Correct tooth position in the 3 planes of space is a major objective of orthodontic treatment. Appropriate axial inclination of the roots with near-parallel roots has been discussed often in the orthodontic literature and is a criterion in the examinations of the American Board of Orthodontics and the European Board of Orthodontics. Root proximity is the term used when the roots of adjacent teeth are 1.0 mm or less apart, as measured radiographically. Furthermore, by dividing the root into 3 sections—apical, middle, and cervical—different severities of root proximity might be obtained.

The clinical diagnosis of root proximity is based mainly on routine radiographic procedures, such as panoramic radiography (OPT). However, OPT provides a distorted and 2-dimensional representation of a 3-dimensional (3D) object. There are large discrepancies between optimal and actual beam directions, resulting in overlapping of teeth, especially in the premolar region.

Cone-beam computed tomography (CBCT) is a new radiographic method with applications in several diagnostic areas such as implant treatment, oral surgery, endodontic treatment, and temporomandibular joint imaging. Compared with conventional computed tomography, CBCT technology in clinical practice provides important advantages such as minimal radiation dose, image accuracy, rapid scan time, fewer image artefacts, and opportunity to use chair-side image display and real-time analysis. In orthodontics, the use of CBCT imaging has been restricted to impacted teeth, temporomandibular joint visualization, and determination of bone volume conducive to orthodontic tooth movement and for cleft patients. Recently, Peck et al evaluated the accuracy of OPT and CBCT for determining mesiodistal root angulations. Using plaster...
models of 5 patients as the gold standard, they reported that CBCT scans can produce accurate measurements of root angulations, and OPT cannot provide reliable data.

By using CBCT as the gold standard, the purpose of this study was to determine whether OPT provides a true assessment of the mesiodistal root relationship of adjacent teeth in subjects approaching the end of orthodontic treatment.

**MATERIAL AND METHODS**

From 119 consecutive patients at a private orthodontic practice in Winterthur, Switzerland, 22 patients (9 female, 13 male; mean age, 16.7 years; range, 12.8-37.3 years) in the permanent dentition were included in this study. They were approaching the end of orthodontic treatment with fixed appliances in both dental arches and had root contacts in the OPT images taken at that time. The patients were further referred to study the proximity of neighboring roots by CBCT.

The images were acquired with an OPT device (Cranex Excel, Soredex, Tuusula, Finland). The CBCT images were obtained with the 3D Accuitomo FPD (J. Morita, Kyoto, Japan). Two sizes of areas (40 x 40 and 60 x 60 mm) were imaged with super-high resolution (2.0 line pairs per millimeter; voxel size, 0.125 mm). The plane of primary reconstruction was aligned parallel to the long axis of the examined tooth by using iDixel software, as suggested by the manufacturer (J. Morita, Kyoto, Japan). Depending on the region of interest, either 1 or 2 CBCT images were taken of each patient.

Two calibrated examiners (M.L. and A.D.) assessed the OPT and CBCT images separately and blindly for root contacts. In case of disagreement between the examiners, a new evaluation was made, and this consensus was used for the final evaluation.

Figures 1 and 2 show the root contacts evaluated by OPT and CBCT, respectively. Root contact was determined when no periodontal space between adjacent roots was visible, resulting in “touching” roots.

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**Table.** Diagnostic accuracy of OPT compared with CBCT (gold-standard test)

<table>
<thead>
<tr>
<th>CBCT</th>
<th>OPT</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No contact</td>
<td>188 (80.0)</td>
<td>230 (97.3)</td>
</tr>
<tr>
<td>Contact</td>
<td>42 (17.9)</td>
<td>5 (2.1)</td>
</tr>
<tr>
<td>Total</td>
<td>230 (97.3)</td>
<td>5 (2.1)</td>
</tr>
</tbody>
</table>

Values are expressed as n (%).
The Pearson chi-square test was used to test the null hypothesis of no difference between the OPT and CBCT methods for evaluating root contacts. The validity of the OPT to detect the true root relationship was assessed by using the CBCT images as the gold standard. The frequency of root contact, the sensitivity and specificity, the positive and negative predictive values, and the likelihood ratio were calculated. The statistical analysis was done with SPSS for Windows (release 13.0, standard version; SPSS, Chicago, Ill).

RESULTS
A total of 235 interdental sites were evaluated for root contacts. The number and percentages of teeth with root contact evaluated by OPT and CBCT are shown in the Table. Root contact was observed in 47 sites (20%) in the OPT images and in only 5 (2.1%) with the CBCT images. The hypothesis of no difference in evaluating root contact on OPT and CBCT images was rejected ($P < 0.001$). The OPT method had excellent sensitivity of 100% (95% CI, 46%-100%), combined with high specificity of 81% (95% CI, 76%-86%); this means that 81% of the areas without contact were diagnosed correctly by the OPT. The positive predictive value of the OPT was found to be quite low (10%), whereas the negative predictive value was 100%. The likelihood ratio for a positive test result was 5.4; this indicates that a positive result is 5 times as likely in an area with root contact than in one without root contact.

From the 47 interdental sites showing root contact in the OPT, 36 were located in the maxilla and 11 in the mandible, whereas, in the CBCT images, 3 were located in the maxilla and 2 in the mandible. Figure 3 illustrates root contact that was obvious in the OPT image, but no contact could be seen in the CBCT image (false positive).

DISCUSSION
Our study has shown that the use of OPT in patients near the end of their orthodontic treatment overestimates root contacts. We compared the OPT findings with those obtained with CBCT: whereas only 5 teeth (2.1%) were seen as having root contact in the CBCT images, 47 teeth (20.0%) showed root contact with OPT. The root contacts seen with the OPT were mainly located in the maxilla, confirming the previous findings of A˚rtun et al., who reported that 72% of root contacts in 25 patients occurred between the maxillary central and lateral incisors.

CBCT produced highly detailed 3D images of super-high resolution, offering optimum viewing without superimpositions. The high number of false positives of root contacts (89%) evaluated by the OPT might be due to projection error, as shown in a recent study that the buccolingual inclination of the root can modify the
mesiodistal root angulation on the image, especially in the premolar region.  

In general, root proximity has been described as a localized but widespread phenomenon that should be considered risk factors for the failure of miniscrews used as orthodontic anchorage and for periodontal disease, especially in periodontal patients and to a lesser extent in the nonperiodontal patients.  

In periodontally healthy patients, root proximity was located in the apical part where it is less critical, but, in patients with periodontitis, root proximity was most often encountered in the coronal and intervening part. Furthermore, subjects with root proximity had a 3.6-times higher chance of periodontitis.

The observation in the control OPT before the end of orthodontic treatment overestimated root contacts, whereas orthodontically induced root resorption was underestimated. Thus, root contacts seen on the OPT should not be the decisive reason to continue the orthodontic treatment for correcting the positions of teeth with the roots in contact, unless the clinical position of the crowns justifies such an intervention. However, this evidence should not be used to legitimize poor orthodontic treatment results.

We found that, compared with OPT, CBCT has an advantage in detecting true root contacts. However, if no anatomic deviations have been observed in the roots of the teeth on the initial OPT (dilacerations and excessive apex angulations), there is no reason for further radiographic examination with CBCT.

CONCLUSIONS

This study indicates that OPT overestimates root contacts, since only few cases showed true root proximity of the adjacent teeth. CBCT offers the opportunity to acquire the highest-quality diagnostic images for studying factors that might be associated with the total success of orthodontic treatment, but it is not justified for the routine control of root contacts, except in special situations.

We thank Dr Alfred Künzler for helping with the CBCT.

REFERENCES