10.5005/jp-journals-10024-1070

ORIGINAL RESEARCH


# Quantitative Digital Subtraction Radiography in the Assessment of External Apical Root Resorption Induced by Orthodontic Therapy: A Retrospective Study

**Raghavendra Sunku, R Roopesh, Pavan Kancherla, Kiran Kumar Perumalla, Palla Venkata Yudhistar, V Sridhar Reddy**

## ABSTRACT

**Aim:** The objective of this study was to evaluate density changes around the apices of teeth during orthodontic treatment by using digital subtraction radiography to measure the densities around six teeth (maxilla central incisors, lateral incisors, and canines) before and after orthodontic treatment in 36 patients and also assess treatment variables and their coorelation with root resorption.

**Materials and methods:** A total of 36 consecutive patient files were selected initially. The selected patients presented with a class I or II relationship and were treated with or without premolar extractions and fixed appliances. Some class II patients were treated additionally with extraoral forces or functional appliances. External apical root resorption (EARR) per tooth in millimeters was calculated and was also expressed as a percentage of the original root length. Image reconstruction and subtraction were performed using the software Regeemy Image Registration and Mosaicing (version 0.2.43-RCB, DPI-INPE, São José dos Campos, São Paulo, Brazil) by a single operator. A region of interest (ROI) was defined in the apical third of the root and density calibration was made in Image J® using enamel (gray value = 255) as reference in the same image. The mean gray values in the ROIs were reflective of the change in the density values between the two images.

**Statistical analysis:** The root resorption of the tooth and the factors of malocclusion were analyzed with a one-way ANOVA. An independent t-test was performed to compare the mean amount of resorption between male and female, between extraction and nonextraction cases. The density changes after orthodontic treatment were analyzed using the Wilcoxon signed-rank test. In addition, the density changes in different teeth were analyzed using the Kruskal-Wallis test. The cut-off for statistical significance was a p-value of 0.05. All the statistical analyses were carried out using SPSS (version 13.0 for Windows, Chicago, IL, USA).

**Results:** Gender, the age at which treatment was started and Angle's classification was not statistically related with observed root resorption. The mean percentage density reduction as assessed by DSR was greatest in both central incisor: by 27.2 and 25.2% in the upper-right and upper-left central incisors, respectively, followed by the upper-right and upper-left canine teeth (23.5 and 21.0%) and then the upper-right and upper-left lateral incisors (19.1 and 17.4%).

**Conclusion:** Tooth extraction prior to treatment initiation and the duration of orthodontic treatment was positively correlated with the amount of root resorption. DSR is useful for evaluating density changes around teeth during orthodontic treatment. The density around the apices of teeth reduced significantly after the application of orthodontic forces during treatment.

**Clinical significance:** Assessment of density changes on treatment radiographs of patients undergoing orthodontic therapy may help in the monitoring of external apical root resorption during course of treatment.

**Keywords:** External apical root resorption, Digital subtraction radiography, Orthodontic therapy.

**How to cite this article:** Sunku R, Roopesh R, Kancherla P, Perumalla KK, Yudhistar PV, Reddy VS. Quantitative Digital Subtraction Radiography in the Assessment of External Apical Root Resorption Induced by Orthodontic Therapy: A Retrospective Study. J Contemp Dent Pract 2011;12(6):422-428.

**Source of support:** Nil

**Conflict of interest:** None declared

## INTRODUCTION

External apical root resorption (EARR) is one of the unfavorable outcomes of orthodontic therapy and has been defined as a reduction in the length of the root from the apex. It is calculated by measuring the entire tooth length, incisal edge to apex in anterior teeth and cusp tip to the most apical point of the root in posterior teeth, both before and after treatment.[1,2]

Various studies, both histologic and radiographic, have attempted to study this phenomenon but produced conflicting results regarding the association of apical resorption with orthodontic treatment which can be attributed to variation in methodology, which limits the comparability of results. In addition, radiographic studies can evaluate only apical root resorption; however, buccal or lingual resorption is less perceptible in the radiographs.[1,3] Although histologic or scanning electronic microscopic investigations provide exact results, but they can only be conducted on single representative teeth and may not be feasible in many clinical situations. Therefore, studies based on larger samples, within and between patients can be performed by using only radiological methods.[4]

In orthodontics, the diagnosis of EARR using conventional radiographs (periapicals, panoramic, lateral cephalograms and various combinations) has been extensively studied.[2,5-9] However, as multitude of factors play a role in interpretation of radiographs and a mineral loss of at least 30 to 60% is required to detect a defect on radiographs, the radiographic detection of early EARR is often not possible by radiographs alone.

Early detection of initial resorptive lesions during orthodontic treatment is essential for identifying teeth at risk of severe resorption.[10] Subsequent interruption of active treatment can help to reduce adverse outcomes during treatment at a later stage.[11]Hence, the possibility of early detection can serve as the basis for appropriate treatment planning or modification of existing treatment plan.

To determine early EARR density changes, quantitative measurements must be recorded. Digital subtraction radiography (DSR) offers this possibility. Limits of detection with DSR *vs* conventional radiographs show that DSR is more sensitive to even minor density changes.[12] However, accurate registration of the images and minimizing the amount of structured noise present in the subtracted images are profound concerns.

Therefore, the aim of this retrospective study was to quantitatively assess the changes of the root area and length of the maxillary and mandibular incisors following orthodontic treatment by means of DSR of panoramic radiographs, as well as to assess whether such changes are related to type and duration of orthodontic treatment.

## MATERIALS AND METHODS

For the appropriate selection of number of patients for this investigation, a power analysis for sample size calculation with $\alpha = 0.05$, $1\text{-}\beta = 0.8$, and effect size index $d = 0.7$ was performed. Calculations revealed that a sample of at least 19 patients was necessary. However, more patients were initially included to account for eventual exclusions.

This retrospective study was based on panoramic radiographs of patients taken with the same equipment (PlanmecaProMax, Planmeca Oy, Finland) before and after orthodontic treatment. These radiographs were part of the standard diagnostic records and consecutively selected from the archives of the Postgraduate Clinic of the Department of Orthodontics. Informed written consent was obtained from all patients or their guardians.

A total of 36 consecutive patient files were selected initially. The selected patients presented with a class I or II relationship and were treated with or without premolar extractions and fixed appliances. Some class II patients were treated additionally with extraoral forces or functional appliances. All treatments were performed by the students of the department under the supervision of faculty members. Inclusion criteria were complete records, including patient history and treatment plans, study casts, pre- and post-treatment panoramic and lateral cephalometric radiographs. Patients with history of trauma or endodontic treatment of the maxillary incisors or incomplete records were excluded from the sample (n = 2). Thus, 34 patients (19 females and 15 males) remained for further evaluation (Tables 1 and 2).

**Table 1:** Sample distribution

| *Variables* | | *N* |
|---|---|---|
| Sex | Male | 15 |
| | Female | 19 |
| Angle's classification | Class I | 12 |
| | Class II, Division 1 | 13 |
| | Class II, Division 2 | 4 |
| | Class III | 5 |
| Extraction | Nonextraction | 12 |
| | Extraction | 22 |

**Table 2:** Variables assessed in the study (continuous)

| *Variables* | *Mean ± SD* | *Minimum* | *Maximum* |
|---|---|---|---|
| Age at start (year) | 13.10 ± 6.05 | 9.08 | 18.42 |
| Overbite (mm) at start | 1.43 ± 2.50 | –4.32 | 14.59 |
| Overjet (mm) at start | 1.97 ± 3.41 | –8.25 | 12.47 |
| Change in overbite (mm) | 1.50 ± 1.48 | 0 | 7.07 |
| Change in overjet (mm) | 2.26 ± 2.06 | 0 | 10.95 |
| Treatment duration (months) | 12.84 ± 7.88 | 5 | 22.10 |

### Geometric Image Registration and Digital Subtraction

Image reconstruction and subtraction were performed using the software Regeemy Image Registration and Mosaicing (version 0.2.43-RCB, DPI-INPE, São José dos Campos, São Paulo, Brazil) by a single operator. This software offered geometric image registration to accommodate differences in projection geometry between images. This registration attempted to produce two images with identical image projection geometry by mapping the information contained in one image onto the projection plane of another image, called the reference image using manually chosen landmarks on the crowns of teeth (Figs 1 and 2). The registered images were then normalized to eliminate contrast differences and subjected to quantitative subtraction with Image J®,

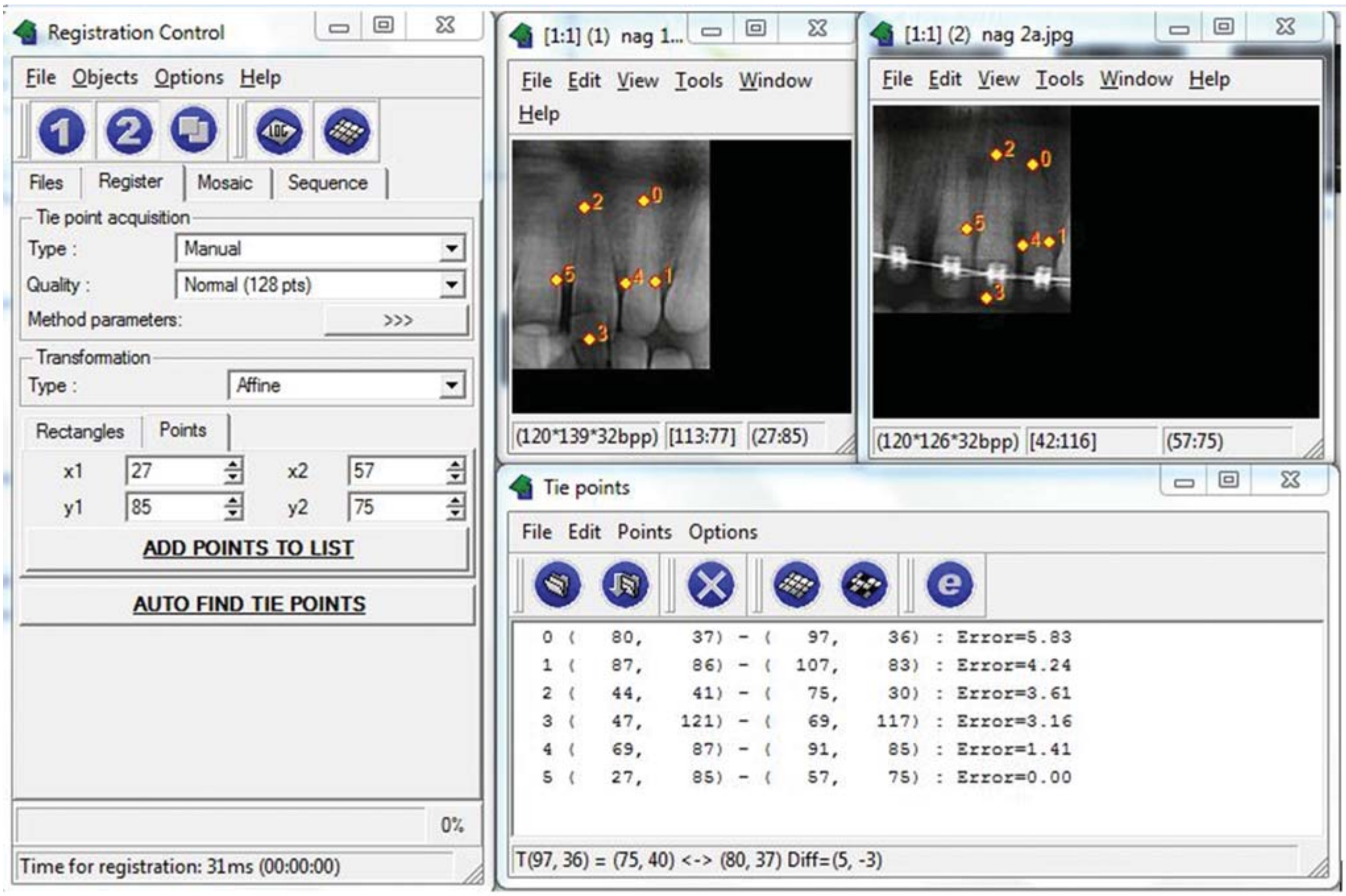


**Fig. 1:** Image registration

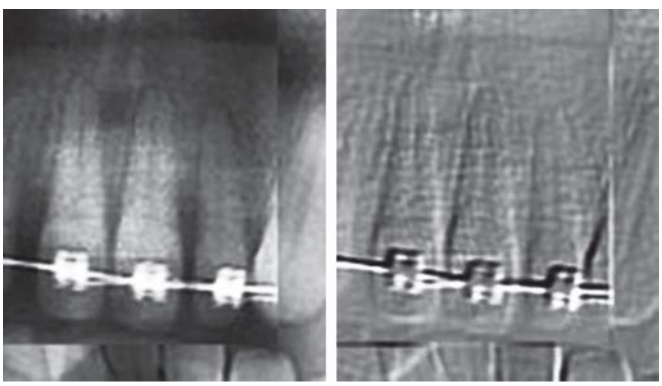

**Fig. 2:** Subtraction of registered images

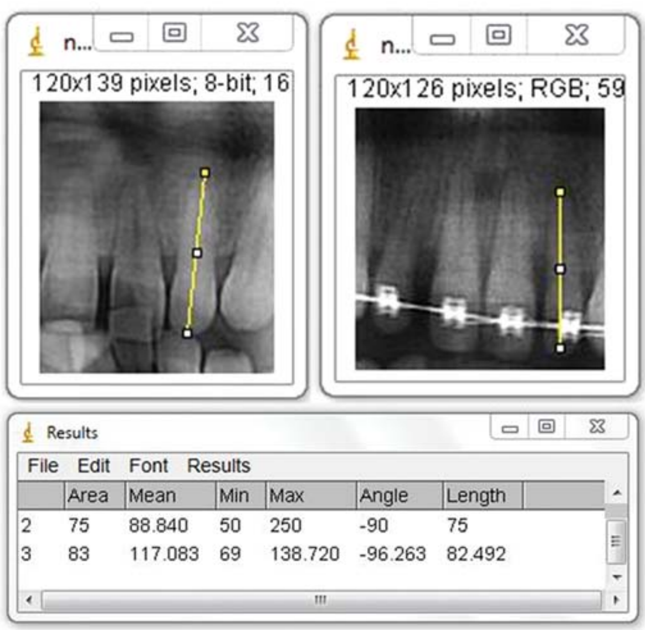


**Fig. 3:** Linear measurements from incisal edge to apex on registered image

developed by National Institutes of Health, Bethesda, Maryland, USA. A region of interest (ROI) was defined in the apical third of the root and density calibration was made in Image Tool using enamel (gray value = 255) as reference in the same image. The mean gray values in the ROIs were reflective of the change in the density values between the two images (Figs 3 and 4).

EARR per tooth in millimeters was calculated using the following formula: EARR = R1-R2. Where, R1 is the root length on the pretreatment radiograph, R2 on the follow-up radiograph. EARR was also expressed as a percentage of the original root length: EARR × 100/R1. Since the images were registered to negate differences in projection geometry, the application of correction factor to compensate for the same was inessential. The density values for only the maxillary anteriors was assessed as lower anterior regions

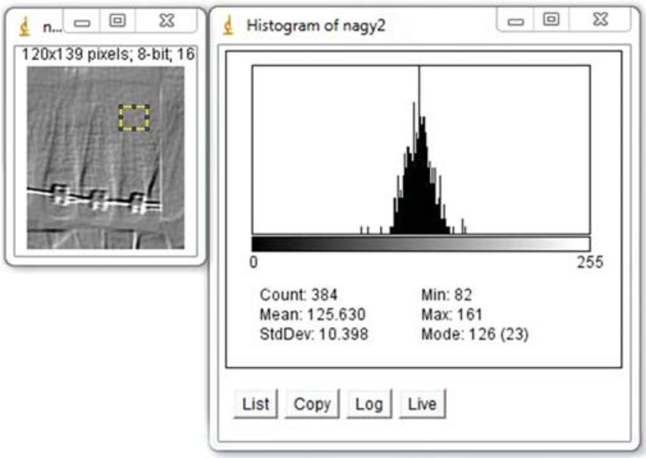


**Fig. 4:** Density measurement of ROI on subtracted image following calibration

in OPGs suffering from fuzziness, distortion and overlapping while other variable measurements were made on both the maxillary as well as mandibular anteriors.

## STATISTICAL ANALYSIS

The root resorption of the tooth and the factors of malocclusion were analyzed with a one-way ANOVA. An independent t-test was performed to compare the mean amount of resorption between male and female, between extraction and nonextraction cases. The correlation coefficients were measured between the amount of root resorption and the age of the start of orthodontic treatment, changes in overbite, overjet and the duration of treatment. The density changes after orthodontic treatment were analyzed using the Wilcoxon signed-rank test. In addition, the density changes in different teeth were analyzed using the Kruskal-Wallis test. The cut-off for statistical significance was a p-value of 0.05. All the statistical analyses were carried out using SPSS (version 13.0 for Windows, Chicago, IL, USA).

## RESULTS

Gender the age at which treatment was started and Angle's classification were not statistically related with observed root resorption. The maxillary central incisor showed the greatest resorption, followed by the maxillary lateral incisor, the mandibular central incisor, and the mandibular lateral incisor. Significant correlations between the change in overbite and the amount of root resorption were found in maxillary and mandibular central incisors and mandibular lateral incisors. For overjet, there was no significant correlation (Table 3). Openbite cases showed more root resorption for maxillary and mandibular central incisors, and mandibular lateral incisors (Table 4). Tooth extraction

**Table 3:** Correlation between the amount root resorption and changes in overbite and overjet (n = 34)

| *Teeth* | *Change in overbite* | | *Change in overjet* | |
|---|---|---|---|---|
| | *r* | *p* | *r* | *p* |
| Maxillary canine | –0.108 | 0.052 | –0.005 | 0.931 |
| Maxillary lateral incisor | –0.031 | 0.572 | 0.030 | 0.594 |
| Maxillary central incisor | –0.112* | 0.043 | –0.010 | 0.853 |
| Mandibular central incisor | –0.138* | 0.013 | –0.054 | 0.330 |
| Mandibular lateral incisor | –0.142* | 0.010 | –0.064 | 0.251 |
| Mandibular canine | –0.101 | 0.067 | –0.024 | 0.665 |

*Pearson correlation, significant at the 0.05 level

prior to treatment initiation was significantly related with posttreatment root resorption (Table 5). The duration of orthodontic treatment was positively correlated with the amount of root resorption ($p < 0.01$, Table 6).

In all patients, with the exception for the apical portion of the upper-left lateral incisor (UL2), the density around the maxilla anterior teeth reduced by 24.3 ± 11.2% (mean ± standard deviation); range 1.8 to 48.0% following the orthodontic treatment.

The mean density reduction was greatest in both central incisor: by 27.2 and 25.2% in the upper-right and upper-left central incisors, respectively (Table 7); followed by the upper-right and upper-left canine teeth (23.5 and 21.0%) and then the upper-right and upper-left lateral incisors (19.1 and 17.4%) (Table 7).

## DISCUSSION

Tooth extraction prior to treatment initiation and the duration of orthodontic treatment was positively correlated with the amount of root resorption. However, gender, the age at which treatment was started and Angle's classification was not statistically related with observed root resorption.The maxillary central incisor showed the greatest resorption, followed by the maxillary lateral incisor, the mandibular central incisor, and the mandibular lateral incisor in concurrence with Spurrier et al and McFadden et al.[13,14]

In our study, all patients, with the exception for the apical portion of the upper-left lateral incisor (UL2), the density around the maxilla anterior teeth reduced by 24.3 ± 11.2% (mean ± standard deviation); range 1.8 to 48.9% following the orthodontic treatment .The mean density reduction was greatest in both central incisor by 27.2 and 25.2% in the upper-right and upper-left central incisors, respectively, followed by the upper-right and upper-left canine teeth (23.5 and 21.0%) and then the upper-right and upper-left lateral incisors (19.1 and 17.4%).

On the other hand, radiographic examination is still left, much to be desired as a diagnostic tool: First of all, because

**Table 4:** The amount of root resorption and overbite at start of treatment

| *Tooth* | *Root resorption** | | | |
|---|---|---|---|---|
| | *Openbite* | *0-4 mm* | *Deepbite* | *p* |
| Maxillary canine | 0.37 ± 0.81 | 0.26 ± 0.51 | 0.15 ± 0.38 | 0.143 |
| Maxillary lateral incisor | 0.71 ± 0.77 | 0.78 ± 0.81 | 0.71 ± 0.70 | 0.747 |
| Maxillary central incisor | 0.95 ± 0.97 | 0.78 ± 0.74 | 0.57 ± 0.54 | 0.046** |
| Mandibular canine | 0.32 ± 0.45 | 0.24 ± 0.45 | 0.16 ± 0.24 | 0.172 |

*Note:* *Average and standard deviation (mm) for this variable. **One-way ANOVA, significantly more root resorption for openbite at the 0.05 level

**Table 5:** Comparison between extraction and nonextraction groups and amount of root resorption

| *Teeth* | *Root resorption** | | |
|---|---|---|---|
| | *Nonextraction (n = 12)* | *Extraction† (n = 22)* | *Total (n = 34)* |
| Maxillary canine | 0.10 ± 0.31 | 0.44 ± 0.69 | 0.26 ± 0.55 |
| Maxillary lateral incisor | 0.52 ± 0.47 | 1.03 ± 0.96 | 0.76 ± 0.79 |
| Maxillary central incisor | 0.60 ± 0.67 | 0.98 ± 0.82 | 0.78 ± 0.76 |
| Mandibular central incisor | 0.39 ± 0.40 | 0.62 ± 0.67 | 0.50 ± 0.56 |
| Mandibular lateral incisor | 0.38 ± 0.45 | 0.63 ± 0.52 | 0.50 ± 0.50 |
| Mandibular canine | 0.14 ± 0.22 | 0.35 ± 0.56 | 0.24 ± 0.43 |

*Note:* *Mean and SD (mm) for this variable, †Extraction group significantly had more root resorption than nonextraction group by independent samples t-test ($p < 0.01$)

**Table 6:** Correlation between treatment duration and the amount of root resorption

| *Tooth* | *r* | *p* |
|---|---|---|
| Maxillary canine | 0.284 | 0.000 |
| Maxillary lateral incisor | 0.438 | 0.000 |
| Maxillary central incisor | 0.332 | 0.000 |
| Mandibular central incisor | 0.394 | 0.000 |
| Mandibular lateral incisor | 0.361 | 0.000 |
| Mandibular canine | 0.264 | 0.000 |

**Table 7:** Percentage density (grayscale value) reductions (mean ± standard deviation values) around the teeth in the apical portion of the 36 patients during orthodontic treatment

| *Tooth* | *UR3* | *UR2* | *UR1* | *UL1* | *UL2* | *UL3* | *Mean ± SD* |
|---|---|---|---|---|---|---|---|
| Percentage density (Apical) | 23.5 ± 13.9 | 19.1 ± 12.1 | 27.2 ± 8.1 | 25.2 ± 9.0 | 17.4 ± 12.3 | 21.0 ± 10.5 | 24.9 ± 11.2 |

*Note:* UR3: upper-right canine; UR2: upper-right lateral incisor; UR1: upper-right central incisor; UL1: upper-left central incisor; UL2: upper-left lateral incisor; UL3: upper-left canine.

of frequent disagreement among evaluators on its interpretation and discrepancies of the same evaluator's interpretation at different times, secondly, many dental lesions often progress slowly, so they cannot be easily evaluated with sequentially obtained radiographs and thirdly, structural 'noise' produces visual confusion and limits the detection of small lesions.

Several noninvasive methods can be used to measure the density, including digital image analysis of microradiographs,[15] dual energy X-ray absorptiometry[16,17] and ultrasound.[18] However, all of these approaches have inherent limitations, such as nonavailability of three-dimensional information and the evaluation being only qualitative. Computed tomography (CT) is one of the most useful medical image techniques for obtaining data on both the structure and density of body tissue. However, CT is not an acceptable approach for evaluating the alveolar bone density during orthodontic treatment due to its high radiation dosage, especially given that patients typically need several CT scans over several months.

The strength of digital subtraction radiography (DSR) is because it cancels out the complex anatomic background, against which the subtle changes occur. As a result, the conspicuousness of the changes is greatly increased. A change in mean calcium mass per image pixel of 0.1 to 0.15 mg is necessary to be detected by DSR. DSR possesses high accuracy to detect small changes in calcium mass.[19]

One disadvantage of digital subtraction radiography techniques, as used presently, is the need for close to identical projection alignment during the exposure of the sequential radiographs. Furthermore, highly specialized computer image processing equipment and software is required for image analyses.

However, some limitations of this study should be considered. Some previous studies have found that the measured grayscale value of an object might vary with the medical software used,[20,21] but, the values obtained with different software programs were found to be strongly correlated. Further, it is important to consider at what stage of orthodontic treatment the density is assessed. It is plausible that depending on the type, duration and direction of force during active tooth movement would determine the net density at the time of evaluation.

Only the teeth in the anterior region of the maxilla were evaluated as mandibular anterior regions in OPGs suffer from fuzziness, distortion and overlapping. The relationship between the density change and direction of tooth movements was also not investigated in this study, and the density around the teeth was only measured at only two time points (before institution and after completion of orthodontic treatment), with no long-term follow-up or assessment at different time intervals during various stages of orthodontic treatment. Further studies, addressing these limitations will be required.

## CONCLUSION

- Within limitations of this study, we conclude that gender, the age at which treatment was started and Angle's classification are not related with observed root resorption.
- Tooth extraction prior to treatment initiation and the duration of orthodontic treatment, was positively correlated with the amount of root resorption.
- The mean density reduction, as assessed by DSR was greatest in the upper-right and upper-left central incisors, respectively, followed by the upper-right and upper-left canine teeth and then the upper-right and upper-left lateral incisors.

## REFERENCES

1. Brezniak N, Wasserstein A. Root resorption after orthodontic treatment: Part 1. Literature review. Am J Orthod Dentofacial Orthop 1993;103:62-66.
2. Hendrix I, Carels C, Kuijpers-Jagtman AM, van't Hof M. A radiographic study of posterior apical root resorption in orthodontic patients. Am J Orthod Dentofacial Orthop 1994; 105:345-49.
3. Reukers E, Sanderink G, Kuijpers-Jagtman AM, van't Hof M. Assessment of apical root resorption using digital reconstruction. Dentomaxillofac Radiol 1998;27:25-29.
4. Fritz U, Diedrich P, Wiechmann D. Apical root resorption after lingual orthodontic therapy. J Orofac Orthop 2003;64:434-42.
5. Lee RY, Artun J, Alonzo TA. Are dental anomalies risk factors for apical root resorption in orthodontic patients? Am J Orthod Dentofacial Orthop 1999;116:187-95.
6. McNab S, Battistutta D, Taverne A, Symons AL. External apical root resorption following orthodontic treatment. Angle Orthod 2000;70:227-32.
7. Harris EF, Butler ML. Patterns of incisor root resorption before and after orthodontic correction in cases with anterior open bites. Am J Orthod Dentofacial Orthop 1992;101:112-19.
8. Sameshima GT, Asgarifar KO. Assessment of root resorption and root shape: Periapical vs panoramic films. Angle Orthod 2001;71:185-89.
9. Beck BW, Harris EF. Apical root resorption in orthodontically treated subjects: Analysis of edgewise and light wire mechanics. Am J Orthod Dentofacial Orthop 1994;105:350-61.
10. Levander E, Malmgren O. Evaluation of the risk of root resorption during orthodontic treatment: A study of upper incisors. Eur J Orthod 1988;10:30-38.
11. Levander E, Malmgren O, Eliasson S. Evaluation of root resorption in relation to two orthodontic treatment regimes. A clinical experimentalstudy. Eur J Orthod 1994;16:223-28.
12. Christgau M, Hiller KA, Schmalz G, Kolbeck C, Wenzel A. Quantitative digital subtraction radiography for the determination of small changes in bone thickness: An in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998; 85:462-72.
13. Spurrier SW, Hall SH, Joondeph DR, Shapiro PA, Riedel RA. A comparison of apical root resorption during orthodontic treatment in endodontically treated and vital teeth. Am J Orthod Dentofacial Orthop 1990;97:130-34.
14. McFadden WM, Engstrom C, Engstrom H, Anholm JM. A study of the relationship between incisor intrusion and root shortening. Am J Orthod Dentofacial Orthop 1989;96:390-96.
15. Jager A, Radlanski RJ, Taufall D, Klein C, Steinhofel N, Doler W. Quantitative determination of alveolar bone density using digital image analysis of microradiographs. Anatomischer Anzeiger 1990;170:171-79.
16. Drage NA, Palmer RM, Blake G, Wilson R, Crane F, Fogelman I. A comparison of bone mineral density in the spine, hip and jaws of edentulous subjects. Clin Oral Implants Res 2007, 18:496-500.
17. Oltramari PV, Navarro Rde L, Henriques JF, Taga R, Cestari TM, Janson G, Granjeiro JM. Evaluation of bone height and bone density after tooth extraction: an experimental study in minipigs. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:e9-16.
18. Al Haffar I, Padilla F, Nefussi R, Kolta S, Foucart JM, Laugier P. Experimental evaluation of bone quality measuring speed of sound in cadaver mandibles. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;02:782-91.
19. M Christgau, Hiller KA, Schmalz G, Kolbeck C, Wenzel A. Accuracy of quantitative digital subtraction radiography for determining changes in calcium mass in mandibular bone: An in vitro study. J Periodontal Res Apr 1998;33(3):138-49.
20. de Oliveira RC, Leles CR, Normanha LM, Lindh C, Ribeiro-Rotta RF. Assessments of trabecular bone density at implant sites on CT images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008,105:231-38.

21. Lagravere MO, Carey J, Ben-Zvi M, Packota GV, Major PW. Effect of object location on the density measurement and Hounsfield conversion in a NewTom 3G cone beam computed tomography unit. Dentomaxillo Facial Radiology 2008;37:305-08.

## ABOUT THE AUTHORS

### Raghavendra Sunku

Reader, Department of Orthodontics and Dentofacial Orthopedics, MNR Dental College and Hospital, Sangareddy, Andhra Pradesh, India

### R Roopesh (Corresponding Author)

Professor, Department of Orthodontics, PMS College of Dental Science and Research, Vattappara, Thiruvananthapuram, Kerala, India
e-mail: dr.roopesh@gmail.com

### Pavan Kancherla

Reader, Department of Orthodontics, Lenora Institute of Dental Sciences, Rajahmundry, Andhra Pradesh, India

### Kiran Kumar Perumalla

Reader, Department of Orthodontics and Dentofacial Orthopedics Mamta Dental College, Khammam, Andhra Pradesh, India

### Palla Venkata Yudhistar

Reader, Department of Orthodontics and Dentofacial Orthopedics Mamata Dental College, Khammam, Andhra Pradesh, India

### V Sridhar Reddy

Professor, Department of Oral Pathology, Rungta College of Dental Science and Research, Bhilai, Chhattisgarh, India