             | 90 (87 %)                | 0.729   |
|                               | Failure         | 26 (12 %)           | 13 (11 %)              | 13 (13 %)                |         |
| Postoperative pain within 1 week | Yes       | 37 (17 %)           | 25 (21 %)              | 12 (12 %)                | 0.055   |
|                               | No              | 183 (83 %)          | 92 (79 %)              | 91 (88 %)                |         |
backward elimination showed the chairside time was reduced by single-visit treatment, use of magnifying loupe, treatment on a single-canal tooth and/or treatment on a non-vital tooth (Table 3).

Among the 117 teeth received single-visit endodontic treatment, 104 did not have signs and symptoms suggesting failure at the final evaluation. The success rate was thus 88.9 % (Table 4). There were 13 teeth (11.1 %) classified as failures, one tooth (0.9 %) was classified based on clinical criteria alone, 12 (10.3 %) were due to the presence of periapical radiolucency in the evaluation radiographs alone and none of the case was classified so by both the clinical and radiograph criteria. Among the 103 teeth received multiple-visit endodontic treatment, 90 teeth (87.4 %) were classified as success. Two teeth (1.9 %) were classified as failure based on both clinical and radiographic criteria, on tooth (1.0 %) on clinical criteria only, and 10 teeth (9.7 %) on radiographic criteria.

**Discussion**

A literature review found the dropout rate in longitudinal clinical studies could be 50 % and was a major source of error [17]. In this study, telephone reminders for follow-up examinations and individual, detailed preoperative explanations were provided to minimise the dropout rate. From the telephone communications, we found some patients considered their teeth had no problems and were not willing to come back for review. There was difference in gender distribution between groups. This could be a source of unknown bias in this study. The dropout rate was 14.1 %, which was considered acceptable when compared with other studies [18].

This study achieved the minimal required number of participants, but the sample was not very large. Therefore, the power of the statistical test used in this study was not high. A larger sample size would have given a higher power in the statistical analysis, but this is often difficult to achieve in clinical practice, where the number of eligible patents are limited [12]. A multi-centre clinical trial could be an option, but it requires more resources. Some researches might suggest a meta-analysis, but such results should be interpreted with caution since the protocol for endodontic treatment and the method for evaluation of treatment outcomes often vary between studies.

The treatment outcome was categorised as a success in this study when the treated tooth had no signs or symptoms in both clinical and radiographic assessments [12, 19]. A review period of at least 18 months was adopted. Pirani and colleagues suggested radiographic evaluation 6–9 months after treatment was an early prognostic tool to determine success [20]. An incomplete healing with a reduced size of apical radiolucency was regarded as a ‘questionable success’ in some studies [10, 11] but was considered as a failure in this study. Studies reported profound radiographic healing often be found after 3 months and mostly within 2 years [21, 22]. In this study, the average review period of the treated teeth was about 30 months, which was adequate for assessment of radiographic healing after endodontic treatment.

According to the results, the first null hypothesis of no differences in the success rate between single-visit and multiple-visit primary non-surgical endodontic treatment was accepted in this study. Moreover, the success rates of both treatment groups were high (88.9 and 87.4 %, respectively). The difference was small and had limited clinical implications. Some dentists believe performing multiple-visit treatment has a higher success rate than single visit [5]. This belief, however, was not substantiated according to the results of this study. The success rate of single-visit endodontic treatment in this study was very similar to another study reported by Field and his co-workers [23], though there was a slight different in the endodontic treatment protocol. In this study, the reasons for the tooth lost (extraction) were tooth fracture and secondary caries. There were only three teeth lost over the study period. The percentage is low and was not considered a significant outcome to be discussed in this study.

The obturation method used in this study was the core-carrier technique, which is different from previous studies that used conventional cold lateral condensation. However, a literature review found no difference in success rate between the cold lateral condensation and core-carrier obturation technique [1]. The core-carrier technique is simple and quick and has become a common obturation technique.
## Table 2 The effects of treatment visit and other variables on treatment success

| Variable                  | Category      | Treatment Outcome | Full model p-value | Final model p-value |
|---------------------------|---------------|-------------------|--------------------|--------------------|
|                           |               | Success No (Row %) | Failure No (Row %) |                    |
| Treatment visit           | Single        | 104 (89 %)        | 13 (11 %)          | 0.764              |
|                           | Multiple      | 90 (87 %)         | 13 (13 %)          |                    |
| Gender                    | Male          | 74 (87 %)         | 11 (13 %)          | 0.980              |
|                           | Female        | 120 (89 %)        | 15 (11 %)          |                    |
| Use of loupe              | Yes           | 99 (88 %)         | 13 (12 %)          | 0.470              |
|                           | No            | 95 (88 %)         | 13 (12 %)          |                    |
| Arch                      | Maxillary     | 130 (93 %)        | 10 (7 %)           | 0.015*             |
|                           | Mandibular    | 64 (80 %)         | 16 (20 %)          | 0.009*             |
| Tooth position            | Anterior      | 46 (94 %)         | 3 (6 %)            | 0.855              |
|                           | Posterior     | 148 (87 %)        | 23 (13 %)          |                    |
| Number of canal           | Single        | 82 (92 %)         | 7 (8 %)            | 0.159              |
|                           | Multiple      | 112 (85 %)        | 19 (15 %)          |                    |
| Apical periodontitis      | Yes           | 107 (83 %)        | 22 (17 %)          | 0.021*             |
|                           | No            | 87 (96 %)         | 4 (4 %)            | 0.010*             |
| C-shaped canal            | Yes           | 4 (100 %)         | 0 (0 %)            | 0.999              |
|                           | No            | 190 (88 %)        | 26 (12 %)          |                    |
| Periodontal pocket        | Yes           | 26 (81 %)         | 6 (19 %)           | 0.247              |
|                           | No            | 168 (89 %)        | 20 (11 %)          |                    |
| Tooth vitality            | Vital         | 35 (95 %)         | 2 (5 %)            | 0.862              |
|                           | Non-vital     | 159 (87 %)        | 24 (13 %)          |                    |
| Tooth mobility            | Yes           | 7 (88 %)          | 1 (13 %)           | 0.365              |
|                           | No            | 187 (88 %)        | 25 (12 %)          |                    |
| Opposing teeth            | Missing       | 6 (100 %)         | 0 (0 %)            | 0.804              |
|                           | Sound         | 136 (89 %)        | 17 (11 %)          |                    |
|                           | Filled        | 36 (84 %)         | 7 (16 %)           |                    |
|                           | Crown         | 16 (89 %)         | 2 (11 %)           |                    |
| Tender to percussion      | Yes           | 95 (87 %)         | 14 (13 %)          | 0.128              |
|                           | No            | 99 (89 %)         | 12 (11 %)          |                    |
| Abscess or sinus tract    | Yes           | 35 (83 %)         | 7 (17 %)           | 0.655              |
|                           | No            | 159 (89 %)        | 19 (11 %)          |                    |
| Preoperative pain         | Yes           | 74 (93 %)         | 6 (8 %)            | 0.086              |
|                           | No            | 120 (86 %)        | 20 (14 %)          |                    |
| Length of root canal filling | Adequate   | 162 (90 %)        | 19 (10 %)          | 0.242              |
|                           | Overfilling   | 28 (85 %)         | 5 (15 %)           |                    |
|                           | Underfilling  | 4 (67 %)          | 2 (33 %)           |                    |
| Density of root canal filling | Adequate   | 182 (90 %)        | 21 (10 %)          | 0.039*             |
|                           | Inadequate    | 12 (71 %)         | 5 (29 %)           |                    |
| Postoperative restoration | Intra-coronal | 62 (89 %)         | 8 (11 %)           | 0.927              |
|                           | Extra-coronal  | 132 (88 %)        | 18 (12 %)          |                    |
| Postoperative pain within 1 week | Yes     | 34 (92 %)         | 3 (8 %)            | 0.943              |
|                           | No            | 160 (87 %)        | 23 (13 %)          |                    |
| Age [Mean (SD)]           |               | 46.07 (14.23)     | 48.65 (12.75)      | 0.535              |
| Preoperative pain intensity [Mean (SD)] |      | 1.64 (2.64)      | 1.15 (2.46)        | 0.653              |

*(Full and final multiple logistic regression) (n = 220)*

*p < 0.05
for general dentists [12]. In this study, the success rate of endodontic treatment was similar to other studies using a core-carrier obturation system [12, 24].

Researchers reported teeth with preoperative radiolucency had a lower chance of success [22, 25, 26]. Nair suggested apical periodontitis was a local tissue destruction resulting from the loss of balance between host responses and the presence of a microbial infection originating from the root canal system [27]. At present, a non-surgical endodontic technique that can ensure complete resolution of apical periodontitis is lacking. Failures still occur even though contemporary endodontic techniques with the highest standards and the most careful procedures are used. There might be unknown factors that influence disinfection of inflamed periapical tissue and, hence, the post-treatment healing of a lesion [27]. This provided explanation to a lower success rate for teeth with apical periodontitis than teeth without apical periodontitis in this study.

This study found no significant difference in postoperative pain between the single-visit and multiple-visit treatment groups. Therefore, the second null hypothesis was accepted. The common perception of dentists that multiple-visit endodontic treatment can reduce postoperative pain was therefore not validated [5]. Practically, quite a number of dentists who subjectively preferred multiple-visit treatment on account of the better success rate and reduced postoperative pain were not justified by this study [6].

The third null hypothesis—that there would be no difference in the chairside time used for single-visit and multiple-visit endodontic treatment—was rejected. Better recall of root morphology, established coronal access and reduction of repeated procedures such as application of rubber dam isolation and local anaesthetic allow dentists to shorten the total chairside time. The chairside time was significantly shorter with the use of a magnifying loupe and treatment on single-canal teeth; these findings concurred with another recent study [28]. From the time management point of view, patients could benefit from single-visit treatment. This may be desirable for anxious patients in need of sedation, those who are medically compromised or those who have special needs, hoping for reduced stresses built up prior to a dental visit and reduced treatment-associated risks [29]. Moreover, a single treatment shortens the time for oral rehabilitation because the tooth can be restored to function sooner.

This study found endodontic treatment success was not related to patients’ age or gender. This finding was in agreement with previous studies [23, 30]. However, this study found maxillary teeth showed a better chance of healing than mandibular teeth. This is either not supported by some previous studies [23, 30] or not investigated in other studies [1]. The distribution of the location of the treated teeth depended on the teeth that required endodontic treatment and, therefore, could not be randomised in this study. There were more maxillary teeth (63 %) and less mandibular teeth, especially mandibular anterior teeth, which required endodontic treatment. The tooth status, extent of caries destruction and prognosis were not recorded in this study. Therefore, whether these factors could affect the treatment outcome remains unknown. Contrary to the results of this study, Huumonen and Orstavik reported maxillary lateral incisors showed the poorest healing rate [21]. The great majority of the teeth with failure were posterior teeth. This finding was in agreement with several studies [22–24]. The difference might be explained by the root morphology, multiple canals and greater complexity [1].

Using periapical radiographs for assessment of success in endodontic treatment is a common practice. One of the problems with this assessment method is

| Variable                      | Estimate | 95 % CI | p-value |
|-------------------------------|----------|---------|---------|
| Single-visit treatment        | -27.83   | -33.80  to -21.87 | <0.001  |
| Use of magnifying loupe       | -24.48   | -30.47  to -18.50 | <0.001  |
| Single-canal tooth            | -33.51   | -39.57  to -27.45 | <0.001  |
| Vital tooth                   | 9.40     | 1.44 to 17.36 | 0.021   |

Table 3 The effects of treatment visit and other variables on chairside time

| Table 4 Clinical and radiographic status of the teeth at the final evaluation |
|---------------------------------|-----------------|-----------------|-----------------|
| Treatment group                 | Single-visit    | Multiple-visit  | All             |
|                                 | n = 117 (%)     | n = 103 (%)     | n = 220 (%)     |
| Successful                      |                 |                 |                 |
| No clinical or radiographic     | n = 104 (88.9 %)| n = 90 (87 %)   | n = 194 (88 %)  |
| failure                        |                 |                 |                 |
| (a) Both clinical and radiograph failure | n = 0 (0 %) | n = 2 (1.9 %) | n = 2 (0.9 %) |
| (b) Clinical failure (radiograph not classified) | n = 1 (0.9 %) | n = 1 (1.0 %) | n = 2 (0.9 %) |
| (c) Radiolucent area present, no clinical sign | n = 12 (10.3 %) | n = 10 (9.7 %) | n = 22 (10.0 %) |
| Total (a) + (b) + (c)           | n = 13 (11.1 %)| n = 13 (12.6 %)| n = 26 (11.8 %)|
Conclusions

In this study, the success rate of single-visit and multiple-visit endodontic treatments had no significant difference. There was also no statistical difference in the prevalence of postoperative pain between two treatment groups. The success rate was lower for mandibular teeth and in the presence of apical periodontitis. The chairside time for single-visit treatment was shorter than multiple-visit treatment.

Competing interests
The authors declare they have no competing interests.

Authors’ contributions
AWY Wong and CSC Tsang performed the endodontic treatment. S Zhang performed the evaluation. SKY Li performed the statistical analysis. CF Zhang and CH Chu planned the study and contributed equally to the supervision of the study. All authors read and approved the final manuscript.

Authors’ information
AWY Wong is a general dentist and PhD student, CSC Tsang is a general dentist, S Zhang is a PhD graduate, SKY Li is a statistician, CH Chu and C Fang are clinical associate professors in the Faculty of Dentistry, The University of Hong Kong.

Acknowledgements
The authors wish to thank the participating patients and the involved staff at the Health Service Dental Clinic of The University of Hong Kong for their support in this clinical trial.

Author details
1Faculty of Dentistry, The University of Hong Kong, Hong Kong, China.
2University Health Service, The University of Hong Kong, Hong Kong, China.

Received: 29 May 2015 Accepted: 7 December 2015
Published online: 19 December 2015

References
1. Wong AW, Zhang C, Chu CH. A systematic review of nonsurgical single-visit versus multiple-visit endodontic treatment. Clin Cosmet Invest Dent. 2014;6:45–56.
2. Fleming CH, Litaker MS, Alley LW, Eleazer PD. Comparison of classic endodontic techniques versus contemporary techniques on endodontic treatment success. J Endod. 2010;36(3):414–8.
3. Inamoto K, Kojima K, Nagamatsu K, Hamaguchi A, Nakata K, Nakamura H. A survey of the incidence of single-visit endodontics. J Endod. 2002;28(5):371–4.
4. Netto DSM, Saavedra F, Simi Junior J, Machado R, EJNL S, Vansan L. Endodontists perceptions of single and multiple visit root canal treatment: a survey in Florianópolis - Brazil. RSBO (South Brazilian Dent J). 2014;11:13–8.
5. Wong AW, Zhang S, Zhang CF, Chu CH. Perceptions of single-visit and multiple-visit endodontic treatment: a survey of endodontic specialists and general dentists in Hong Kong. J Investig Clin Dent. 2015;0:1–9.
6. Sathorn C, Paradhos P, Messer H. Australian endodontists’ perceptions of single and multiple visit root canal treatment. Int Endod J. 2009;42(9):811–8.
7. Slaus G, Bottenberg P. A survey of endodontic practice amongst Flemish dentists. Int Endod J. 2002;35(9):759–67.
8. Figini L, Lodj G, Gomi F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth: a Cochrane systematic review. J Endod. 2008;34(9):1041–7.
9. Wahl MJ. Myths of single-visit endodontics. Gen Dent. 1996;44(2):126–31.
10. Peak JD, Hayes SJ, Bryant ST, Dummer PM. The outcome of root canal treatment. A retrospective study within the armed forces (Royal Air Force). Br Dent J. 2001;190(3):140–4.
11. Peak JD. The success of endodontic treatment in general dental practice: a retrospective clinical and radiographic study. Prim Dent Care. 1994;1(9):13.
12. Chu CH, Lo EC, Cheung GS. Outcome of root canal treatment using Thermafil and cold lateral condensation filling techniques. Int Endod J. 2005;38(3):179–85.
13. Polycarpou N, Ng YL, Canavan D, Mole DR, Gulabivala K. Prevalence of persistent pain after endodontic treatment and factors affecting its occurrence in cases with complete radiographic healing. Int Endod J. 2005;38(3):169–78.
14. Chu CH, Lo EC. Patients’ satisfaction with dental services provided by a university in Hong Kong. Int Dent J. 1999;49(1):53–9.
15. Chu CH, Yeung CY, Lo EC. Monitoring patient satisfaction with university dental services under two fee-paying systems. Community Dent Oral Epidemiol. 2001;29(5):390–8.
16. Mohan SM, Kaushik SK. Root canal treatment using thermoplasticized carrier condensation technique. Med J Armed Forces India. 2009;65(4):336–41.
17. Wu MK, Shemesh H, Wesselink PR. Limitations of previously published systematic reviews evaluating the outcome of endodontic treatment. Int Endod J. 2009;42(8):656–66.

18. Chen SK, Oviir T, Lin CH, Leu LJ, Cho BH, Hollender L. Digital imaging analysis with mathematical morphology and fractal dimension for evaluation of periapical lesions following endodontic treatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005;100(4):467–72.

19. Gutmann JL, Baumgartner JC, Gluskin AH, Hartwell GR, Walton RE. Identify and define all diagnostic terms for periapical/periradicular health and disease states. J Endod. 2009;35(12):1658–74.

20. Pirani C, Chersoni S, Montebognoli L, Patti C. Long-term outcome of non-surgical root canal treatment: a retrospective analysis. Odontology. 2015;103(2):185–93.

21. Huumonen S, Orstavik D. Radiographic follow-up of periapical status following endodontic treatment. Clin Oral Investig. 2013;17(9):2099–104.

22. Imura N, Pinheiro ET, Gomes BP, Zaia AA, Ferraz CC, Souza-Filho FJ. The outcome of endodontic treatment: a retrospective study of 2000 cases performed by a specialist. J Endod. 2007;33(11):1278–82.

23. Field JW, Gutmann JL, Solomon ES, Rakusin H. A clinical radiographic retrospective assessment of the success rate of single-visit root canal treatment. Int Endod J. 2004;37(1):70–82.

24. Hale R, Gatti R, Glickman GN, Opperman LA. Comparative analysis of carrier-based obturation and lateral compaction: a retrospective clinical outcomes study. Int J Dent. 2012;2012:954675.

25. Ng YL, Mann V, Gulabivala K. A prospective study of the factors affecting outcomes of nonsurgical root canal treatment: part 1: periapical health. Int Endod J. 2011;44(7):583–609.

26. Chugal NM, Clive JM, Spangberg LS. A prognostic model for assessment of the outcome of endodontic treatment: Effect of biologic and diagnostic variables. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2001;91(3):342–52.

27. Nair PN. Pathogenesis of apical periodontitis and the causes of endodontic failures. Crit Rev Oral Biol Med. 2004;15(6):348–81.

28. Wong AW, Zhu X, Zhang S, Li SK, Zhang C, Chu CH. Treatment time for non-surgical endodontic therapy with or without a magnifying loupe. BMC Oral Health. 2015;15(1):40.

29. Vela KC, Walton RE, Trope M, Windschitl P, Caplan DJ. Patient preferences regarding 1-visit versus 2-visit root canal therapy. J Endod. 2012;38(10):1322–5.

30. Benenati FW, Khajotia SS. A radiographic recall evaluation of 894 endodontic cases treated in a dental school setting. J Endod. 2002;28(5):391–5.

31. Saunders WP, Chestnutt IG, Saunders EM. Factors influencing the diagnosis and management of teeth with pulpal and periradicular disease by general dental practitioners. Part 1. Br Dent J. 1999;187(9):492–7.

32. Friedman S, Mor C. The success of endodontic therapy—healing and functionality. J Calif Dent Assoc. 2004;32(6):493–503.

33. Ray JJ, Kirkpatrick TC. Healing of apical periodontitis through modern endodontic retreatment techniques. Gen Dent. 2013;61(2):19–23.

34. Halse A, Molven O. Increased width of the apical periodontal membrane space in endodontically treated teeth may represent favourable healing. Int Endod J. 2004;37(8):552–60.

35. Cheung GS, Wei W, McGrath C. Agreement between periapical radiographs and cone-beam computed tomography for assessment of periapical status of root filled molar teeth. Int Endod J. 2013;46(10):889–95.

36. Venskutonis T, Plotino G, Tecici L, Gambardini G, Maimiskas J, Juddzbalyus G. Periapical and endodontic status scale based on periapical bone lesions and endodontic treatment quality evaluation using cone-beam computed tomography. J Endod. 2015;41(2):190–6.