Showa Univ J Med Sci **27**(4), 241～249, December 2015

Original

Prognostic Evaluation of Endodontic Retreatment —A Cone Beam Computed Tomography-based Study—

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Abstract: This retrospective study used cone beam computed tomography (CBCT) to evaluate various radiographic prognostic indicators that affect the outcome of root canal retreatment. The study population was selected from consecutive patients examined in the endodontic department from June 1 to December 31, 2013. In total, data were collected for 143 patients (mean age 47.7 years; female: 89, male: 44) who underwent CBCT examination, including 276 roots with periapical radiographs of 158 teeth. CBCT images were re-interpreted independently by one oral radiologist for cases of periapical root resorption and periapical hypercementosis. Nonsurgical endodontic retreatment was indicated for 125 roots, and was subsequently performed by one of four certified endodontists. Each case was followed up and the prognosis was assessed in October 2014. Of 125 root canal-treated cases, 96 were deemed to have a "satisfactory" prognosis, 27 were considered "questionable" and 2 were considered "unsatisfactory". In the 96 "satisfactory" cases, 15 showed periapical hypercementosis, and 51 showed periapical root resorption. The chi-squared test was used to analyze differences between groups. A value of $P < 0.05$ was considered significant. There was a significant difference in the prognosis between the hypercementosis cases and the other groups. Several studies suggest that the presence of root resorption may worsen the prognosis of endodontic treatment. In this study, the presence of root resorption did not affect prognosis. This study provides evidence that CBCT is helpful in evaluating the prognosis of endodontic retreatment cases.

Key words: cone beam computed tomography (CBCT), endodontic retreatment, prognosis, periapical region, hypercementosis, periapical root resorption

Introduction

Cone beam computed tomography (CBCT) allows the morphology of roots and their root canals to be evaluated in three dimensions. De Paula-Silva *et al*[1)] demonstrated the accuracy of CBCT in assessing histopathological conditions, concluding that CBCT was more sensitive in detecting apical periodontitis (AP) than periapical radiography. The diagnostic possibilities of

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Table 1. Characteristics of the study population

Age (y)	Number
≤40	43
40–69	94
≥70	6

Table 2. Characteristics of the included teeth

Location	Number of teeth
Maxilla	100
Mandible	58

Tooth type	Number of teeth
Incisor	46
Premolar	35
Molar	77

Upper molar teeth were most frequently examined.

CBCT extend to endodontic treatment, as shown by Tyndall and Rathore[2] and Patel *et al*[3] demonstrating that CBCT imaging could potentially replace 2-D intraoral imaging, especially for endodontic applications.

The usefulness of CBCT for therapeutic decision-making in endodontics was indicated by Mota de Almeida *et al*[4], whereby differences in endodontic treatment planning were compared before and after CBCT examination. The results showed that over half of the changes in treatment planning were attributed to CBCT findings.

Although a great deal of useful information can be obtained from CBCT, we must also consider that CBCT is a radiographic technique with an exposure dose that is significantly greater than intraoral radiography. To avoid overuse or abuse of CBCT, several guidelines have been published[5, 6]. In order to use CBCT more effectively, retrospective study data related to the prognosis of treatment is required. This retrospective aimed to identify CBCT findings, obtained from endodontic retreatment patients, that are strongly related to an improved endodontic treatment prognosis.

Materials and methods

Study population

Ethical approval for this retrospective study was granted by the institutional review broad, and patient consent was not required. The study population was recruited from the Department of Endodontics at Showa University Dental Hospital from June 1 to December 31, 2013. These patients were referred from private dental clinics because of primary endodontic treatment failure. All patients had been examined using intraoral or panoramic radiography, and a diagnosis of refractory periapical disease was confirmed prior to referral for CBCT examination.

In total, 143 patients were selected for inclusion in this study. Table 1 shows the characteristics of the study population and Table 2 shows the characteristics of the teeth that were examined. The first maxillary molar was most frequently examined.

CBCT imaging protocols

All CBCT examinations were performed with a 3DX Multi-Image Micro CT FPD system (J Morita Manufacturing Corporation, Kyoto, Japan), using the following exposure factors: 90 kV, 5 mA, 360°. Isotopic voxels with a size of 0.08 mm for 40 × 40 mm and 0.25 mm for 60 × 60 mm were used. Image reconstruction was performed in axial, coronal, and sagittal planes. In total, 158 teeth with 276 roots were examined using 3DX.

Clinical treatment planning

After CBCT examination, endodontic treatment was planned and delivered by a certified endodontist, and four of these cases were subsequently analyzed in this study.

Of the 276 CBCT-examined roots, 127 roots were excluded, most commonly due to "fracture" and "examination only", including "treatment declined". The remaining 149 roots were subjected to endodontic treatment; 125 roots were subjected to nonsurgical root canal retreatment and 24 underwent surgical root canal retreatment. In this study, we focused on the nonsurgical endodontic retreatment cases.

Assessment of CBCT images

The study design was independently reviewed and approved by the Institutional Ethics in Research Committee. CBCT images were independently re-evaluated by one radiologist who was blinded to the treatment process. The images were assessed by analysis of the lesion in three dimensions, with CT slices obtained in mesio-distal, bucco-lingual, and oblique directions. All CBCT images were assessed by a licensed maxillofacial radiologist. In this study, the following two conditions were assessed:

Presence of periapical root resorption

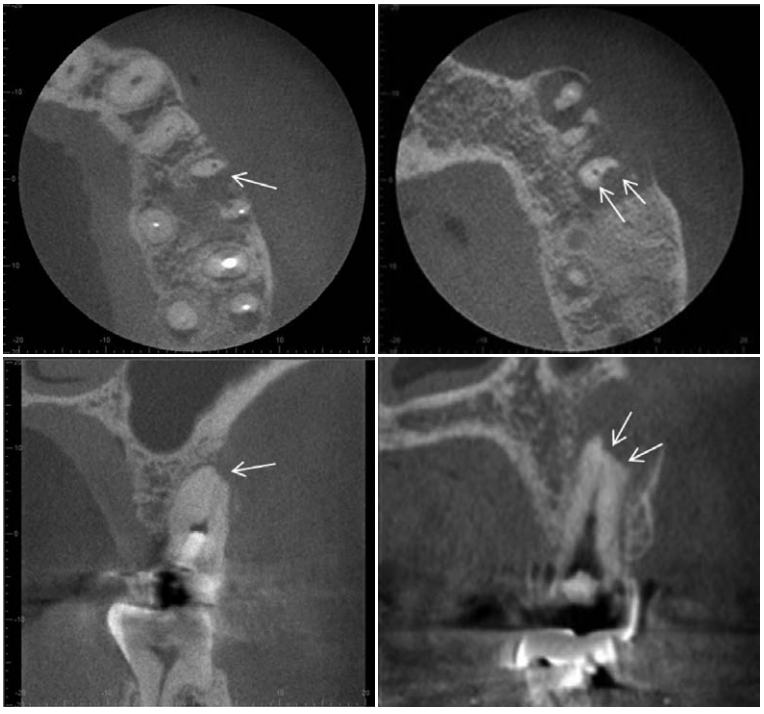
The presence and degree of periapical external root resorption or destruction of the root tip was evaluated according to the American Association of Endodontists Endodontic Case Difficulty Assessment Form. A score for root resorption was given as follows; Grade 0: no resorption evident, Grade 1: minimal apical resorption, Grade 2: extensive apical resorption. Sample images demonstrating these scores are shown in Fig. 1.

Presence of periapical hypercementosis

The presence of hypercementosis of the periapical region was assessed, using the following scores: 0: no hypercementosis, 1: moderate hypercementosis involving less than 1/3 of the root surface, 2: severe hypercementosis involving more than 1/3 of the root surface. Sample images demonstrating these scores are shown in Fig. 2.

Assessment of prognosis

The clinical history of each patient was followed up until October 2014 and the prognosis was subsequently assessed. Patients who had no complications after treatment and who had completed prosthodontic treatment by the end of the follow-up period, were given a score of 3 (satisfactory). If root canal treatment was finished but some complaints still remained, a score



Grade 1 Grade 2

Fig. 1. Sample images for each root resorption score
The presence and degree of periapical external root resorption or destruction of the root tip was evaluated according to the American Academy of Endodontists Endodontic Case Difficulty Assessment Form.
Grade 1 : minimal apical resorption (arrow) seen on the mesiobuccal root of the left maxillary first molar.
Grade 2 : extensive apical resorption (arrows) resorbing almost 1 / 3 of the periapical root surface of the left maxillary second premolar.

NOTE : All 4 photos should be defined.

Fig. 2. Sample images for each hypercementosis score
Score 1 : moderate hypercementosis involving less than 1 / 3 of the root surface, seen on the upper left canine.
Score 2 : severe hypercementosis involving more than 1 / 3 of the root surface, seen on the upper left second premolar.

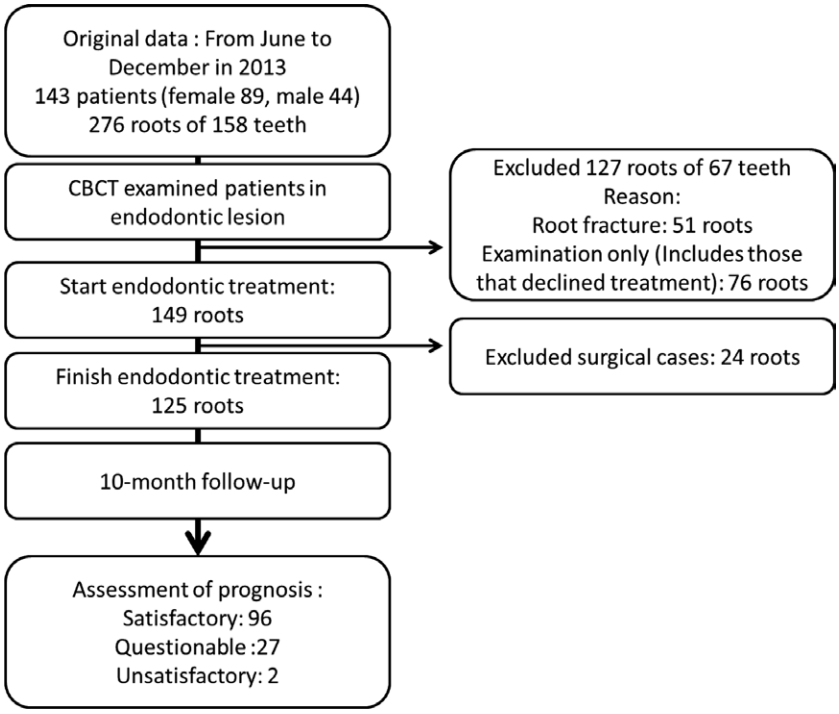


Fig. 3. Study design
The study design and the number of roots at each step are shown. In total, 125 roots were analyzed in this study.

of 2 (questionable) was given. If there was still remaining pain after treatment associated with the tooth, a score of 1 (unsatisfactory) was given. A flowchart of this process is shown in Fig. 3.

Statistical analysis

The relationships between the interpretation of CBCT images and prognosis were assessed by statistical analysis. The chi-squared test was used for analyzing differences in distribution between the groups. A value of $P < 0.05$ was considered statistically significant. Excel Toukei-kaiseki Ver. 7 (Esumi Co. Ltd., Tokyo, Japan) and JMP Pro Ver. 11.00 were used in this study for statistical analyses.

Results

Treatment prognosis

In this study, we considered the prognosis as "satisfactory" for cases that underwent endodontic and prosthodontic treatment, without any patient complaints after the treatment was completed. In total, 96 root canal treated cases were considered "satisfactory", 27 were considered "questionable", and 2 were considered "unsatisfactory".

Interpretation of CBCT images

Table 3 shows the prevalence of periapical root resorption and periapical hypercementosis

Table 3. Prevalence of periapical root resorption and periapical hypercementosis

Prognosis : periapical root resorption	1	2	3
Grade 0 : no resorption (no root surface breakdown)	1	14	45
Grade 1 : root surface roughness	0	9	32
Grade 2 : obvious resorption (root surface breakdown evident)	2	4	19

Prognosis : 1 = unsatisfactory, 2 = questionable, 3 = satisfactory

Prognosis : hypercementosis	1	2	3
Score 0 : no hypercementosis	0	25	81
Score 1 : moderate hypercementosis	2	2	9
Score 2 : severe hypercementosis	0	0	6

Prognosis : 1 = unsatisfactory, 2 = questionable, 3 = satisfactory

A significant difference in the distribution of hypercementosis and prognosis was noted.

using 3DX in endodontic treatment cases. Severe hypercementosis was only seen in the satisfactory prognosis group. There was a significant correlation between the presence of hypercementosis and a "satisfactory" prognosis, suggesting that a root with hypercementosis is more likely to have a favorable endodontic outcome.

Discussion

There is no study on the relationship of the findings obtained from CBCT and the prognosis of retreatment of endodontics. This study presents the first analysis of CBCT findings with respect to prognosis following endodontic retreatment. The results indicated that periapical root resorption did not significantly affect the prognosis and that hypercementosis seems to show a significant positive effect on endodontic prognosis.

The use of CBCT in endodontics facilitates the identification of periapical root resorption and periapical hypercementosis, especially in multi-rooted teeth that are often difficult to examine using 2-D radiography. Several studies have assessed CBCT for periapical assessment prior to endodontic retreatment ; however, there is currently insufficient information available to determine the relationship between these findings and prognosis. Based on our results, the presence of hypercementosis appeared to be related to an improved prognosis for endodontic treatment.

Estrela *et al*[7] proposed a new periapical index based on CBCT, and assessed the accuracy of detecting inflammatory root resorption (IRR) using CBCT. They concluded that IRR was detected in 100% (154 root surfaces) of the CBCT scans. Venskutonis *et al*[8] presented a new complex diagnostic periapical and endodontic status scale by means of CBCT analysis, focusing on root resorption. Several authors expressed concerns about the ability to accurately detect resorption, perforavtions, and vertical and horizontal root fractures using CBCT[9–11]. Periapical root resorption and hypercementosis may occur secondary to a periapical lesion, although despite recent studies on periapical root resorption, literature investigating hypercementosis appears to be

limited.

In this study, we focused on the morphology of the periapical region and the prognosis of endodontic retreatment. Gorni and Gagliani[12] compared the success rate of root canal retreatment cases with and without anatomical root canal morphological change by using periapical radiograph. The success rate of root canal treatment in morphology-altered (RCMA) cases was 47%, compared with 86.8% in the root canal morphology-respected (RCMR) group. They concluded that the clinical success of endodontic retreatment is dependent on alterations in the natural course of root canals caused by the primary root canal treatment.

In a histopathological study to assess the presence of hypercementosis, Ricucci *et al*[13] analyzed persistent symptoms after appropriate endodontic treatment and considered the need for surgical endodontic retreatment based on histological and histobacteriological investigations. They noted that hypercementosis presented in some areas as a thick multilayered band of normal cementum, whereas in other areas it manifested as an irregular deposition of calcified tissue on the external radicular surface with deficiencies entrapping necrotic debris. They also noted that bacterial biofilms of endodontic origin had formed between the layers of the apical cementum.

In a separate study, Lin *et al*[14] focused on the histopathological assessment of nonsurgical root canal treatment cases with large, cyst-like periapical lesions. They noted that during periapical wound healing, cells from the remaining viable periodontal ligament in adjacent root surfaces had proliferated to cover the root surfaces where the periodontal ligament and surface cementum had been damaged by inflammation and removed by activated macrophages. This phenomenon might be one of the reasons for periapical root resorption in endodontically treated teeth. Also, following cementum resorption in mature teeth, the extracellular matrix and growth factors of the sequestered cementum are capable of inducing proliferation, migration, attachment, and differentiation of the multipotent stem cells of the periodontal ligament into cementoblasts, thereby producing cementum on the root surface denuded of periodontal ligament. The etiology of hypercementosis is thought to be related to this process.

Noiri *et al*[15] morphologically examined the role of extraradicular biofilm in refractory periapical periodontitis, and concluded that bacterial biofilms formed in extraradicular areas were related to refractory periapical periodontitis. They suggested that such biofilm formation resulted from the resorption associated with the periapical root surface. And this was suspected to contaminate the root surface. However, in the present study, the periapical surface resorption did not correlate with a worsened prognosis, and hence it does not appear to be an important factor in the assessment of prognosis. This apparent discrepancy may be related to the development of new endodontic instruments and techniques enabling improved treatment outcomes.

Recent technical advancements (microscopic endodontic treatment, surgical microscope, ultrasonic retrotips, new root-end materials, nickel-titanium instruments, rotary systems, *etc.*) and reviewed retreatment strategies have changed the scope of endodontic retreatment and, potentially, endodontic decision making. Previous studies have demonstrated that the presence of hypercementosis impairs our ability to visually assess the apical portion of root canals on a periapical radiograph, thereby contributing to reduced endodontic treatment predictability. However, in our

study, the presence of hypercementosis was related to an improved prognosis. Hypercementosis occurs secondary to an inflammatory reaction in the periapical region, and its presence suggests cellular activity associated with the periapical root surface. It is therefore possible that in combination with the aforementioned advancements in endodontic microtechnology, which allow more thorough intracanal debridement, teeth with hypercementosis without less contamination improved healing because of this periapical cellular activity. However, further research is required to investigate this theory.

In this study, we focused on conventional orthograde root canal retreatment cases and excluded surgical cases. In a future study, we plan to investigate the factors related to favorable treatment outcomes in surgical retreatment cases.

In conclusion, we followed up 276 CBCT-examined roots. In the 125 root canal retreated cases, the prognosis tended to be favorable in cases with hypercementosis. This study provides evidence that CBCT is useful in assessing the prognosis of nonsurgical endodontic retreatment cases. This is also the first report suggesting that hypercementosis is associated with improved outcomes in nonsurgical endodontic retreatment cases, based on CBCT assessment. Furthermore, our findings suggest that the presence of periapical resorption does not affect the prognosis of root canal treatment.

Conflict of interest disclosure

The authors have declared no conflict of interest.

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[Received May 29, 2015 : Accepted August 5, 2015]