Cone-beam computed tomography in the assessment of periapical lesions in endodontically treated teeth

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Abstract

Objective: This study aimed to evaluate the relationship between the quality of the coronal restoration and the root canal filling on the periapical status of endodontically treated teeth using CBCT. Materials and Methods: CBCT data were obtained from the records of patients who deny any dental treatment in the 2 years prior to the CBCT examination. CBCT images (90 kVp and 7 mA, exposure time of 23 s, and a voxel size of 0.2 mm, with a field of view of 13 cm × 13 cm) of 1011 endodontically treated teeth were observed. A score was given to the quality of the root filling and the quality of the coronal restoration. Statistical Analysis Used: Data were statistically analyzed to correlate the periapical status with gender, dental group, and quality of endodontic treatment and restoration (Chi-square test with a significance level of P < 0.001). Results: Absence of periapical periodontitis was found in 54.9% of the cases. The periapical outcome was not related to gender or dental group (P > 0.05). A statistically significant factor (Chi-square test, P < 0.0001) resulted when different qualities of sealing were compared. Conclusions: CBCT showed that high-quality root canal treatments followed by an adequate coronal sealing restoration avoid the presence of periapical periodontitis in time.

Key-words: Cone-beam computed tomography, endodontic treatment, periapical periodontitis, restorative

Introduction

In 1995, Ray and Trope evaluated the relationship between the quality of coronal restoration, root canal obturation, and the radiographic periapical status of endodontically treated teeth. They found a radiologic success rate of 61.07% and stated that the technical quality of the coronal restoration had a greater impact on the endodontic success (defined as the radiographic absence of periapical radiolucency) than the technical quality of the endodontic obturation.¹

In literature, there is consensus on the importance of hermetic three-dimensional, apical and coronal seal to prevent bacterial reinfecion of root canals after endodontic treatment.²-⁶ On the other hand,
the statement about the quality of coronal sealing being more important than the root canal obturation is controversial and has been corroborated by some studies[7,8] and not supported by others.[9-14]

The evaluations on endodontic success have been mainly performed by means of only periapical radiographs,[1,10,12,14,15] combined with clinical examination[7,9,16] and, more recently, it has been performed by means of cone-beam computed tomography (CBCT).[14,17] The use of CBCT technology overcome the two-dimensional limitation of the radiographic images and improved the accuracy in the detection of periapical lesions compared to other dental radiographic means.[18-23]

Clinical and histological studies have shown that CBCT enables the detection of apical periodontitis before they would be apparent on the conventional radiographs, presenting findings closer to the gold standard, which is the histologic evaluation.[18,24] The detection of apical lesions in radiographs is adequate only when there is a significant mineral bone loss, due to the reduced size in early stages, anatomical noise, and poor irradiation geometry.[18,25,26] This means that radiographs present a low predictive value to detect the periapical disease or confirm the health status, while CBCT minimizes the false diagnoses and provides superior validity and reliability.[18,24-26] Therefore, it has been suggested that the assessment of the success of endodontic treatment derived from only a two-dimensional evaluation of periapical radiographs may be insufficient.[22,26-28]

The endodontic treatment ideally should be clean, disinfect, and seal all the root canals and their ramifications, aiming to prevent or cure the apical periodontitis.[29] However, even the most modern techniques are not capable to completely overcome the complex root canal anatomy neither provide a perfect seal. Therefore, the influence of both quality of root canal treatment and coronal restoration on the long-term success of endodontic treatment is still a current topic of investigation.[14,5,12,13,17]

Given the increased diagnostic capacity of CBCT, the aim of this retrospective study was to use this three-dimensional examination to evaluate the relationship of the quality of root canal obturation and coronal restoration on the periapical status of endodontically treated teeth, using a study design similar to the one described by Ray and Trope in 1995.[1]

**MATERIALS AND METHODS**

Images were obtained from the records of patients visited for implant placement and/or surgical therapies and consequently were scanned with CBCT prior to any treatment. Ethical Committee protocol number was 528/17 and informed consent was obtained from all the individual participants included in the study. A total of 232 patients were randomly selected (age range between 25 and 65 years), who had not received any dental treatment in the 2 years prior to the CBCT examination.

The CBCT images were taken by using the Gendex GXDP-500 (Gendex Dental, Biberach, Germany), operated at 90 kVp and 7 mA, with exposure time of 23 s and a voxel size of 0.2 mm, with a field of view of 13 cm × 13 cm. A total of 1011 endodontically treated teeth were selected for this research. The main inclusion criterion was the presence of previous endodontic treatment, i.e., radiopaque material placed inside the root canal space. However, the teeth restored with posts and/or presented large metal restorations or metallic crowns were excluded, to prevent biased analyses from scattering and beam hardening.

Before the evaluation and scoring, an oral radiologist and an endodontist were calibrated based on the criteria and variables established. The calibration included reviewing a random set of 100 images of endodontically treated teeth in a PowerPoint (Microsoft, Redmond, WA) presentation.[4] Inter-examiners’ agreement during the calibration resulted in a high kappa score (0.81). The CBCT scans were evaluated in a room with a dimmed light, simultaneously by the two reviewers to reach a consensus for the interpretation. The images were examined by using specific software (i-CAT Vision, Imaging Sciences International, Hatfield, PA) in a personal computer running under Microsoft Windows XP Professional (Microsoft Corp, Redmond, WA). The monitor used to view the images was a 22” flat screen with a resolution of 1680 × 1050 pixels. The raters were allowed to adjust brightness, contrast, and zoom. For the evaluation of the quality of restorations, a panoramic image perpendicular to the dental arch was created by using a curved MPR.

The quality of their endodontic obturation and coronal restoration was categorized as follows:

1. Good endodontic filling (GE): All the canals were obturated, with no visible voids, and apical limit of the obturation was in the 0–2 mm range short to the apex [Figure 1a-c]
2. Poor endodontic filling (PE): One or more of the above-stated criteria\(^1\) were not met [Figure 1d, e and f]

3. Good restoration (GR): Any permanent restoration that appeared to have an adequate radiographic marginal seal [Figure 1a and e]

4. Poor restoration (PR): Teeth without a restoration, or presenting any restoration that did not meet the above criteria\(^3\) or presented signs of open margins and/or over- or under-filled restorations [Figure 1b and c].

The CBCT apical health status of apical one-third and surrounding structures was evaluated by a modified CBCT periapical index (CBCTPAI score).\(^{[27]}\)

The CBCTPAI consists of an ordinal 6-point (0–5) scale ranging from no disease to severe periodontitis with two additional variables, expansion bone and destruction of cortical bone. The CBCTPAI score is given by the largest extension of the lesion, measured in three dimensions (buccal, palatal, mesiodistal, and diagonal). In the present research, aiming to establish a comparison with Ray and Trope’s study, the CBCTPAI score was adapted as follows:

- Absence of periapical lesion (APL): CBCTPAI 0 (intact periapical bone structures) presenting the contour, width, and structure of the periodontal ligament normal or slightly widened (≤0.5 mm) if an excess of filling material was present [Figure 1a and b]
- Presence of periapical lesion (PPL): presence of periapical radiolucency with the diameter >0.5 mm (CBCTPAI 1 or greater) [Figure 1c-e].

The multirooted teeth were ranked according to the root with the worst score. Data were statistically analyzed to correlate the periapical status with gender, dental group, and quality of endodontic treatment and restoration (Chi-square test with a significance level of \(P < 0.001\)). The combinations of treatment quality were contrasted with their respective percentages of APL and PPL outcome (Z proportions’ test). The logistic regression models were estimated for each of the variables to determine the odds ratios (ORs) of PPL outcome (significance level of \(P < 0.05\)).

**RESULTS**

The results showed that 555 teeth (54.9%) met the success criteria of APL, while 45.1\% \((n = 456)\) of endodontically treated teeth presented PPL on CBCT. Table 1 presents the periapical status according to gender, dental group, and quality of endodontic treatment and restoration. The periapical outcome was not related to gender or dental group \((P > 0.05)\). The good quality of both endodontic treatment and restoration significantly presented more APL \((P < 0.0001)\). The odds of PPL outcome was 2.01 (95% confidence interval [CI]: 1.52–2.66) times greater for the PE compared to GE, while it was 1.84 (95% CI: 1.43–2.36) times greater for the PR compared to GR.

The different combinations of treatment quality were found to be a statistically significant factor (Chi-square test, \(P < 0.0001\)). Table 2 presents the outcomes of the periradicular status according to the combinations of treatment for all teeth, also when separated into anterior and posterior. The combination of GE/GR resulted in the greatest APL outcome, followed by GE/PR. The teeth with PE/GR presented with significantly more PPL compared to GE/GR and lower than PE/PR. The PE/PR teeth resulted in the worst outcome, with statistically more PPL than APL, and the OR shows that it is 3.3 times more probable to present PPL compared to GE/GR.

For the anterior teeth, the combinations of GE/PR and PE/GR were intermediate but not significantly different from the higher APL outcome (GE/GR) or the lower (PE/PR). For the posterior teeth, the teeth with both PE/GR and PE/PR presented significantly less APL than GE/GR. The OR showed that for the anterior teeth, the PE/PR combination is 2.7 times
more probable to present PPL while for posterior teeth the OR is 3.7.

**DISCUSSION**

One of the fundamental assumptions of scientific studies is the reproducibility, in order to allow the confirmation or refusal of previous findings. The 1995’ Ray and Trope’s cross-sectional study\[11\] has been reproduced by different research groups and in different populations, as shown in Table 3.

Unfortunately, regardless of the geographic location and some differences in the methodology, most of these epidemiological studies presented high rates of inadequate root fillings and a prevalence of periapical radiolucencies varying from 32.5% to 67%\[4,7,9,11,13,15\]. In the present study, the overall prevalence of lesions in endodontically treated teeth was 45.1%, which is within the range reported in the literature.

Differently, cohort studies with controlled clinical environments and standardized techniques have

### Table 1: Periapical status for endodontically treated teeth according to different factors

| Gender          | n  | PPL, n (%) | APL, n (%) | P* | OR (95% ICW) |
|-----------------|----|------------|------------|----|--------------|
| Female          | 480| 232 (43.05)| 248 (56.95)| 0.159| 1.00 (reference) |
| Male            | 531| 224 (47.45)| 307 (52.55)| 1.19| (0.93-1.53) |
| Dental group    |    |            |            |    |              |
| Maxillary anterior | 154| 71 (46.10)| 83 (53.90)| 0.926| 1.00 (reference) |
| Mandibular anterior | 55 | 24 (43.63)| 31 (56.37)| 0.90| (0.49-1.68) |
| Maxillary bicuspid | 218| 93 (42.66)| 125 (57.34)| 0.87| (0.57-1.31) |
| Mandibular bicuspid | 136| 59 (43.38)| 77 (56.62)| 0.89| (0.56-1.42) |
| Maxillary molar | 225| 107 (47.56)| 118 (52.44)| 1.06| (0.70-1.59) |
| Mandibular molar | 223| 102 (45.73)| 121 (54.27)| 0.98| (0.65-1.49) |
| Endodontic treatment |    |            |            |    |              |
| Good (GE)       | 311| 104 (33.44)| 207 (66.56)| <0.0001| 1.00 (reference) |
| Poor (PE)       | 700| 352 (50.28)| 348 (49.72)| 2.01| (1.52-2.66) |
| Coronal restoration |    |            |            |    |              |
| Good (GR)       | 564| 217 (38.48)| 347 (61.52)| <0.0001| 1.00 (reference) |
| Poor (PR)       | 447| 239 (53.47)| 208 (46.53)| 1.84| (1.43-2.36) |

*Chi-square test. PPL: Presence of periradicular lesion, APL: Absence of periradicular lesion, OR: Odds ratio, Wald confidence interval (95%). GE: Good endodontic, GR: Good restoration, PR: Poor restoration, PE: Poor endodontic

### Table 2: Periapical status for various combinations of treatment quality

| Coronal restoration | n  | PPL, n (%) | APL, n (%) | OR (95% ICW) |
|---------------------|----|------------|------------|--------------|
| Good (GE)           | 194| 58 (29.90) | 136 (70.10)| 1.00 (reference) |
| Good (GE)           | 117| 46 (39.32) | 71 (60.68)| 1.52 (0.93-2.46) |
| Poor (PE)           | 370| 159 (42.97)| 211 (57.03)| 1.76 (1.22-2.56) |
| Poor (PE)           | 330| 193 (58.48)| 137 (41.52)| 3.30 (2.26-4.81) |
| Total               | 1011| 456 (45.10)| 555 (54.90)|              |
| Anterior            |    |            |            |              |
| Good (GE)           | 74 | 25 (33.78) | 49 (66.22)| 1.00 (reference) |
| Good (GE)           | 22 | 11 (50.00) | 11 (50.00)| 1.96 (0.75-5.14) |
| Poor (PE)           | 68 | 33 (48.53) | 35 (51.47)| 1.85 (0.94-3.64) |
| Poor (PE)           | 45 | 26 (57.78) | 19 (42.22)| 2.68 (1.25-5.75) |
| Total               | 209| 95 (45.45) | 114 (54.55)|              |
| Posterior           |    |            |            |              |
| Good (GE)           | 120| 33 (27.50) | 87 (72.50)| 1.00 (reference) |
| Good (GE)           | 95 | 35 (36.84) | 60 (63.16)| 1.53 (0.86-2.74) |
| Poor (PE)           | 302| 126 (41.72)| 176 (58.28)| 1.89 (1.19-2.99) |
| Poor (PE)           | 285| 167 (58.60)| 118 (41.40)| 3.73 (2.34-5.94) |
| Total               | 802| 361 (45.01)| 441 (54.99)|              |

Different superscripts in lowercase letters indicate statistically significant difference within the column of each section. Different superscripts in uppercase letters indicate statistically significant difference within row (Z-test). GE: Good endodontic, GR: Good restoration, PR: Poor restoration, PE: Poor endodontic, OR: Odds ratio, PPL: Presence of periradicular lesion, APL: Absence of periradicular lesion, Wald confidence interval (95%)
shown higher success rates (85%–90%).[16,30] Indeed, a cross-sectional study design has some limitations because it provides information about a population at one point in time, and there are no information about how the root canal treatments were performed. Of the four factors influencing the outcome of root canal treatment identified in a systematic review,[3] three can be assessed in a transversal study: the quality of coronal restoration, the density of the obturation, and its apical extent; the only lacking factor is the preoperative apical status. Since there are no available information about the pathological history and systemic conditions of the patients, it is not possible to determine whether if the apical lesion is healing or progressing. However, in the present study, only patients who reported to have not received any dental treatment in the last 2 years before the CBCT scans were selected. This is a consistent period of time in order to detect apical alterations after an endodontic treatment.[22,31] Moreover, the substantial number of randomly selected patients/teeth compensates the misdiagnoses that might occur in a cross-sectional study, validating the meaning of the results.[22]

The present study design was as similar as practically possible to Ray and Trope’s,[1] the same amount of randomly selected teeth was evaluated, with similar selection and evaluation criteria. However, more than replicating a study, it is important to detect the relevant parameters that might influence the experimental protocol. In this sense, there are three main differences between the 1995’s and the present study: (1) the use of CBCT, aiming at more accurate diagnosis of the periapical status; (2) the comparison among dental groups; and (3) the technical improvements that occurred in dentistry in these two decades.

Compared to Ray and Trope,[1] we found more deviations in our study leading to categorizing unsatisfactory treatments and more periapical lesion diagnosis. The percentage of GE, GR, and overall success rate was lower, as well as the APL percentage in GE/GR, GE/PR, and PE/GR [Table 3]. Our study diagnosed higher number of PPL 456 versus 372, 5 from Ray and Trope (45.1% vs. 38.93%, respectively), and our number of PE/PR is almost doubled (330 vs. 188, respectively, 41.52% vs. 18.1%).

| Year | Authors               | Country      | Evaluation | n   | GE (%) | GR (%) | Overall (%) | GE/GR (%) | GE/PR (%) | PE/GR (%) | PE/PR (%) |
|------|-----------------------|--------------|------------|-----|--------|--------|-------------|------------|------------|------------|------------|
| 1995 | Ray and Trope         | The United   | RX         | 985 | 50.2   | 64.2   | 60.07       | 91.4       | 44.1       | 67.6       | 18.1       |
| 2000 | Tronstad et al.       | Norway       | RX         | 1001| 50.5   | 66.2   | 67.4        | 80.8       | 71.1       | 56.2       | 57         |
| 2002 | Hommez et al.         | Belgium      | RX/clinical| 745 | 34.3   | 67.4   | 67.5        | 79.3       | 65.9       | 68.1       | 56.8       |
| 2003 | Dugas et al.          | Canada       | RX/clinical| 383 | 38.9   | 42.3   | 42.3        | 51.0       | 60.8       | 46.7       | 43         |
| 2004 | Segura-Egea et al.    | Spain        | RX         | 93  | 34.4   | 35.48  | 35.5        | 68.8       | 37.5       | 29.4       | 25         |
| 2005 | Siqueira et al.       | Brazil       | RX         | 2051| 56.9   | 46.7   | 47.1        | 71.2       | 65.3       | 37.9       | 18         |
| 2008 | Georgopoulou et al.   | Greece       | RX         | 1120| 42.5   | 45.5   | 45          | 60.8       | 32.9       | 43.9       | 32.4       |
| 2009 | Tavares et al.        | France       | RX         | 1035| 19.13  | 64.54  | 67          | 93.5       | 82.2       | 64.1       | 56         |
| 2011 | Gunduz et al.         | Turkey       | RX         | 1014| 41.9   | 30.6   | 32.1        | 76.2       | 45         | 10.8       | 3.7        |
| 2013 | Kalender et al.       | Cyprus       | RX         | 2200| 38.2   | 93     | 38          | 77.2       | 64.7       | 23.1       | 5.2        |
| 2013 | Moreno et al.         | Columbia     | RX         | 1086| 33.2   | 39.9   | 51          | 66         | 56         | 52         | 43         |
| 2014 | Song et al.           | South Korea  | RX/clinical| 1030| 35.6   | 68.6   | 59.1        | 82.3       | 56.3       | 54.7       | 41.2       |
| 2015 | Gomes et al.          | Brazil       | CBCT       | 1290| 55.12  | 94.73**| 48.83       | 59.44      | 51.52      | 37.13      | 22.85      |
| 2015 | Present study         | Italy        | CBCT       | 1011| 30.76  | 55.78  | 54.9        | 70.1       | 60.68      | 57.03      | 41.52      |

*Number of roots. **Only the presence of coronal restorations was evaluated. GR: Good restoration, PR: Poor restoration, PE: Poor endodontic treatment, GE: Good endodontic, RX: Radiographic, CBCT: Cone-beam computed tomography, APL: Absence of periapical lesion
extension, increasing the reliability of the data.\cite{27} In this perspective, when comparing our results with Ray and Trope’s,\cite{41} the shift in success rate from 61.07\% (1995) to the present 54.9\% is lesser than expected. We consider our findings as a result of endodontic improvement in the last two decades. Similarly, recent CBCT studies reported an overall absence of lesions in 48, 83\%\cite{4} and 54.4\%,\cite{17}

The quality of root filling has been categorized in the literature with different methodologies. However, not only the length of the obturation but also the lateral seal (absence of voids) has been correlated with the periapical status.\cite{33} Regarding the overall quality of treatment, our percentage of GE and GR was lower than that of most of the previous studies [Table 3]. This is mainly explained by the increased capacity of CBCT to detect voids and precisely define the apical extent of root canal fillings.\cite{26,31} While the periapical radiographs can only provide the mesiodistal aspect, thus underestimating the presence of voids,\cite{34} the CBCT might lead to an overestimation.\cite{35} Liang et al.\cite{18} showed that approximately 10\% of filling with adequate length in the X-rays appeared too long in the CBCT and also that the detection of voids was three times greater with the three-dimensional examination.

In accordance with most of the previous studies, the present success rate of endodontic treatment was positively correlated with the good technical quality of the root filling.\cite{2,9‑14,33} However, differently as stated by Ray and Trope,\cite{1} in the present study, the endodontic obturation had a slightly higher impact than restoration in the long-term success of the endodontic treatment. Results from the present study are similar to Hommez et al.\cite{7} which reported that the periapical status was not significantly influenced by the quality of restoration when combined with a GE. Some researchers also showed that endodontic quality had significantly higher impact on the outcome of endodontic treatments.\cite{9,10,14}

The present study results showed odds of PPL outcome 1.84 greater when a PR was present, while Ray and Trope reported OR of 11.12 (95\% CI: 8–15.47). Recently, Gomes et al.\cite{4} using CBCT reported only a 0.6 times OR for a healthy periapical condition with the presence of coronal restoration when compared with its absence. These authors did not report the quality of restorations due to impossibility of elimination of artifacts, which means that good and badly adapted restorations were categorized as the same. In fact, the CBCT evaluation of both coronal restorations and endodontic fillings might be complicated due to scattered X-ray artifacts.\cite{36} The CBCT has been reported in the evaluation of the quality of restorations and detection of caries.\cite{17,37,38} In the present study, the cases that presented images with scattered artifacts were excluded (e.g., metallic posts and large metal restorations) and the criteria for the quality of restorations were limited to its marginal sealing, which is similar to an evaluation of a standard radiographic examination. Even though, as many other previous studies evaluate only images (X-rays or CBCT), the lack of clinical evaluation could be itself a potential bias.\cite{38}

The anatomic complexities of the root canal system are more frequently found in bicuspids and molars.\cite{39} Some previous studies have demonstrated the correlation between posterior endodontically treated teeth with PPL.\cite{2,4} Although in the Ray and Trope’s\cite{1} study the difference among dental groups was not described, in the present study, this factor was also investigated. Results showed that the anatomic group was not a significant factor with the presence of PPL [Table 1]. However, since a larger number of posterior teeth were evaluated (802 vs. only 209 anterior), the statistical analysis was also performed for these distinct groups regarding the different combinations of treatment quality [Table 2]. The results showed that for posterior teeth, the PE/GR presented a significantly higher percentage of PPL compared to GE/GR and lesser than PE/PR. For anterior teeth, excluding the GE/GR combination, there were no relevant differences among the other combinations of treatment quality. This means that the quality of restoration was slightly more relevant for the posterior teeth. Furthermore, for the combination of PE/PR, the odds of presenting PPL was 3.7 for posterior teeth, while for anterior, it was 2.7 times greater when compared to GE/GR.

A 10-year radiographic follow-up study by Kirkevang et al.\cite{40} showed that PE primarily affected the risk of PPL and, to a smaller extent, the risk of extraction, whereas a PR primarily affected the risk of extraction and, to a smaller extent, the PPL. Our results showed that the quality of endodontic treatment was slightly more relevant than restoration in the APL outcome; the PR teeth presented significantly more PPL than teeth with GR, which means that clinically both quality of restoration and obturation are relevant to obtain endodontic success. This is in agreement with different previous researches and one meta-analysis which addressed no significant differences in the odds of healing between GE/PR and PE/GR.\cite{8‑7}
Finally, the criteria used by Ray and Trope,\(^1\) defining the presence of radiolucencies as inflammation, are not appropriate because sometimes healing may result in fibrous scar tissue, which is radiographically indistinguishable from an apical granuloma.\(^4\) However, there is no available imaging examination to determine the histological content of a radiographic apical lesion; therefore, the PPL is still currently related to clinical failure. Although the CBCT is a reliable tool for the diagnosis of periapical status, the long-term success of endodontically treated teeth might consider not only the absence of periapical lesions, but also the criteria of a functional and asymptomatic tooth. Future researches should combine clinical evaluation of coronal restoration integrity and CBCT monitoring of the apical status, for a more complete understanding of endodontic outcomes.

**CONCLUSIONS**

Congruent with Ray and Trope,\(^1\) results of the present study confirm that the combination of both high-quality endodontic obturation and coronal restoration increases the success of endodontically treated teeth. However, the coronal restoration quality had a lesser impact on endodontic treatment outcome than the root canal obturation.

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**Conflicts of interest**

There are no conflicts of interest.

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