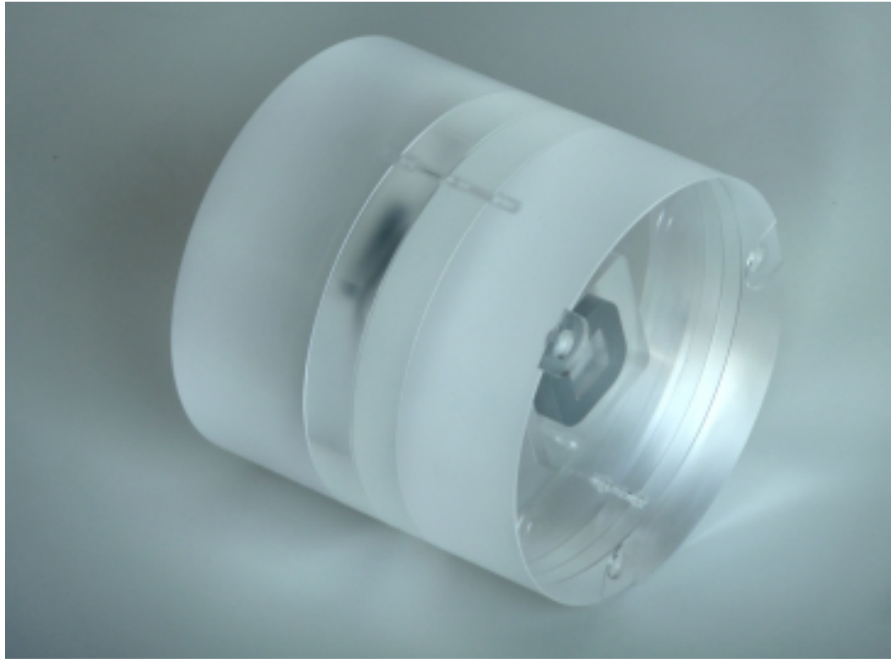


perhamed

Work instructions

per DIN 6868-161

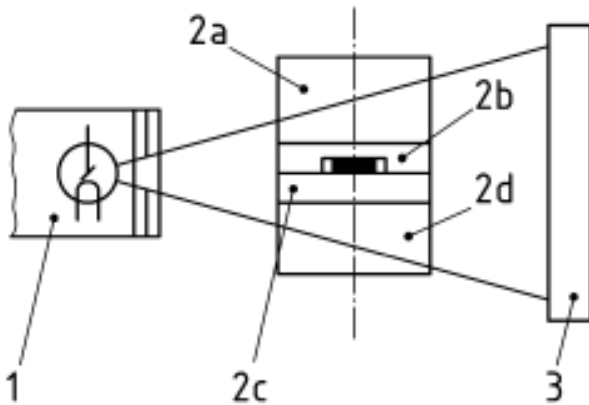


Devices for dental digital volume tomography may differ in basic design features. Optimizing the systems of different tasks leads to difference-union review of parameters such as dose, noise and resolution. These parameters can not be provided in accordance with the uniform limits. In order to achieve adequate monitoring of devices, specific indicators should be introduced which combine quantifiable system parameters in an appropriate manner and provide the fairest possible evaluation of systems.

The test positions are partly checked by evaluating Prüfkörperaufnahmen. The test specimen is described in the following. It must be positioned so that to determine the resolution provided for in 4.3.5 structures of the specimen are shown. The exposure parameters are used according to the manufacturer's instructions for a standard patient and creates a picture. The acquisition parameters must be documented. The evaluations must be carried out at the original data set.

Testphantom

The testphantom is made of PMMA (polymethylmethacrylate), positioning aids, millings and additional structural elements. The test specimen consists of cylindrical surfaces that are superimposed-layered so introduced into the beam path that the relevant structures are mapped (see Figure 1).



Picture 1 – Setting the testphantom into the beam

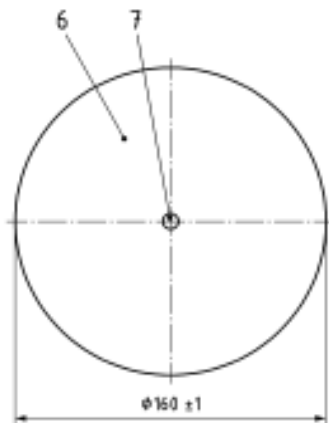
legend

1 X-ray

2a through 2d specimens areas

3 image receiver / detector

Three specimens of areas in Figure 1 are cylindrical parts of thickness $60 \text{ mm} \pm 0.25 \text{ mm}$ (range 2), $20 \text{ mm} \pm 0.25 \text{ mm}$ (range 2c) and $50 \text{ mm} \pm 0.25 \text{ mm}$ (range 2d) completely made of PMMA, optional with millings for positioning (see figure 2)



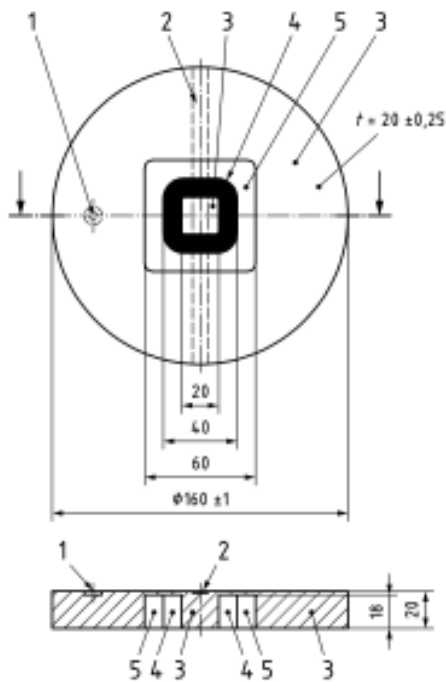
Picture 2 – testing homogeneous parts

legend

6 PMMA body

7 milled for positioning (optional)

The region 2b of the specimen is provided with additional structural elements, an incorporated rigid PVC ring (1.4 g / cm^3), and an air-filled milled. The following figures show the structural elements of the test specimen (Figure 3).



Picture 3 - testing structural elements, supervision and side section

legend

- 1 positioning aid (optional)
- 2 positioning aid (optional)
- 3 PMMA body
- 4 PVC ring
- 5 air

Test positions-visual and functional test

The need for the right application information on the use and operation as well as data of parameters of the X-ray apparatus including the imaging system must be taken from the accompanying documents for X-ray equipment.

The following information is checked by a visual inspection or functional testing for the presence of:

- characteristics such as X-ray tube voltage (kV), X-ray tube current (mA), X-ray tube loading time (s), scan time (s) recognizable;
- focal spot denomination recognizable according to DIN EN 60336 on nameplate;
- value of the total filtration on nameplate recognizable;
- positioning aid according to the manufacturer, and functional;
- indication of the dose area PRODUCT.

Alignment of the beam active detector area

Requirement

The beam shall however outshine the detector by more than 2% of the focus-detector distance in one direction by a maximum of 3% in both directions in the image receptor layer. Below an edge length of the active field of the detector of 8 cm deviation from the nominal size, however, must not exceed 2% exceed a maximum of 1% of the focus-detector distance in one direction in two directions.

examination

The maximum adjustable active beam-area is determined at the level of the detector edge with a probe in all four directions and compared to the physical size of the detector. NOTE ways of checking are the representation of a suitable receptacle on the picture-player with all-round unexposed edge or the expression of a relevant screenshots and the expression of a vendor-provided protocol or the documentation of the sequential application of a suitable semiconductor detector horizontally and vertically on the edge of the image receiving surface.

Reproducibility of the dose

Requirement

The deviation of three dose measurements from their average value D_d may not be greater than 10%.

examination

The dose is measured in free air (air kerma) without Testphantom as close to the image receptor plane. This exposure parameters are used according to the manufacturer for a standard patient.

Spatial resolution of the reconstruction

General

The existing in the test body spatial structures are represented in the various systems different. For known dimensions of suitable structures in the test body, the reconstruction of limited maximum spatial resolution can be determined.

Requirement

The value of the spatial resolution of the reconstruction is compared with the manufacturer's instructions and documented. The value must be within the tolerance range specified by the manufacturer.

examination

It will be selected a structure of the testphantom in the incidence of at least 5 mm in length directions of the pixel rows and columns in the data record of an axial layer. The number of pixels p along b is determined. The corresponding spatial resolution of the reconstruction is given by the equation

$$\sigma_f = \frac{b}{p}$$

Nyquist frequency v_n of the image is given by equation (1).

$$v_n = \frac{1}{2} \cdot \frac{p}{b}$$

It is

v_n the Nyquist frequency of the image;

p is the number of pixels;

b the extension in a main pixel direction.

NOTE This probe monitors the correct length measurement of structures in axial slices.

Spatial resolution

General

The characteristic of the system to represent finely textured objects with a corresponding CONTRAST is judged by resolution indicators. These are derived from the MODULATION transmission behavior.

NOTE Nyquist frequency has proven to describe the actual resolution as inadequate. The modulation transfer is determined in an axial layer after approximation method described in Annex A. This method quantifies the MODULATION transmission behavior reliably and with reasonable accuracy. It is largely independent of the applied image reconstruction and image processing.

The accurate determination of the modulation transfer function of the image of an edge requires a complex procedure. A very precise determination is therefore not possible because the treated here devices typically do not provide raw data in a standardized output format.

Requirement

The dissolution INDICATOR 50 is documented. The dissolution INDICATOR 10 must be ≥ 1 lp / mm.

examination

The modulation transfer characteristic is determined under the simplified procedure in Appendix A. The modulation transfer behavior is documented graphically or as a table of reference points.

The dissolution INDICATOR 50 and the dissolution INDICATOR 10 are from the modulation transfer behavior determines (mathematical interpolation or reading in the graph).

ACCEPTANCE INDICATOR

General

The CNR indicator is dependent on the dose and prescribed by the system axial spatial resolution. To check the systems considered independently of this dependence, the decrease INDICATOR AI was introduced.

NOTE There is a relatively high dose limit was introduced because it is to apply as a common threshold for different imaging volume and spatial resolutions represented. However, a higher-resolution system with a larger volume Pictured must exert correspondingly more dose. The current text ensures that the applied dose is in

reasonable proportion to the outcome. The required imaging volume and the required resolution can be determined by the doctor only in the context of justifying indication.

requirements

It is the requirement

$$AI \geq 100 \frac{1}{\text{mGy} \cdot \text{cm}^2}$$

The dose D in the isocentre must not exceed 50 mGy.

examination

For the determination of the value may be arithmetically averaged over as many axial slices which contain the structural elements that the total thickness of the layers does not exceed 1 mm. Result of "averaged layer record".

NOTE 1 This parameter is independent of the selected pixel scale (gain, windowing) of the systems investigated by the terms of the noise. The noise of both areas is equally involved here.

The dose D at the isocenter is determined from the The dose D_d (description before) and the geometric data. The necessary geometrical data are the distance of the focal spot from the center of rotation (a), the distance of the focal spot from the detector (b), the horizontal diameter (c) of the scanned volume and the horizontal diameter (d) of the radiation field at the detector. The dose in the axis of rotation D is calculated according to equation :

$$D = D_d \cdot \frac{b}{a} \cdot \frac{d}{c}$$

It is

D the dose in the axis of rotation;

D_d the average dose;

a is the distance of the focal spot from the center of rotation;

b is the distance of the focal point from the detector (place of dose measurement);

c the horizontal diameter of the scanned volume;

d the horizontal diameter of the radiation field at the detector (place of dose measurement).

NOTE 2 The manner of determining the dose in the axis of rotation compensates for different scanning geometries. On this basis the dosage in the axis of rotation D is independent of the selected scan geometry. The fact that the radiation field - adapted to the task - can be homogeneously distributed over the diameter of the scanned area is taken into account here. For the simplest scan geometries and homogeneous fields corresponds to the value of the CT DOSE INDEX OUTDOOR CTDI *free air*.

From the results so far the decrease INDICATOR AI is determined by equation:

$$AI = \frac{KRI}{D \cdot \left(\frac{1}{2 \cdot v_{50\%}} \right)^2}$$

It is

AI acceptance indicator;

KRI the CNR indicator;

D the dose in the axis of rotation;

$v_{50\%}$ RESOLUTION INDICATOR 50

INDICATOR HOMOGENEITY

Requirement

The value of H for the UNIFORMITY indicator must be > 5 .

examination

The basis is, the reconstruction of a homogeneous PMMA layer. Five fields of the same size are selected (each about 2% to 3% of the displayed testphantom surface). One is selected in the center of the testphantom the others equidistant from the center. The peripheral fields must be from the center of the illustrated test body surface at least half their radius away. Taken are the arithmetic mean of the pixel values of the field in the center (H_z), and the four other fields H_l (left), H_r (right), H_o (above) and H_u (below). To calculate the large HOMOGENEITY INDICATOR H the greatest difference in the values H_z , H_L , H_R , H_o and H_u is from its mean H_M in relation to the basic contrast $P_{mmax} - P_{mmin}$ (see Appendix B) according to equation set:

$$H = \frac{P_{mmax} - P_{mmin}}{\text{Max} \left\{ |H_z - H_M|, |H_o - H_M|, |H_l - H_M|, |H_r - H_M|, |H_u - H_M| \right\}}$$

H homogeneity indicator;

P_{mmax} the average of the pixel values of the pixel row m_{max} (see Appendix B);

P_{mmin} the average of the pixel values of the pixel row m_{min} (see Appendix B);

H_z the arithmetic mean of the pixel values of the field in the center;

H_l the arithmetic mean of the pixel values of the field on the left;

H_r the arithmetic mean of the pixel values of the field on the right;

H_o , the arithmetic mean of the pixel values of the field above;

H_u , the arithmetic mean of the pixel values of the field below;

H_M the average of the values H_z , H_L , H_R , H_o and H_u .

NOTE 2 This parameter is a result of the terms of the contrast regardless of the selected pixel scale of the studied systems. A high value corresponds to a high large-scale homogeneity.

Annex A

Simplified determination of MODULATION transmission behavior

As the basis of determining the transmission behavior MODULATION a rectangular box is selected of the testphantom in an axial layer of the reconstructed data of the test specimen.

The pages of this field must extend along the pixel rows and columns. The field can only map fields of the test specimen made of PVC and air. The transition between the two materials must be included as an edge parallel to the field boundaries. The parallel imaging can be optimized by Repositio-ordination of the specimen and repeat the recording.

The page length of the field parallel to the edge corresponds to 5 mm in length in the test body (tolerance: 1 pixel). The page length of the field perpendicular to the edge corresponds to both sides of at least 3 mm in length specimen.

a) data collection

The pixel values of the field are in rows parallel to the averaged image of the edge between PVC and air, arithmetically. The averages are numbered and recorded ($M_1, M_2, M_3, \dots, M_n$).

b) differentiation

Neighboring averages are subtracted from each other. This results in the differences $D_1, D_2, D_3, \dots, D_{n-1}$, according to equation (A.1).

$$D_m = M_{m-1} - M_m$$

It is

D_m the difference between the averages of pixel values of consecutive lines;
 M_{m+1} the mean of the pixel values of the pixel row $m+1$;
 M_m the average of the pixel values of the pixel row m .

c) Restriction to the transition area

The difference values $D_1, D_2, D_3, \dots, D_{n-1}$ contain a D_k , which is greater in amount than any other. From this starting of the symmetrically adjacent region is detected, for which the differences have the same sign $D_{k-1}, D_{k-1}+1, \dots, D_k, D_{k+1}-1, D_{k+1}$

NOTE 2 This restriction is used to separate the edge image of the comparatively small differences arising from Heel effect and noise.

d) Fourier transforms

The number of values $|D_{k-1}|, |D_{k+1}|, \dots, |D_k|, \dots, |D_{k+1}|, |D_{k+1}|$ is complemented by zeros to a power of two, discrete Fourier transform and the Fourier coefficients are normalized to their maximum. The first half of the sums so established, the transfer coefficients

F_0, F_1, \dots, F_m is taken.

Likewise, the number of arithmetic values $\frac{1}{2} |D_{k-1} - D_{k+1}|, \frac{1}{2} |D_{k+1} + D_{k+1}|, \dots, \frac{1}{2} |D_k - D_k|, \dots, \frac{1}{2} |D_{k+1} - D_{k+1}|, \frac{1}{2} |D_{k+1} + D_{k+1}|$ is symmetrized.

Power of two supplements, discrete Fourier transformed, normalized to its maximum and

given the amounts determined the transfer coefficients $\tilde{F}_0, \tilde{F}_1, \dots, \tilde{F}_m$ in the spatial frequency range from 0 up to the Nyquist frequency ν_n .

e) averaging

There are the arithmetic means $\bar{v}_p = \frac{1}{2}(v_p + v_{p-1})$ included and the spatial frequencies assigned $v_p = p \cdot \frac{v_n}{m}$ zugeordnet ($p = [0, 1, \dots, m]$).

NOTE 3 The values m_p serve as reference points of the MODULATION transmission behavior in the spatial frequency range between 0 and the Nyquist frequency v_n .

f) Graphical display

The value pairs $(F_p; v_p)$ are represented as points on a graph and straightforward connected. The abscissa shows the values of the spatial frequencies v_p on a linear scale. The ordinate shows the values of the transmission factors F_p on a linear scale.

Annex B

Calculation of CNR (contrast-noise) INDICATOR

The basis of the characterization of the CNR INDICATOR a rectangular box is selected in an axial layer of the rekonstruierten record of the test specimen.

The pages of this field must extend along the pixel rows and columns. The field can only map fields of the test specimen made of PVC and PMMA. The transition between the two materials must be included as an edge parallel to the field boundaries.

The page length of the field parallel to the edge equal to 10 mm in length in the test body (tolerance: 1 pixel). The page length of the field perpendicular to the edge corresponds to both sides of at least 3 mm in length specimen.

The calculation of the contrast-to-noise indicator takes place in the following steps:

a) data collection

The pixel values of the field are evaluated in parallel with the image of the edge between PMMA and PVC line by line. The mean values ($P_1, P_2, P_3, \dots, P_n$) and standard deviations ($S_1, S_2, S_3, \dots, S_n$) of the rows are numbered and recorded.

b) First differentiation

The first differentiating a sliding average over neighboring values is formed. The differences $P'_5, P'_6, \dots, P'_{n-4}$ are calculated using Equation (B.1).

$$P'_m = \frac{1}{5}(P_{m+4} - P_{m+3} - P_{m+2} + P_{m+1} - P_m) - \frac{1}{4}(P_{m+4} + P_{m+3} + P_{m+2} + P_{m+1})$$

It is

P_m is the mean of the pixel values of the pixel row m ;

P'_m the difference from the average of $4 + P_m, P_m + 3, P_m + 2, P_m + 1$ and P_m and the mean value of $P_{m-4}, P_{m-3}, P_{m-2}$ and P_{m-1} .

NOTE The moving average is the reliable localization of the edge.

c) Second Differentiation

The differences $P''_6, P''_7, \dots, P''_{n-6}$ are calculated using Equation .

$$P''_m = P'_{m+1} - P'_m$$

It is

P''_m the difference of P'_{m+1} and P'_m .

From the series, the indices now m_{max} and determined m_{min} the largest value $max P''_{m_{max}}$ and the smallest value $P''_{m_{min}}$.

d) CNR INDICATOR

The CNR indicator is determined according to equation:

$$KRI = \frac{|P_{r_{max}} - P_{r_{min}}|}{\sqrt{\frac{1}{2}(S_{r_{max}}^2 + S_{r_{min}}^2)}}$$

It is

KRI the CNR indicator;

$P_{r_{max}}$ the average of the pixel values of the pixel row m_{max} ;

$P_{m_{min}}$ the average of the pixel values of the pixel row m_{min} ;
 $S^2_{m_{max}}$ the variance of the pixel values of the pixel row m_{max} ;
 $S^2_{m_{min}}$ the variance of the pixel values of the pixel row m_{min} .

NOTE The edge caused in the course of the line means ($P_1, P_2, P_3, \dots, P_n$) of the pixel values of two extreme values of the curvature behavior. These are found in the extreme values of the second derivative. The jump height between the corresponding pixel values $P_{m_{max}}$ and $P_{m_{min}}$ is a measure of the contrast in the image. The moving average in the first differentiation serves to stabilize the result.