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ORIGINAL ARTICLE

Increasing the Apical Sizes of Canal preparation Influences the Outcome of Root Canal treated Single-rooted Teeth with Apical Periodontitis

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ABSTRACT

Objective: To investigate the effect of increasing the apical size of roots enlarged for root canal filling on the outcome of non-surgical endodontic treatment for teeth with apical periodontitis.

Methods: In this retrospective study, a total 210 cases of single-rooted canals treated were included at the dental units between October 2009 and January 2022. The International Organization for Standardization (ISO) standard number of gutta-percha points used for root canal filling and the presence or absence of apical bone resorption on dental radiographs were analysed to evaluate the treatment outcome and analyzed by chi-square test and multivariate logistic regression model.

Results: The number of teeth with a root apical size of ≤50 and ≥55 were 158 and 52, respectively. For the teeth with a root apical size of ≤50, 144 (68.6%) had good prognoses and 14 (6.7%) had poor prognoses. For the teeth with a root apical size of ≥55, 28 (13.3%) teeth had good prognoses and 24 (11.4%) had poor prognoses ($p<0.0001$).

Conclusion: Unfavourable clinical outcomes were observed in root canal-filled teeth with an enlarged apical root size of ≥ 55. Thus, these sizes potentially indicate poor outcomes of nonsurgical endodontic treatments.

Keywords: Apical periodontitis, non-surgical endodontic treatment, single-rooted canal

HIGHLIGHTS

- This study retrospectively investigated the effect of increasing the apical size of roots enlarged for root canal filling on the treatment outcome for non-surgical endodontic treatment of teeth with apical periodontitis.
- A total of 210 cases of single-rooted canals were included and the clinical outcomes of teeth with enlarged root apical size from the ISO standard numbers 25–100 were investigated.
- Of the teeth with a root apical size ≤ 50 (n=158), 144 had good prognoses and 14 had poor prognoses.
- Of the teeth with a root apical size ≥ 55 (n=52), 27 had good prognoses and 25 had poor prognoses.
- Unfavourable clinical outcomes were observed in root canal-filled teeth with an enlarged apical root size of ≥ 55, suggesting that these sizes potentially indicate poor treatment outcomes of nonsurgical endodontic treatments.

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INTRODUCTION

Aseptic procedures to control root canal infection are essential for successful root canal treatment (1, 2). Root canal filling aims to create a tight seal within the root canal to prevent exudate from entering through the apical foramen and bacteria and toxic substances from leaking from the coronal portion of the tooth to the root apex (3, 4). Previous studies have revealed success rates of approximately 80% and 90% for nonsurgical endodontic treatment for teeth with and without periapical lesions, respectively, when the physiological anatomy of the root canal was maintained (5–7). However, healing in cases of nonsurgical root canal treatment is challenging when the morphology of the root canal is severely lost due to external or internal resorption and perforation defects (5).

Under the Japanese insurance system, root canal filling is performed with gutta-percha points and a root canal sealer in cases where the anatomy of the root apex is maintained or lost. When the morphology of the root apex is maintained, the root canal can be adequately sealed by gutta-percha points and root canal sealer. However, even the use of these two materials may not provide favourable clinical outcomes in a tooth with apical periodontitis with a destroyed root apex. Furthermore, poor sealing at the root apex renders bleeding or exudate from the apical periodontal tissue to flow into the root canal, resulting in a poor treatment outcome (8). Additionally, the healing is hampered when the two materials exit the root apex (5). Thus, the maintenance of the morphology of the root apex is considered to have an impact on treatment outcome. The clinical challenge is the inability to determine the extent of root canal destruction. Clinical indicators are indispensable for determining the outcome of root canal treatment. Therefore, this study aimed to retrospectively investigate the effect of increasing the size of the root apex enlarged for root canal filling on the outcome of nonsurgical endodontic treatment for teeth with apical periodontitis.

MATERIALS AND METHODS

Ethics Approval

The Ethics Review Committee for Epidemiological Research at the Hiroshima University approved this study (Registration number: E2022-0015), which was performed in accordance with the Principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects" (amended in October 2013). Consent was obtained via an opt-out method (information disclosure and opportunity for refusal) from the institution's public information website.

Study Participants and Eligibility Criteria

Two hundred and ten teeth of 152 patients that underwent root canal treatment at our dental units between October 2009 and January 2022 were included in the study.

Patients who had been diagnosed with apical periodontitis, and treated by a dentist with at least 5 years of experience, and had single-root canal treated teeth with at least one follow-up visit were included in the study. Patients with severe clenching habits and bruxism and teeth with endodontic-periodontal lesions, perforations, and those that underwent root canal treatment without rubber dam isolation were excluded. Figure 1 shows the study flowchart based on the inclusion and exclusion criteria.

Evaluation of Treatment Outcome

The parameters analysed included age, sex, tooth type, preoperative signs and symptoms, type of treatment, preoperative radiolucency at the apex, and observation period. The International Organization for Standardization (ISO) standard number of gutta-percha points used for root canal filling and the presence or absence of apical bone resorption on dental radiographs were analysed to evaluate the treatment outcome. The outcome after root canal filling according to the pre- and postoperative dental radiographs was evaluated as good when the bone resorption at the root apex disappeared or reduced and poor when it remained unchanged or increased, which was based on a previous report (9). In cases where bone resorption at the root apex disappeared or decreased but patients still experienced subjective symptoms or other clinical issues, the outcome was classified as poor. Postoperative treatments for teeth graded as poor after root canal filling included extraction, apicoectomy, and retreatment of the root canal.

Non-surgical Endodontic Treatment Methods

Non-surgical endodontic treatment was performed as follows. The teeth were isolated using a rubber dam, followed by the determination of the working length using an electric apex locator (Root ZX; Morita Co., Osaka, Japan). The root canals were cleaned and shaped using hand files (RT file; MANI. inc., Tochigi, Japan) using the standardized endodontic technique, accompanied by the use of microscopes and magnifying glasses when needed. Then, 3–10% sodium hypochlorite (NaOCl) (Neo Cleaner; Neo Dental Chemical Products Co., Tokyo, Japan) and 3% EDTA (Smear Clean; Nihon Shika Yakuhin Co., Yamaguchi, Japan) were used as irrigants during treatment, while calcium hydroxide paste (Calcipex Plane II; Nihon Shika Yakuhin Co.) was used as an intracanal medicament. To seal the access opening, a temporary dressing (GC Corporation, Tokyo, Japan) and glass polyalkenoate cement (SHOFU INC, Kyoto, Japan) were used. After multiple visits of root canal therapy (average 4.54 times) were conducted until the symptoms were subsided, bacterial examination using an anaerobic culture system was performed to evaluate the presence or absence of bacteria in the root canals. The root canal filling was performed using lateral compaction in which gutta-percha points (GC Corporation, Tokyo, Japan) and a non-eugenol root canal filling sealer (Canals-N; Showa Yakuhin Kako Co., Ltd.).

Statistical Analysis

Statistical data analysis was performed using JMP Pro software version 17.0 (SAS Institute, USA), and a P-value of 0.05 or less was considered to indicate statistical significance. To compare the success rates between the two groups, a Chi-square test was performed. A multivariate logistic regression model was used to evaluate the relationship between treatment outcome and age groups, sex, tooth type, preoperative signs and symptoms, type of treatment, preoperative radiolucency at the apex, and size of gutta-percha points used for root canal filling. Interaction tests were performed for more analysis in which two models were constructed, as follows: Model 1, involving

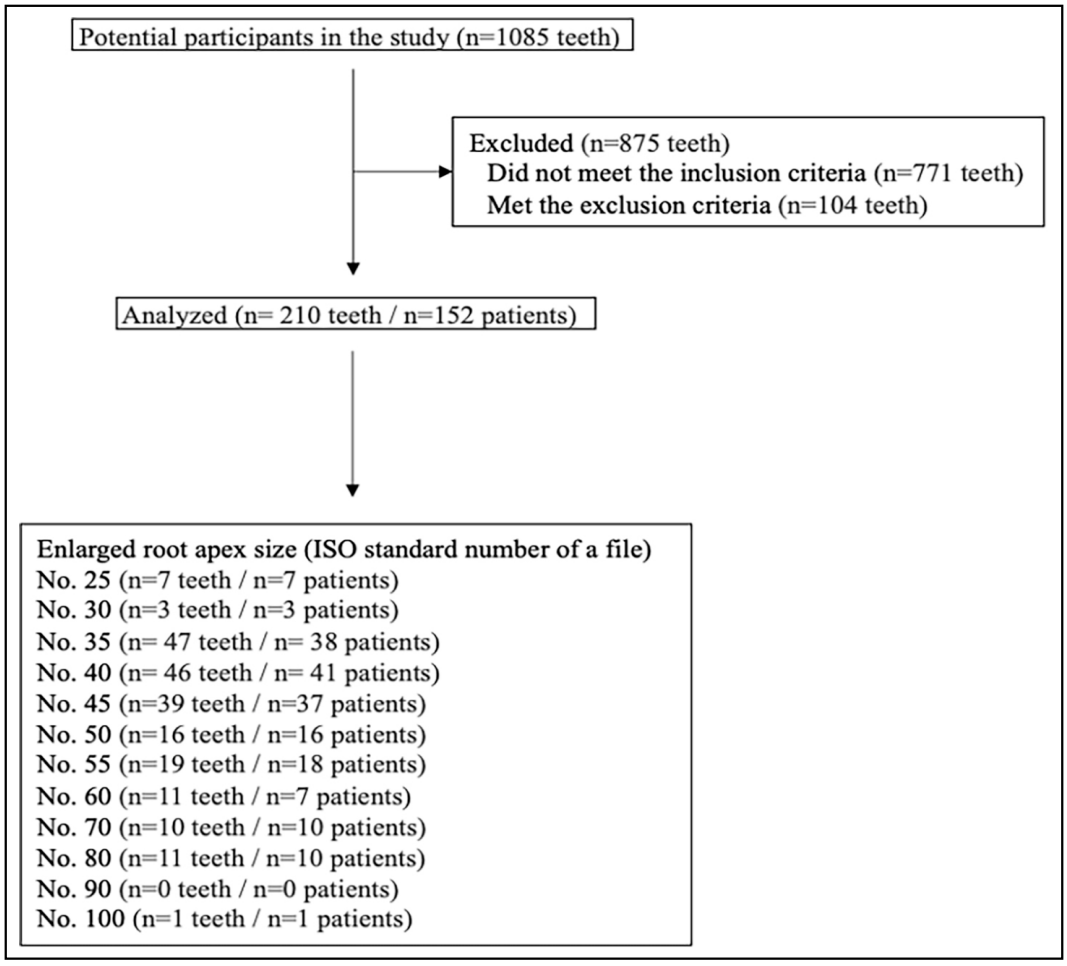

Figure 1. Flowchart of the study with the inclusion and exclusion criteria
ISO: The International Organization for Standardization

no adjustment for covariates; and Model 2, adjusting for all covariates (age groups, sex, tooth type, preoperative signs and symptoms, type of treatment, preoperative radiolucency at the apex, and size of gutta-percha points used for root canal filling).

RESULTS

Between October 2009 and January 2022, 1085 teeth that were diagnosed with apical periodontitis and treated for infected single root canals were selected for the study (Fig. 1). Of these, 210 teeth from 152 patients with a confirmed treatment outcome were evaluated (Fig. 2). The demographic distribution of the cases in this study is shown in Table 1.

The treatment outcome was evaluated according to the ISO standard number of gutta-percha points used for root canal filling (Table 2). The success rate of the teeth with enlarged root apical size of ISO number ≥55 was <70% and that of the teeth with enlarged root apical size of ISO number ≤50, except ISO number 30, was >80% (Table 2). Subsequently, 210 teeth were then examined for treatment outcome for each of the characteristics. There were no significant differences in treatment outcomes for age groups, sex and tooth type. In contrast, significant differences were observed in preoperative signs and symptoms, type of root canal treatment and preoperative radiolucency at the apex. Further, the treatment outcome was assessed based on the number of ISO cases: cases with ISO number of ≤ 50 and those with an ISO number of ≥55; a significant difference in treatment outcome was observed between the two groups (Table 3). Logistic regression analysis was then performed. In Model 1, involving no adjustment for variables, there was a significant difference in treatment outcome between the two groups (odds ratio, 8.81; 95% confidence interval, 4.12–19.55; p<0.0001). Furthermore, after adjusting for variables in Model 2, there was still a significant difference in treatment outcome between the two groups (odds ratio, 5.37; 95% confidence interval, 1.98–14.55; p=0.0009, (Table 4).

DISCUSSION

Teeth with destruction at the root apex (root resorption defects) and teeth with immature roots are the two main categories for teeth with open apex. Root canal treatment of these teeth is challenging owing to the difficulty in determining the working length, removing the infected bacteria, and filling the root canals (10, 11). Currently, no clear definition exists concerning the enlarged size of the root apex in a tooth with an open apex (12, 13). To ensure accurate diagnosis, appropriate treatment, and anticipate the clinical outcome for non-surgical endodontic treatment of teeth with apices, the clinical outcome of teeth with root apical size enlarged from ISO standard numbers from 25 to 100 was investigated in this study. The results showed that the favourable outcome was observed in only 40.0–68.7% for teeth with apical canal en-

Figure 2. Representative cases of apical sizes for root canal filling with ISO number 50 and 55. Before (a) and after (b) treatment of a case of mandibular left second premolar with root canal filling with ISO number 50 gutta-percha points. Two-year follow-up radiograph shows healing of the periapical lesion (good outcome). Before (c) and after (d) treatment of a case of maxillary left central incisor with root canal filling with ISO number 55 gutta-percha points. Seven-month follow-up radiograph does not show healing of the periapical lesion (poor outcome)

ISO: The International Organization for Standardization

TABLE 1. Demographic distribution of the cases

	Total			Total	
	n	%		n	%
Age (year), median (IQR)	67.0 (53–75)		Tooth type		
Sex			Mandibular first premolars	23	10.9
Male	58	38.2	Mandibular second premolars	33	15.7
Female	94	61.8	Preoperative signs and symptoms		
Tooth type			Absent	126	60.0
Maxillary central incisors	37	17.6	Present	84	40.0
Maxillary lateral incisors	41	19.6	Type of treatment		
Maxillary canine	27	12.8	Initial treatment	88	41.9
Maxillary first premolars	2	1	Retreatment	122	58.1
Maxillary second premolars	6	2.9	Preoperative radiolucency at the apex		
Mandibular central incisors	12	5.7	Absent	56	26.7
Mandibular lateral incisors	17	8.1	Present	154	73.3
Mandibular canine	12	5.7	Observation period (month), median (IQR)	16 (7–31.75)	

IQR: Interquartile range

TABLE 2. Treatment outcome after treatment by enlarging the root apical size

ISO standard number of the gutta-percha points used for root canal filling	Total	Good		Poor	
	n	n	%	n	%
25	7	7	100.0	0	0.0
30	3	2	66.7	1	33.3
35	47	43	91.5	4	8.5
40	46	43	93.5	3	6.5
45	39	35	89.7	4	10.3
50	16	14	87.5	2	12.5
55	19	13	68.4	6	31.6
60	11	6	54.5	5	45.5
70	10	4	40.0	6	60.0
80	11	5	45.5	6	54.5
90	0	-	-	-	-
100	1	0	0.0	1	100.0

ISO: The International Organization for Standardization

TABLE 3. Treatment outcome for each study parameter

	Good		Poor		p
	n	%	n	%	
Age groups					
10–19 years	2	0.95	3	1.43	0.4300
20–29 years	6	2.86	1	0.48	
30–39 years	7	3.33	2	0.95	
40–49 years	12	5.71	5	2.38	
50–59 years	28	13.33	5	2.38	
60–69 years	42	20.00	8	3.81	
70–79 years	51	24.29	10	4.76	
80–89 years	20	9.52	4	1.90	
90–99 years	4	1.90	0	0.00	
Sex					
Male	69	32.9	12	5.7	0.3227
Female	103	49.1	26	12.4	
Tooth type					
Maxillary central incisors	23	10.95	14	6.7	0.1262
Maxillary lateral incisors	34	16.2	7	3.3	
Maxillary canine	25	11.9	2	0.95	
Maxillary first premolars	2	0.95	0	0.0	
Maxillary second premolars	5	2.4	1	0.5	
Tooth type					
Mandibular central incisors	11	5.2	1	0.5	
Mandibular lateral incisors	15	7.1	2	0.95	
Mandibular canine	10	4.8	2	0.95	
Mandibular first premolars	18	8.6	5	2.4	
Mandibular second premolars	29	13.8	4	1.9	
Preoperative signs and symptoms					
Absent	111	52.9	15	7.1	0.0047
Present	61	29.1	23	10.9	
Type of treatment					
Initial treatment	80	38.1	8	3.8	0.0029
Retreatment	92	43.8	30	14.3	
Preoperative radiolucency at the apex					
Absent	52	24.8	4	1.9	0.0074
Present	120	57.1	34	16.2	
Size of gutta-percha points used for root canal filling					
≤50	144	68.6	14	6.7	<0.0001
≥55	28	13.3	24	11.4	

TABLE 4. Associations between the size of gutta-percha points used for root canal filling and treatment outcome

	Model 1, OR (95% CI), p	Model 2, OR (95% CI), p
Size of gutta-percha points used for root canal filling (≥55/≤50)	8.81 (4.12–19.55) p<0.0001	5.37 (1.98–14.55) p=0.0009

Interaction tests were performed. Two models were constructed: Model 1, no adjustment for covariates; Model 2, adjusting for all covariates (age groups, sex, tooth type, preoperative signs and symptoms, type of treatment, preoperative radiolucency at the apex, and size of gutta-percha points used for root canal filling). OR: Odds ratio, CI: Confidence interval

largement at sizes >55. These rates indicate that the success rates of non-surgical root canal treatment is impaired when the morphology of the root canal is over-prepared (5–7, 14), suggesting that a tooth with an enlarged root apical size of ISO number ≥55 might have pathological changes in the anatomy of the root apex. Thus, apical root sizes of ISO num-

ber ≥55 upon nonsurgical endodontic treatment are potential clinical indicators of poor prognosis.

This retrospective study has some limitations, such as a small sample size, the absence of data regarding the first apical binding size (FABF), and the unknown history of previous root canal treatment in cases of re-treated teeth. For initial root canal treatment, it has been reported that the enlargement of the canal to three sizes larger than the FABF is adequate (15, 16). However, if the size of the FABF is already large, such as in cases of retreatment or external resorption, we must consider how much enlargement is appropriate. Previous studies have demonstrated the diameter width of the original root apical foramen to be 0.30, 0.35, 0.40, and 0.50 mm for the mandibular anterior teeth, mandibular first premolars, maxillary central and lateral incisors, and mandibular canines, respectively (17, 18), supporting the hypothesis of the current study that teeth with enlarged root apical size of ISO number ≥55 may have a root apex with pathological changes.

In this study, only teeth with an enlarged root apex size of ISO number 30 had a lower rate of good outcome at 66.7% among the teeth with enlarged root apex size of ISO number ≤50; this may be attributable to the small number of cases (n=3).

In contrast to the practices in many countries, such as the United States of America (19–23), the use of mineral trioxide aggregate (MTA) as a root canal filling material is limited by Japanese insurance rules. In the Japanese insurance system, MTA is only applied for direct pulp capping owing to its potent ability for reactionary dentine formation via the induction of two major non-collagenous dentine proteins, Dentin sialophosphoprotein and Dentin matrix protein-1 (24, 25). In the future, clinical trials comparing teeth with enlarged root apical size of ISO ≥55 filled with gutta-percha points and root canal filling sealer and those filled with MTA should be performed. Such trials could pave the way for improved dental treatment options for patients with apical periodontitis.

CONCLUSION

Increasing the apical root size for root canal filling influenced the treatment outcome for teeth affected by apical periodontitis. Moreover, an apical preparation size of ISO number ≥ 55 indicated poor outcomes.

Disclosures

Ethics Committee Approval: The study was approved by the Epidemiological Research at the Hiroshima University Ethics Committee (no: E2022-0015, date: 06/06/2022).

Authorship Contributions: Concept – S.H.T.; Design – S.H.T., D.F., N.S.N.; Supervision – S.H.T., H.S.; Data collection and/or processing – S.H.T., D.F., N.S.N., T.N. T.K., S.N., A.M., S.S., N.S., K.Y., J.N.; Data analysis and/or interpretation – S.H.T., D.F., N.S.N., S.M.; Literature search – S.H.T., D.F., N.S.N.; Writing – S.H.T.; Critical review – S.H.T., C.W., K.T., H.S.

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