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# Effect of X-Ray Tube Focal Spot Size on Radiovisiograph Resolution

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*The effect of the X-ray tube focal spot size on radiovisiograph resolution was tested experimentally.*

## Introduction

The goal of this work was to discuss recent information available from international sources indicating that X-ray focal spot size has an effect on the quality of images obtained using radiovisiographs [1, 2]. It was reported in [2] that focal spot size reduction from 0.8 × 0.8 to 0.4 × 0.4 mm increased sharpness of dental images.

In the domestic medical literature the problem of correlation of X-ray focal spot size and image quality had been discussed in detail [3]. The effects on the image sharpness, contrast, exposure dose, and power consumption were discussed for the case of a dental X-ray tube with diameter of 0.1 mm [4]. In collaboration with one of the leading domestic manufacturers of X-ray equipment, further research was performed to study the special case of dental radiovisiography.

## Materials

Standard contact X-ray was used in the study [5]. The X-ray focal spot diameter $d$ was 1 mm. The distance $f$ from the object to the X-ray source was large, while the distance to the detector was very short to provide contact X-ray. The focal spot diameter $d$ and distance $f$ from the object to the X-ray source exerted a significant effect on image quality (sharpness). The distance $f$ was selected to meet the requirements for X-ray image sharpness taking into account the actual values of focal spot diameter $d_1$ and object thickness. Even slight changes in the distance $\Delta f$ resulted in considerable reduction of the image sharpness.

The ratio $(f + \Delta f)$ determines magnification of the image of the object $m$:

$$m = (f + \Delta f)/f.$$

At focal spot diameter $d$ and detector resolution $R_n$ the maximal resolution is calculated from [6]:

$$R_{\max} = \sqrt{R_n^2 + \left(\frac{1}{d}\right)^2}.$$

This equation shows that the maximal resolution of modern dental systems depends on focal spot diameter. The dependence for the typical value of $R_n = 20$ line pairs per mm is given in Table 1.

Focal spot diameter $d = 0.1$ mm and $R_n = 20$ line pairs per mm provide a 10% increase in the X-ray system resolution relative to contact X-ray with $d = 0.7$ mm. Focal spot diameter $d = 0.05$ mm provides a 1.4-fold increase in the X-ray system resolution.

## Methods

Contact X-ray of a reference test pattern and a dental X-ray of a skeletonized mandible with soft tissue phantom

**TABLE 1.** Calculated Values of Radiovisiograph Resolution

| $d$, mm | 0.7 | 0.5 | 0.3 | 0.2 | 0.1 | 0.05 |
|---|---|---|---|---|---|---|
| $R_{max}$, line pairs per mm | 20.0 | 20.1 | 20.3 | 20.6 | 22.4 | 28.3 |

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were performed under laboratory conditions. The experimental setup is shown in Fig. 1. An ERGON-X HF X-ray apparatus (Italy) with focal spot size 0.7 × 0.7 mm or PARDUS X-ray apparatus (Russia) with focal spot sizes ranging from 0.05 to 0.5 mm were used as X-ray source 1.

X-Ray imaging of object 4 was implemented using the SOPIX-2 (Italy) and RENTGENOVIDEOGRAPH (ELTEH-Med, Ltd., Russia) detectors based on CCD matrix 3 with pixel size 20 × 20 μm.

The following parameters of X-ray imaging were varied: focal spot diameter $d$, source-object distance $f$, and object–detector distance $\Delta f$. Image sharpness and radiovisiograph resolution were tested using wedge test pattern. The maximal density of test pattern lines was 30 line pairs per mm.

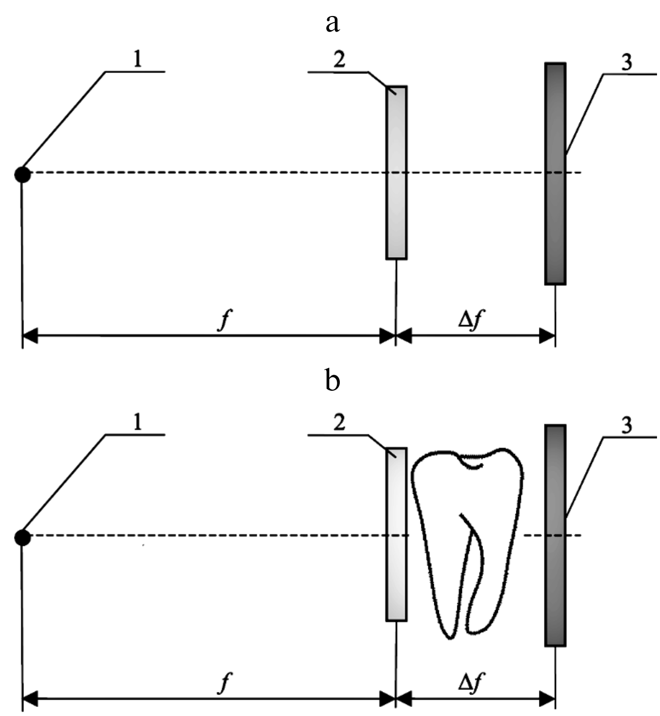


**Fig. 1.** X-Ray of test pattern (a) and mandible (b): 1) focal spot; 2) test pattern; 3) X-ray detector; 4) object.

## Results

Results of visual evaluation of radiovisiograph resolution from test pattern images are shown in Table 2.

Figures 2 and 3 show photographs of the mandible taken using a SOPIX-2 detector and PARDUS apparatus with focal spot diameter 0.2 mm. The object–detector distance (ODD) was 200 and 50 mm. Photographs obtained using an ERGON-X HF apparatus with focal spot 0.7 × 0.7 mm and ODD 200 mm are also shown in Figs. 2 and 3.

**TABLE 2.** Visual Evaluation of Radiovisiograph Resolution (line pairs per mm)

| $d$, mm | Test pattern photograph | | | Mandible photograph | |
|---|---|---|---|---|---|
| | $f$ = 200 mm, $\Delta f$ = 0 | $f$ = 200 mm, $\Delta f$ = 10 | $f$ = 50 mm, $\Delta f$ = 10 | $f$ = 200 mm, $\Delta f$ = 10 | $f$ = 50 mm, $\Delta f$ = 10 |
| 0.7 | 18 | 16 | 14 | 12 | 13 |
| 0.4 | 18 | 17 | 17 | 12 | 13 |
| 0.1 | 19 | 18 | 18 | 17 | 17 |

**TABLE 3.** Physicotechnical Conditions of Dental Imaging Using Portable Apparatuses

| Imaging conditions | PARDUS-R | ERGON-X HF |
|---|---|---|
| Voltage, kV | 65 | 65 |
| Current, mA | 0.15 | 7 |
| Focal spot diameter, mm | 0.2 | 0.5 × 0.5 |
| Power, W | 10 | 450 |
| Exposure time, sec | 0.15 | 0.06 |
| Exposure dose, mA·sec | 0.02 | 0.42 |
| ODD, mm | 50 | 200 |

Visual analysis of the mandible photographs demonstrated:

– decreasing the focal spot diameter from 0.5 to 0.2 mm at ODD 200 mm improved the radiovisiograph resolution from 14 to 18 line pairs per mm (Fig. 2). This was due to the increase in image sharpness caused by the decrease in the focal spot diameter. Further decrease in the focal spot diameter is not reasonable because of detector resolution limitations;

– a decrease in the ODD from 200 to 50 mm at focal spot diameter 0.2 mm reduced the radiovisiograph resolution from 18 to 17 line pairs per mm (Fig. 3). This was due to the decrease in image sharpness caused by the decrease in ODD.

The averaged physicotechnical conditions of dental imaging using two X-ray apparatuses with different focal spot diameters and the same detector (RENTGENOVIDEOGRAF) are given in Table 3.

## Discussion

Improvement of X-ray resolution in the case of dental long-focus contact X-ray and digital detection can be

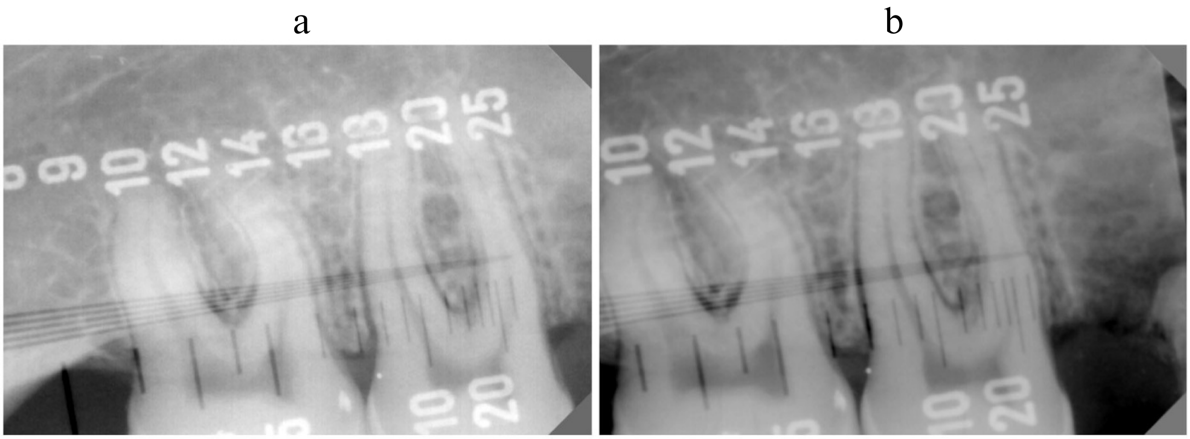


**Fig. 2.** Photographs of mandible taken using apparatus with focal spot diameters of 0.7 mm (a) and 0.2 mm (b).

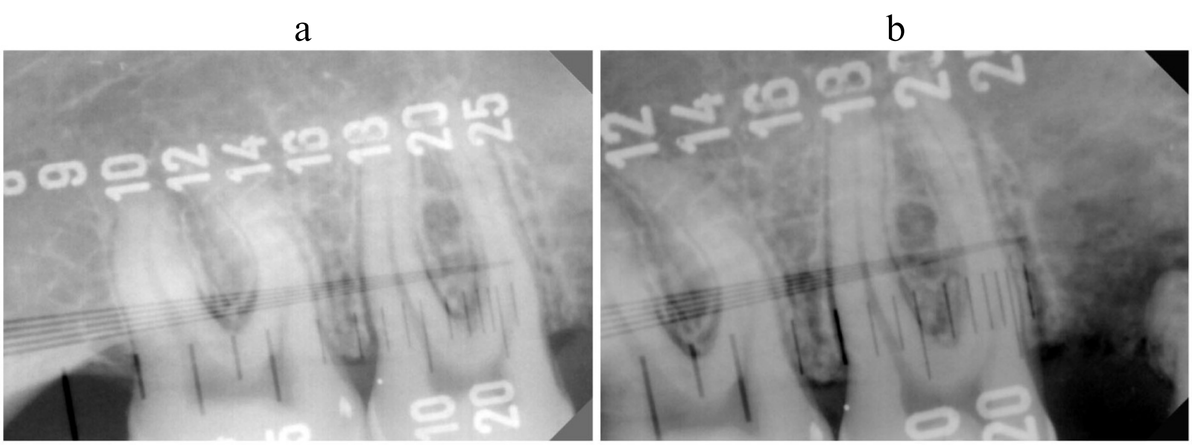


**Fig. 3.** Photographs of mandible taken using apparatus with focal spot diameter of 0.2 mm at ODD 200 mm (a) and 50 mm (b).

attained by pixel size reduction. However, a $\kappa$-fold decrease in the pixel size results in $\kappa^2$ decrease in pixel area, thereby reducing the detector sensitivity.

The decrease in X-ray detector sensitivity should be compensated by increasing the X-ray dose, which leads to an increase in radiation load on patient and personnel. In dentistry, focal spot diameter and ODD should be decreased. Such decrease allows microfocal imaging to be implemented with image magnification. This provides:

1) $n$-fold decrease in the focal distance with $n^2$ decrease in the X-ray dose;

2) $m^{1/2}$-fold increase in the X-ray resolution with m-fold increase in the image magnification [6, 7].

It follows from Table 3 that, for a given voltage, the current is 50 times lower and the image exposure is 20 times shorter for focal spot diameter 0.2 mm as compared to focal spot size 0.7 × 0.7 mm.

## Conclusions

Microfocal imaging is the most promising X-ray method in dentistry and maxillofacial surgery because it reduces power consumption and X-ray dose received by patients and medical personnel, as well as provides high image quality and information value.

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