A CBCT comparison of anterior root resorption in SureSmile and conventional edgewise treatments

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Aim: To utilize cone beam computed tomography (CBCT) to analyze the amount of linear root resorption that occurs in maxillary and mandibular permanent incisors during orthodontic treatment when comparing the SureSmile technique with conventional edgewise treatment. In addition, patient and treatment factors that may be correlated with root resorption were studied.

Methods: The records of 28 patients (14 SureSmile and 14 edgewise) treated in an orthodontic office were used for this study. CBCTs were taken of all patients prior to (T1) and after completion of orthodontic treatment (T2). Total tooth length of the permanent incisors were measured on the CBCTs at T1 and T2. Root resorption was calculated for each tooth by subtracting T1 from T2.

Results: No statistically significant differences in mean root resorption (MRR) were found for the permanent incisors when comparing SureSmile patients with conventional edgewise patients. The MRR for each tooth was found to be less than 1 mm when using either treatment modality. Subjects with increased resorption included Class II malocclusion, severe overjet, and treatment time greater than or equal to 25 months. Sex and the use of Class II elastics showed no significant differences in mean root resorption.

Conclusion: No differences were found in root resorption of the permanent incisors when comparing SureSmile and edgewise treatments. ORTHODONTICS 2012;13:100–109.

Key words: CBCT, edgewise, root resorption, SureSmile

A typical root resorption is an undesirable and unpredictable effect in the majority of patients undergoing orthodontic treatment. In rare cases where severe root resorption is observed, orthodontic treatment is often halted to prevent any further damage to the integrity of the root structure.1–4 Over the years, numerous studies have been conducted to determine the causes of root resorption, but the topic continues to remain an enigma in the orthodontic field and is believed to be a multifactorial problem involving biologic variation and treatment-related factors.1–8

The radiographic methods commonly utilized to diagnose and evaluate root resorption include panoramic and periapical radiographs and lateral cephalograms. Although they are widely used and readily available, these methods...
may be limited in their accuracy and/or reproducibility for evaluating root re- 
sorption due to magnification errors, distortion, superimposition of structures, 
and improper patient positioning.9–13 More recently, Dudic et al14 reported 
that apical root resorption may be underestimated on panoramic radiographs 
compared with cone beam computed tomography (CBCT) images.

The introduction of CBCT in orthodontics allows the clinician to obtain a 
three-dimensional (3D) image of a patient to evaluate information such as 
the location of the airway and impacted teeth. Benefits of CBCTs compared 
with conventional CTs include rapid scan time, chairside image display, and 
decreased radiation dose.15 In contrast to the popular two-dimensional ra-
diographic techniques mentioned above, linear measurements of structures 
in the dentomaxillofacial area have been found to be relatively accurate on 
a CBCT.16–18 Recent studies have also shown that CBCT images provide ac-
curate and reliable measurements of root length19 compared with periapical 
radiographs.20

The clinical applications of CBCTs have been rapidly expanding and imple-
mented in other areas of orthodontics. These clinical applications include the 
SureSmile system (OraMetrix). The first step in the SureSmile process is to cap-
ture a 3D image of the patient’s dentition using a handheld scanning device 
(OraScanner, OraMatrix) or a CBCT.21–23 The second component is its software, 
which allows the clinician to view the patient’s dentition in 3D for diagnosis 
and treatment simulation to establish an electronic prescription that is used to 
design a customized archwire. The third aspect of SureSmile is the fabrication 
of custom archwires by robotic technology.21,22,24

The robotic technology places bends in copper nickel-titanium (Ni-Ti) alloy 
while preserving its superelastic characteristics. Treatment times have been 
shown to be reduced with SureSmile compared with conventional edgewise 
treatment.24 Although these aspects are beneficial to the clinician and patient, 
the impact SureSmile has on the dentition has been a topic of interest since 
these advantages may pose a hazard to the roots. To our knowledge, no stud-
ies have been conducted to compare these effects of SureSmile with conven-
tional edgewise treatment.

The purpose of this study was to analyze the amount of linear root resor-
ption that occurred in maxillary and mandibular permanent incisors during orth-
odontic treatment utilizing CBCT when comparing the SureSmile technique 
with conventional edgewise treatment. In addition, this study evaluated pa-
tient- and treatment-related variables that may be correlated with root resor-
tion, regardless of the treatment modality.
METHODS

Following approval from the Institutional Review Board of the University of Oklahoma Health Sciences Center, Oklahoma City, Oklahoma, USA, the records of 73 patients treated between 2004 and 2009 were gathered based solely on the availability of records from a private practice in Reno, Nevada, USA. Prior to receiving any records, all patients were deidentified by using only the patients’ record numbers. The records received for each patient included an initial and final CBCT, a diagnostic summary sheet, and a treatment card that provided information about each patient’s malocclusion and treatment notes from each visit.

Selection criteria were complete fixed appliances and a single-phase treatment. Exclusion criteria were age older than 18 years, any race other than Caucasian, missing teeth, craniofacial syndromes, orthognathic surgery, extractions, and orthodontic retreatment or transfer from another orthodontist. Forty-two patients were eliminated from the original sample due to the exclusion criteria, and three patients were also removed due to poor-quality CBCT images. Therefore, 28 patients remained in the study. Individual teeth were also eliminated for various reasons including poor image quality, endodontic treatment, incomplete development of roots, transposition, and severe dilaceration.

Of the 28 subjects, 14 patients (8 girls and 6 boys; mean age, 12.67 ± 1.18 years) were treated with the SureSmile technique and 14 patients (5 girls and 9 boys; mean age, 12.76 ± 1.59 years) were treated with conventional prescription edgewise treatment (Table 1). For all patients, 0.018-inch MBT prescription brackets (3M Unitek) and 0.0175 × 0.0175-inch heat-activated Ni-Ti and/or round superelastic Ni-Ti archwires were used during the leveling and aligning stages. Then, 0.017 × 0.025-inch copper Ni-Ti wires were individually prescribed and utilized until the completion of treatment for detailing and finishing stages of treatment for all SureSmile patients. The mean length of time for SureSmile wires for subjects in this study was 5 months.

All patients in the study had received two CBCTs. The first was taken prior to orthodontic treatment (T1). The second was taken at debonding or within 3 months posttreatment (T2). A 36-second scan utilizing a NewTom 3G (AFP Imaging) was taken of all patients who received a CBCT scan prior to June 10, 2008. After this date, subjects received an 8.9-second scan utilizing an i-CAT scanner (Imaging Sciences International). All eight maxillary and mandibular permanent incisors of each patient were measured at T1 and T2 by the same calibrated examiner (N.P.).

The InVivoDental software (Anatomage) was used to view all CBCT images and calculate the length of each tooth. The slice thickness was set to 0 but was associated with the resolution of the scan. Resolutions were 0.42 for NewTom 3G scans and 0.30 for i-CAT scans. The teeth were visualized in three planes (axial, sagittal, and coronal) and via 3D rendering on the same screen (Fig 1).
Each tooth was oriented so that it was upright in the sagittal and coronal views. In the coronal view, the slice was made through the long axis of the tooth. All measurements were taken in the sagittal plane. Images were viewed in grayscale. An additional purple/yellow contrast was used to obtain accuracy in landmark identification.

Following orientation, four measurements were taken on each tooth. The first and second measurements were taken from the facial to lingual cementoenamel junction (CEJ) to determine the midpoint. The third measurement was measured from the incisal edge to the apex of the tooth to determine the total tooth length. The final measurement was taken from the midpoint of the CEJ (second measurement) to the root apex to determine the root length. Both the third and fourth measurements were used as data to ensure greater interreliability in the results. T2 measurements were made first, with images being captured and saved for accuracy in landmark identification for T1 measurements. Root resorption was calculated for each tooth by subtracting the T1 measurement from the T2 measurement. Therefore, a negative result indicated root resorption. The unit of analysis was the individual tooth and/or the group of teeth where the differences were averaged across the teeth included in the group. The analyses were conducted using these differences.

**Statistical analysis**

SAS 9.1 (SAS Institute) was used to analyze the data. Chi-square tests were performed to determine if the distributions differed between the two treatment groups and other categorical variables. Descriptive statistics were computed for all teeth individually and as pairs. Analysis of variance (ANOVA) tests were used to determine if the mean root resorption (MRR) differed between the two treatment groups. Assessment of MRR differences across patient characteristics by tooth and tooth groups were performed with independent t tests and ANOVA tests. If differences were demonstrated, the Student-Newman-Keuls test was used to determine which of the groups contrasted. The level of significance was .05.
A post hoc power analysis determined that with a power of 80%, the sample size was great enough to detect an MRR difference of 0.5 mm between the two treatment modalities. For individual teeth, the range was between 0.6 and 0.9 mm.

Three weeks after the initial data collection, a total of 56 randomly selected teeth (seven patients) were remeasured at T1 and T2 for assessment of error. The standard error of measurement was 0.291.

Regardless of the measurement method utilized, all conclusions were identical concerning MRR. Therefore, statistics on total tooth length will be reported.

RESULTS

No significant differences were found between the SureSmile and conventional edgewise treatments for any of the teeth (Table 2). The overall amount of resorption was also calculated for each treatment modality by using the mean amount of resorption of all incisors for each subject. SureSmile subjects had a mean difference of 0.09 mm greater resorption than conventional edgewise patients, with no significant differences.

In addition, root resorption was analyzed by grouping each tooth with its counterpart on the opposite side of the same arch (Table 3). No significant differences in MRR were found when comparing treatment modalities.

Since no significant differences in MRR were found when comparing the two treatment modalities, further analyses were conducted combining all subjects into one group to determine what other factors might have played a role in root resorption. The MRR for all subjects was calculated for individual teeth and groups of teeth (Table 4). No significant differences were found in MRR when comparing boys with girls (Table 5).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>MRR in individual teeth and overall—SureSmile vs conventional edgewise treatment</th>
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<tbody>
<tr>
<td>Tooth</td>
<td>Group</td>
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<tr>
<td>Maxillary right central incisor</td>
<td>SureSmile</td>
</tr>
<tr>
<td></td>
<td>Edgewise</td>
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<tr>
<td>Maxillary left central incisor</td>
<td>SureSmile</td>
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<td></td>
<td>Edgewise</td>
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<tr>
<td>Maxillary right lateral incisor</td>
<td>SureSmile</td>
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<tr>
<td></td>
<td>Edgewise</td>
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<tr>
<td>Maxillary left lateral incisor</td>
<td>SureSmile</td>
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<td></td>
<td>Edgewise</td>
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<tr>
<td>Mandibular right central incisor</td>
<td>SureSmile</td>
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<td></td>
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<td>Mandibular left central incisor</td>
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<td>Edgewise</td>
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<tr>
<td>Mandibular right lateral incisor</td>
<td>SureSmile</td>
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<td></td>
<td>Edgewise</td>
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<tr>
<td>Mandibular left lateral incisor</td>
<td>SureSmile</td>
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<tr>
<td></td>
<td>Edgewise</td>
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<tr>
<td>Overall</td>
<td>SureSmile</td>
</tr>
<tr>
<td></td>
<td>Edgewise</td>
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* MRR, mean root resorption; SD, standard deviation. *Negative result indicates root resorption.
Class II subjects tended to have greater resorption compared to Class I subjects. A statistically significant difference was found for only the maxillary lateral incisors (Table 6).

Overjet was classified as mild (0.5 to 3.0 mm), moderate (3.5 to 5.5 mm), or severe (≥ 6 mm). Significant differences were found for the maxillary lateral incisors ($P = .0042$) and mandibular central incisors ($P = .0014$), in which a Student-Newman-Keuls test showed that MRR for severe overjets was greater than mild and moderate overjets (Table 7).

MRR with Class II elastics (3/16 inch, 4 oz) was calculated for the maxillary right and left central and lateral incisors. Although subjects with Class II elastics had greater resorption for all of the maxillary incisors compared with those who did not have Class II elastics prescribed, no significant differences were found (Table 8).

The mean length of treatment was 15.57 months for the SureSmile group and 17.07 months for the conventional edgewise group. The mean difference was approximately 1.5 months and was not found to be statistically significant between the two groups ($P = .6806$). Length of treatment was also grouped into ≤ 12 months, 13 to 24 months, and ≥ 25 months to evaluate the MRR in tooth groups, regardless of treatment modality (Table 9). Significant differences were found in MRR among the time periods for the maxillary lateral and mandibular central incisors. Teeth with treatment times ≥ 25 months showed greater root resorption when compared with those with shorter treatment times.
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**DISCUSSION**

The aim of this study was to utilize the CBCT and evaluate the amount of root resorption that occurred in the maxillary and mandibular permanent incisors during orthodontic treatment when comparing the SureSmile technique with the conventional prescription edgewise treatment. In addition, patient and treatment variables that may have an effect on the resorption process during

<table>
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<th>Table 5</th>
<th>MRR of permanent incisors (entire sample)—Sex</th>
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<tbody>
<tr>
<td>Sex</td>
<td>Maxillary lateral incisors</td>
</tr>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Female</td>
<td>13</td>
</tr>
<tr>
<td>Male</td>
<td>14</td>
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MRR, mean root resorption; SD, standard deviation. *Negative result indicates root resorption.

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<tr>
<th>Table 6</th>
<th>MRR of permanent incisors (entire sample)—Classification of malocclusion</th>
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<tr>
<td>Classification of malocclusion</td>
<td>Maxillary lateral incisors</td>
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<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>I</td>
<td>11</td>
</tr>
<tr>
<td>II</td>
<td>16</td>
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MRR, mean root resorption; SD, standard deviation. *Negative result indicates root resorption. †P < .05.

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<tr>
<th>Table 7</th>
<th>MRR of permanent incisors (entire sample)—Overjet</th>
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<tr>
<td>Severity of overjet</td>
<td>Maxillary lateral incisors</td>
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<tr>
<td></td>
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<tr>
<td>Mild</td>
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<tr>
<td>Moderate</td>
<td>7</td>
</tr>
<tr>
<td>Severe</td>
<td>3</td>
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MRR, mean root resorption; SD, standard deviation. *Negative result indicates root resorption. †Mild overjets were significantly different from moderate and severe overjets.

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<th>Table 8</th>
<th>MRR of maxillary permanent incisors (entire sample)—Use of Class II elastics</th>
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<tbody>
<tr>
<td>Use of Class II elastics</td>
<td>Maxillary right lateral incisor</td>
</tr>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>No</td>
<td>13</td>
</tr>
<tr>
<td>Yes</td>
<td>14</td>
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</table>

MRR, mean root resorption; SD, standard deviation. *Negative result indicates root resorption.

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<tr>
<th>Table 9</th>
<th>MRR of permanent incisors (entire sample)—Length of treatment</th>
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<tr>
<td>Length of treatment (mo)</td>
<td>Maxillary lateral incisors</td>
</tr>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>≤ 12</td>
<td>13</td>
</tr>
<tr>
<td>13–24</td>
<td>11</td>
</tr>
<tr>
<td>≥ 25</td>
<td>3</td>
</tr>
</tbody>
</table>

MRR, mean root resorption; SD, standard deviation. *Negative result indicates root resorption. †≤ 12 mo was significantly different from > 25 mo.

1≤ 12 and 13–24 mo were significantly different from ≥ 25 mo.
orthodontic treatment were analyzed. This study is unique in that previous studies have not measured linear orthodontic root resorption directly from a CBCT. In addition, no studies have compared the effects of SureSmile with conventional edgewise treatment.

The MRR for each tooth was found to be less than 1 mm when using either treatment modality, and no pattern of root resorption could be seen when comparing the treatment groups.
Evaluation of groups of teeth revealed the following from greatest to least mean root resorption: maxillary lateral incisors, maxillary central incisors, mandibular central incisors, and mandibular lateral incisors. With the exception of the mandibular incisors, Sameshima and Sinclair reported a similar pattern. Their calculations revealed almost twice the amount of resorption as found in our study, with the exception of the mandibular central incisors. Possible differences may be attributed to the method chosen for measuring root resorption or the sample size and its characteristics.

Sex was found to have no relationship with the degree of root resorption. Previous studies have been inconsistent with regard to sex and root resorption, with some showing a relationship between the two and others showing no correlation.

Subjects with a Class II malocclusion tended to have greater root resorption than those with a Class I malocclusion. The only significant difference was found for the maxillary permanent lateral incisors, in which the Class II subjects had a mean of 0.60 mm greater root resorption compared with Class I subjects. A difference may have been seen in the maxillary incisors, because Class II treatment mechanics often involves retraction of the maxillary teeth with a large degree of movement of the root apices. Other characteristics associated with Class II malocclusions and their treatment mechanics, such as severe overjets and use of Class II elastics, also showed a positive relationship with root resorption.

Previous studies have had conflicting conclusions on the relationship between duration of treatment and the degree of root resorption. Some have shown overall treatment time to be related to the degree of root shortening, while others have shown no relationship between the two. In this study, an increasing amount of root resorption was seen as the length of treatment increased. Subjects with treatment ≥ 25 months had approximately two to four times greater mean root resorption compared with those with ≤ 12 months of treatment.

There were several aspects of this study that one could criticize. The availability of pre- and posttreatment CBCTs made this study possible; however, the use of two different cone beam machines proved to be challenging. The i-CAT images demonstrated greater clarity. In addition, metal appliances were present on some teeth in the CBCT scans, which compromised the quality of some images. A sample size of 28 patients was considered adequate for our study. However, a greater sample could have gained additional strength.

CONCLUSION

This retrospective study of 28 patients was conducted to evaluate linear differences in MRR when using CBCTs and comparing conventional prescription edge-wise treatment with the SureSmile technique. In addition, patient and treatment variables that may influence the amount of root resorption during orthodontic treatment were studied. The following conclusions can be made from this study:

- No significant differences in root resorption of the permanent incisors were observed when comparing the SureSmile technique with conventional edge-wise treatment. The MRR for each tooth was found to be less than 1 mm when using either treatment modality.
- Subjects with increased resorption included those presenting with Class II malocclusion, severe overjet, and treatment times greater than or equal to 25 months.
- Sex and the use of Class II elastics were shown to have no significant effect on mean root resorption.
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REFERENCES