ABSTRACT

Objective: Compare Accu-I-Tomo (3DX) limited cone beam CT (Morita Co Ltd, Tokyo, Japan), Digora® FMX (Soredex Corporation, Helsinki, Finland) and F-speed film (Eastman Kodak, Rochester, NY) in assessing depth of proximal caries.

Material and Methods: Radiographs of a dry mandible with carious teeth were obtained with F-speed film, Digora® FMX image plate system, and limited cone beam CT. In 17 molar and 24 premolar proximal surfaces, 2 observers independently measured lesion depth. Correlation of measurements was assessed with Pearson’s correlation coefficient. Comparison of different sized lesions (<1.5 mm and >1.5 mm) as assessed in film or SP images was done using Wilcoxon’s signed rank test.

Results: Correlation between observers’ measurements was high for all methods and only small inter-observer differences (mean of 0.01-0.05 mm) were found. For lesions <1.5 mm in film or image plate images about 1.60 times larger depth values were found with the 3DX method while lesions >1.5mm were measured as, respectively, 0.94 and 0.97 times smaller.

Conclusion: For proximal carious lesions >1.5 mm, as measured in film or image plates, similar depth values are obtained with the 3DX method but for lesions <1.5 mm depth is estimated as being much larger with the latter method which thus appears as a promising tool for the detection and monitoring of proximal carious lesions.

KEYWORDS
Cone-beam, X-ray CT, Digital radiography, Dental

ÖZET

Amaç: Bu çalışmanın amacı konik ışın hüzmeli tomografi cihazı Accu-I-Tomo (3DX, Morita Co Ltd, Tokyo, Japonya), Digora® FMX (Soredex Corporation, Helsinki, Finlandiya) ve F-hızındaki film sistemlerini (Eastman Kodak, Rochester, NY) aproksimal çürük derinliğinin saptanması yönünden karşılaştırmaktır.

Gereç ve Yöntem: Üzerinde çürük dişler bulunan kadavra insan mandibulası F-hızında filmler, Digora® FMX görüntü plağı sistemi ve konik ışın hüzmeli tomografi cihazı kullanılarak görüntülendi. 17 molar ve 24 premolar dişe ait aproksimal çürük lezyonlarının boyutlarını saptadı. Ölçümler arasındaki korelasyon, Pearson korelasyon katsayısının hesaplanması ile belirlendi. Film ve fosfor plak görüntülerinin <1,5 mm ve >1,5 mm olarak saptanma karışımların Wilcoxon testi ile yapıldı.

Bulgular: Araştırıcılardan ölçümler arasındaki uyum tüm yöntemler için yüksek bulundu, araştırmacılar arasındaki farklı çok az olduğu gözlemdi (ortalama 0,01-0,05 mm). Film ve fosfor plaklarında < 1,5 mm olarak saptanan lezyonların 3DX ölçümüne yaklaşık olarak 1,60 kat daha büyük, > 1,5 mm olarak saptanan lezyonların ise sırasıyla 0,94 ve 0,97 kat daha küçük saptandığı bulundu.

Sonuç: Film ve fosfor plak görüntülerinde 1,5 mm’den büyük olan lezyonları saptanan aproksimal çürük lezyonlarını için 3DX yöntemi ile benzer sonuçlar elde edildi ancak 1,5 mm’den küçük lezyonlar için bu yöntemle alınan sonuçlar lezyonların daha büyük olduğunu göstermektedir. Buna göre, 3DX yönteminin özellikle başlangıç dönemdekili aproksimal çürük lezyonlarının saptanması ve izlenmesi için gelecekte olan bir yöntemi olduğunu söylenebilir.

ANAHTAR KELİMELER
Konik ışın, X-ışın BT; Dijital radyografi, Dental
INTRODUCTION

Radiography is widely used for estimating depth of carious lesions. The validity of radiographic depth assessments on proximal surfaces in film images is strongly associated with the lesion depth and for small lesions validity is poor. The apparent depth can also vary as a function of X-ray beam angulation and radiographic density. Variations in perceived, although not actual, lesion depth can lead dentists to erroneously believe that caries has progressed or regressed and result in unnecessary restorative intervention or delay in treatment.

Alternative methods, such as digital image acquisition and image analysis techniques, have been suggested in an attempt to overcome some of the insufficiencies of conventional radiography. Computer-aided image analysis has been investigated in the hope that it would result in a reduced frequency of errors by a more objective evaluation of carious lesions. However, as far as diagnostic accuracy is concerned, digital and conventional radiography mostly seem to give similar results for various clinical tasks. This may be due to the limitations of the basically 2-dimensional imaging of 3-dimensional structures by either radiographic modality. Nevertheless, when tuned aperture computed tomography – TACT – was compared with conventional 2-D radiography for the diagnosis of proximal caries better results with TACT were not achieved. Differences in angular disparity had little effect on the detectability of proximal caries, nor did the number of basis images.

In 2000, 3DX limited cone beam CT (Morita Co Ltd, Tokyo, Japan) was developed allowing for 3-dimensional imaging of, above all, the hard tissues in small volumes of the head and neck region. 3DX uses independently developed proprietary software that produces a cylindrical volume (height of 30mm, diameter of 40mm) from which tomographic layers (0.125-2mm thick) can be obtained in any direction. It uses a cone shaped X-ray beam, an image intensifier and a solid-state sensor for image capturing. Image data are collected during a single 360-degree rotation round the patient and displayed in all 3 planes after a processing time of about 85s. Using 1mm thick slices there are 30 images in the vertical direction and 40 in the frontal and sagittal directions. The limited cone beam CT produces volume imaging quicker and easier than does conventional CT. Doses are much lower and geometric resolution considerably better than in conventional CT. With this technique it should be theoretically possible to overcome the irradiation geometry problems that can cause errors in 2D-imaging for caries diagnosis. In addition, the low contrast of many carious lesions due to the small mass difference relative to the surrounding sound tissue should become less of a problem since only a slice of tissue is displayed.

The aim of this preliminary study was to compare the performance of Accu-I-Tomo (3DX) (Morita Co Ltd, Tokyo, Japan), the Digora® (So-redex Corporation, Helsinki, Finland) image plate system and F-speed film (Eastman Kodak, Rochester, NY) for determining depths of proximal caries lesions.

MATERIALS AND METHODS

Fourteen extracted human permanent premolars and 16 molars without fillings were selected. In 17 molar and 24 premolar surfaces caries was found just under the proximal contact point. Its clinical appearance ranged from incipient caries to large cavity formation. Before radiography the roots of the teeth were cut off. One premolar and two molars from the left side of a dry mandible were removed and replaced with test teeth. The original teeth at either end created natural contact points.

F-speed films and blue storage phosphor (SP) plates, later to be scanned in a Digora® FMX scanner, were exposed with a Gendex Oralix DC (Gendex Dental Systems, Milan, Italy) dental x-ray unit operating at 60 kVp, 7mA, 1.5 mm Al equivalent filtration, and a half-value layer of 1.9
mm Al. Film and Digora® images were acquired by using bite-wing projection geometry at a focus-receptor distance of 20 cm. An optical bench was used to standardize irradiation geometry. A 20-mm thick soft tissue equivalent material was placed on the dry mandible. F-speed films and SP plates were exposed with respectively 0.25 and 0.12s. Films were developed using an AP-200 (plh Medical Ltd, United Kingdom) automatic processor with a processing time of 6min at 23.5°C. The processed radiographs were mounted in non-transparent frames, placed on a light box and viewed with a magnifying (2x) loupe with a measuring scale divided in tenths of mm in a room where the light was dimmed. SP plates were scanned in the Digora® FMX-scanner calibrated for a highest exposure of 0.4s. The resulting images were analyzed with the Digora for Windows software program using the associated measuring tool.

The 3DX images were taken at 80kV and 1.5mA. The filtration was 3.1 mm Al equivalent and the exposure time 17.5 s. Horizontal, cross-sectional and sagittal section images are simultaneously displayed on the monitor. The depth of each carious lesion was measured, using the length measurement tool provided by the system software, in that image layer (axial, cross-sectional or sagittal) in which the lesion was best perceived. Measurements were taken to the nearest 0.1mm for all modalities used.

Two radiologists – one with previous experience with all imaging modalities, the other with no previous experience of 3DX-images – independently measured the depth of the carious lesions at or close to the proximal contact point.

Correlation between the measurements of two observers was analyzed using Pearson’s correlation analysis. Differences between imaging modalities in depth measurements were compared using paired t-test and repeated measure ANOVA with Bonferroni correction (p<0.05). Comparison of different sized lesions (<1.5 mm and >1.5 mm) as assessed in film or SP images was done using Wilcoxon’s signed rank test.

RESULTS

The correlation between the measurements of the two observers was 0.979 for film, 0.997 for Digora and 0.998 for 3DX. The correlation between the measurements obtained with the different modalities was high for all of them (0.911 and 0.906 for film vs Digora, 0.880 and 0.864 for 3DX and film, and 0.831 and 0.834 for SP-plates and 3DX). For film and Digora measurements, depth values obtained by one observer were higher than those of the other in 20 and 17 surfaces, respectively, of the 41 being evaluated. The mean difference was 0.05 mm and 0.01mm, both statistically insignificant (p>0.05). Depth values assessed in 3DX images were higher for one of the observers in 27 images. This gave a small (0.024 mm) but statistically significant difference (p<0.05).

The measurements (average values of the two observers) obtained with the different image modalities, 3DX, film and Digora image plates, were 2.25±1.06, 2.16±1.20 and 1.98±1.16, respectively. The mean values of each observer and modality are given in Table I. None of the differences between modalities was statistically significant (p>0.05) either for each observer’s individual results or for their averaged results. However, it should be noted that, for both observers, the 3DX modality on average yielded the largest depth measurements.

The mean value of measurements for lesions less than and more than 1.5 mm deep, as measured in film images, are shown in Table II. Lesions <1.5 mm were, on average, assessed as 0.58 mm deeper (1.61 times) in 3DX images and those >1.5 mm were assessed as 0.18 mm (0.94 times) less deep. Lesions assessed in SP-images as being <1.5 mm deep were on average 0.6-5mm deeper (1.60 times) in 3DX images while those being >1.5 mm were 0.12 mm (0.97 times) less deep (Table III).
DISCUSSION

The present study aimed to compare 2-dimensional (digital radiography and film) and 3-dimensional imaging modalities (3DX) with regard to caries depth measurement. There was a strong correlation between two observers in their assessment of lesion depth for each radiographic modality. Both observers were well acquainted with caries assessment in conventional radiographs and digital images and no significant difference was found between their measurements in such images. The substantial concordance indicates homogeneity between observers’ caries conception. One of the observers was not familiar with 3DX images which could be a reason why a large number (66%) of her measurements in those images were lower than those of the other observer.

<table>
<thead>
<tr>
<th>Observer</th>
<th>3DX (mean± SD)</th>
<th>Film (mean± SD)</th>
<th>Digora® (mean± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HGG</td>
<td>2.26±1.07</td>
<td>2.18±1.22</td>
<td>1.97±1.17</td>
</tr>
<tr>
<td>BGA</td>
<td>2.24±1.06</td>
<td>2.13±1.19</td>
<td>1.98±1.15</td>
</tr>
</tbody>
</table>

**TABLO II**

*Comparison of 3DX measurements with two different lesion sized groups as measured in film.*

<table>
<thead>
<tr>
<th>Lesion size according to film (mm)</th>
<th>3DX (Mean caries depth)</th>
<th>Film (Mean caries depth)</th>
<th>Difference of 3DX &amp; film measurements (mm)</th>
<th>% difference of 3DX &amp; film</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.5</td>
<td>1.53</td>
<td>0.95</td>
<td>0.58</td>
<td>61*</td>
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<tr>
<td>&gt;1.5</td>
<td>2.65</td>
<td>2.83</td>
<td>0.18</td>
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</tr>
</tbody>
</table>

* significant difference compared with other imaging modality

**TABLO III**

*Comparison of 3DX measurements with two different lesion sized groups as measured in Digora.*

<table>
<thead>
<tr>
<th>Lesion size according to Digora (mm)</th>
<th>3DX (Mean caries depth)</th>
<th>Digora (Mean caries depth)</th>
<th>Difference of 3DX &amp; Digora measurements (mm)</th>
<th>% difference of 3DX &amp; Digora</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.5</td>
<td>1.73</td>
<td>1.08</td>
<td>0.65</td>
<td>60*</td>
</tr>
<tr>
<td>&gt;1.5</td>
<td>2.78</td>
<td>2.86</td>
<td>0.12</td>
<td>3</td>
</tr>
</tbody>
</table>

* significant difference compared with other imaging modality
Accu-I-Tomo is capable of creating slices at the level of one voxel (0.125mm) and making distance measurements. However, if the operator fails to choose the slice that shows the deepest extension of the lesion, he/she does not get the intended information. The variation between the two observers in the 3DX measurements may therefore be due to differences in experience and skill with regard to 3-dimensional images. It is, however, noteworthy that the mean difference between the measurements of the observers was approximately 0.02 mm which may be regarded as clinically insignificant.

The advantage of 3D-imaging of 3D anatomic structures can be easily appreciated given that methods with sufficient resolution can be used. In addition, they must yield considerably lower doses than does conventional CT-images. Both conditions are fulfilled with the 3DX unit which, therefore, seems to significantly decrease the technology gap between 2D-radiography and CT in the dental area.

The results from the present study indicate that measurement of caries depth in proximal surfaces can be done at least as reliably in 3DX-images as in film and phosphor plate images. However, for both observers the 3DX modality showed, on the average, the largest extent of the lesions seen from the tooth surface towards the pulp.

3DX measurements were in fairly good agreement with those from both film and Digora images for carious lesions deeper than 1.5mm. However, for smaller lesions there was a large discrepancy between film/Digora images on the one hand and 3DX on the other with the latter being perceived as much deeper. This result can be theoretically expected. Small lesions that are shaped like a cone with its apex inwards means that in its innermost part there can be such a small mass difference between the lesion and its surrounding tissue that it will not be reflected in a perceptible density difference in the summation 2D-images. The 3DX technique, by producing slices, removes the tissues on either side (back and front or above and below) of the lesion which makes the mass difference between lesion and sound tissue larger contributing to a higher signal-to-noise ratio and higher image contrast. Why the same difference between 2D- and 3D-images is not observed for larger lesions can be due to the larger lesions being more rounded in their inner parts. The small difference being observed between the 2D-images and the 3DX-images, with the latter showing somewhat (<0.2 mm on the average) smaller lesions, can therefore be caused by an irradiation geometry when obtaining the 2D-images that was not perfectly perpendicular to the longitudinal axis of the lesion.

We conclude that the 3DX technology is better than conventional 2D-techniques for determining the depth of proximal carious lesions and that, therefore, it can be a technique well suited for monitoring caries lesion behaviour over time. Nevertheless, further studies of the 3DX technique, not only for assessment of caries depth, are indicated. Some are also in progress.

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