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SHORT COMMUNICATION

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Manipulated radiographic material – capability and risk for the forensic consultant?

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Abstract As interest is being increasingly focused on the digital processing of radiographs for identification of the deceased, the benefits and risks of electronic image processing are presented. With digitization of all kinds of radiographic equipment being on the increase and image processing personal computers being readily accessible, increasing quantities of manipulated radiographic material are to be expected in the future. This potential risk is meanwhile highlighted from the legal aspect.

Key words Digital radiography · Legal aspect · Identification · Manipulation

Introduction

While image processing software permits the contour and focus to be corrected, it has the inherent risk of allowing the image to be misleadingly manipulated. With digitization of all kinds of radiographic equipment being on the increase and image processing personal computers being readily accessible, increasing quantities of manipulated radiographic material are to be expected in the future [13, 15, 17]. This development calls upon the forensic expert to use these capabilities to make pathology findings more clearly but also to be critical in the assessment of images produced by the new digital generation and to challenge the legal validity of that previously unchallenged piece of evidence, the X-ray. As interest is being increasingly focused on the digital processing of radiographs in identification of the deceased, the benefits and risks of electronic image processing are presented.

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Digital image processing

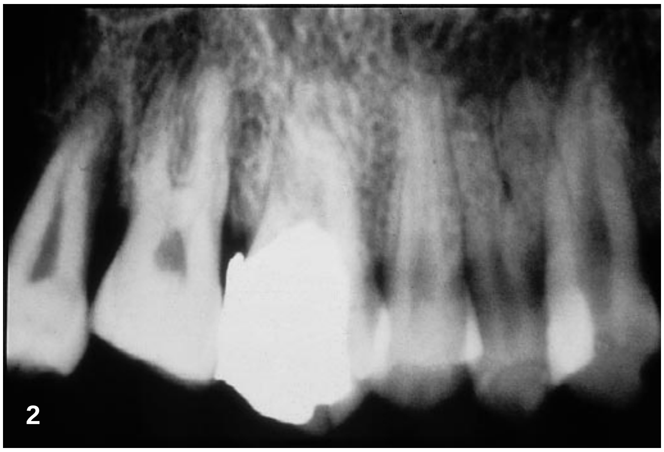
Admissible image manipulations

Contrast enhancement

The resolution of an optical apparatus is defined by the smallest distance between two points which can be separately perceived. For instance, the healthy human eye is capable of distinguishing two points placed 0.1 mm apart from a distance of 25 cm [10]. In contrast, the digital image is split into 2–4 μm pixels in varying gray tones, depending on the technique used. Unlike human vision, image points can be distinguished even when they are immediately adjacent to each other. Whereas a conventional X-ray has a contrast potential comprising 160 gray levels, up to 4096 levels (MR and CT) can be distinguished in the computer. The computer-aided contrast is thus approximately 63 times greater than with the human eye, which can distinguish 35–95 gray levels [10, 25]. In forensic practice, this expansion of the photographic contrast enables the viewer to tamper with those parts of the image which are of interest in such a way that structures which he would have overlooked when viewing the original film become clearer or even simply visible. Low contrast X-rays can be optimized in the density and gradation, greatly simplifying appraisal of the content by the user.

Brightness correction

Faults in exposure and development are the main causes underlying non-uniformity of X-ray exposures. In the preparation of postmortem images, exhibits with complete or partial loss of the soft tissue covering result in further differences in contrast, often making it more difficult to assess details. In such cases, over- or underexposed sections can be digitally corrected. Figure 1 shows a digitized plain film which was then subjected to subsequent contrast enhancement and brightness reduction (Fig. 2).



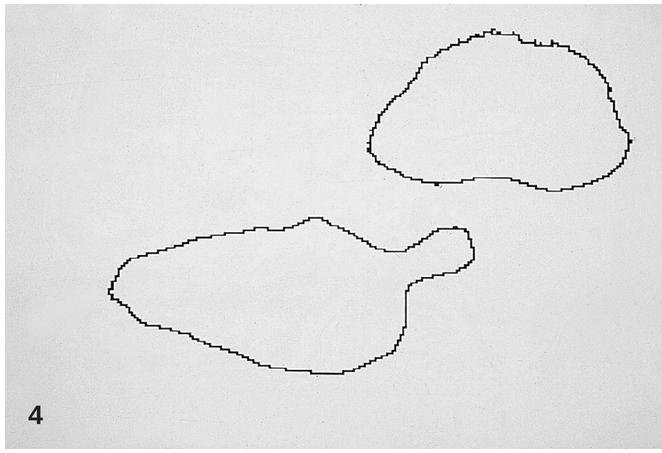


Fig. 1 Authentic X-ray digitized with the Kodak digital science photo CD system after photographic reproduction

Fig. 2 The same X-ray as in Fig. 1 after contrast enhancement and brightness reduction to increase the informative value of the image

Fig. 3 X-ray with poorly contoured metal-impermeable shadows

Fig. 4 Digital determination of all points with identical grey level differentials produces a contour line delineated from the adjacent tissue

Fig. 5 Pseudo-relief image of the X-ray shown in Fig. 3

Digital contour comparison

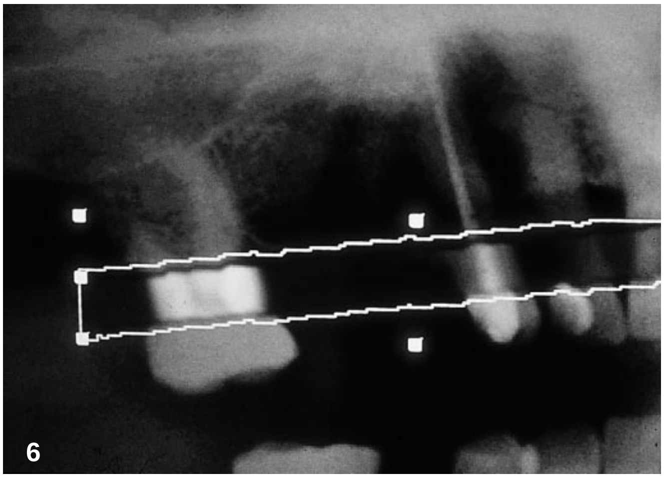
Postmortem identification using antemortem and postmortem X-rays is based primarily on a comparison of radiologically well-defined contours. Poorly defined contours (e.g. osteomyelitis) are less suited to this purpose than fracture lines, the bony contours of the paranasal sinuses, cysts, sutures or metal-impermeable shadows of incorporated foreign bodies. Various graphic programs (e.g. Corel Draw) provide gradient-aided contour detection by scanning the images using a gradient specified by the individual user. The computer determines the coordinates of all points with identical grey level differentials, so that the sum total can be composed into a contour line delineated from the adjacent tissue [21] (Figs. 3 and 4).

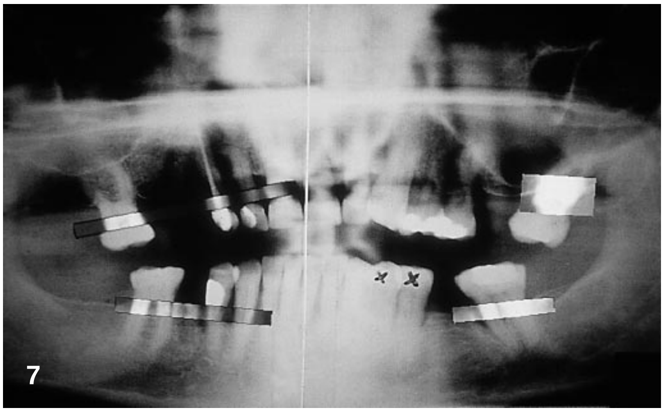
Pseudo-relief images

If an original X-ray negative is superimposed with only a negligible offset onto a transparent positive copy obtained by contact copying, the two-dimensional X-ray creates a plastic, slightly raised impression. Such a pseudo-relief image offers edge enhancement [2], and the informative value of the image can be increased by contrast enhancement induced by subsequent monochromatic staining and subjective perception (Fig. 5).

Segmentation images

Various software products (eg Corel Draw) allow so-called threshold values to be stipulated. Imaging points with a brightness below this threshold are suppressed on the monitor, resulting in a segmentation image in which essential contour characteristics are highlighted.





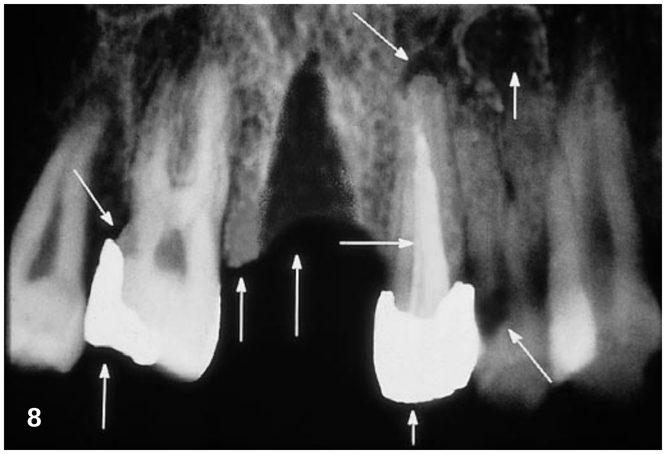


Fig. 6 Postmortem orthopantomogram of an unidentified fire victim

Fig. 7 Slice interposition according to Wood et al. [26]. After digitization, individual sections from the postmortem X-ray (Fig. 6) were merged into the comparative premortem X-ray. The concordance of the contours permitted identification

Fig. 8 This figure shows the same X-ray as in Fig. 1 after digital manipulation: tooth 16 has undergone digital "extraction", the healthy tooth 17 has been provided with a filling with marginal caries, the osteoseptum between 16 and 17 has been augmented, tooth 15 has been given a filling, a root filling and apical osteolysis, tooth 14 has been manipulated to display profound caries and a radicular cyst

Fig. 9 With manipulation completed, the entire image has undergone additional digital "curvature"

Slice interposition according to Wood et al. [26]

For direct comparison of premortem and postmortem X-rays, sections can be cut out of the postmortem image and inserted at the presumed place in the premortem image. Direct contour comparison makes for reliable classification [22, 26]. However, it must be borne in mind that the length/width ratio of the interposed section must not be changed. Changes in size are permissible only in accordance with the laws of constant angulation. The authors recommend this method for the comparison of interradicular osteosepta in the dentigerous jaw area if dental restorations are missing or have been destroyed (Figs. 6 and 7).

The classification of intravital dental films may give rise to postmortem problems if the anatomical region cannot be unequivocally determined. In such cases it is advisable to prepare postmortem orthopantomograms, since they provide a side-accurate overview of the entire maxilla and mandible. Following secondary digitization, classification is based on the slice-interposition principle. Contrast and focus can also be optimized if necessary.

Digital superimposition for identification purposes

Helmer [11] reported on the possibility of superimposition for postmortem identification, using a standard PC and an analog video camera. For this purpose the comparative photos were first digitized and then compared with the static video image of the skeletonized skull [12, 14].

Inadmissible manipulations

Any manipulations which distort radiologically visible structures by changing their angular relationship are inadmissible [1, 5, 7–9, 18]. All enlargements or reductions have to be executed strictly in accordance with the laws of constant angulation to ensure that the figure and image retain a consistent angle in all events. Modern image processing software offers a number of opportunities for alien application, enabling the user to manipulate and falsify image contents fundamentally after a short practice period.

With a broad range of drawing tools at his disposal, the user is capable of retouching, accentuating or fading out contours. In this way, Jung et al. [16] demonstrated how readily root fillings of any shape and size can be entered into X-rays or removed. The same applies to any kind of pathology and non-pathology morphology (Figs. 8 and 9).

Results and discussion

In contrast to the opinion expressed by Benz et al. [3] that digital manipulations can always be detected, the present authors see justified doubt in the probative value of digitally processed images, especially of X-rays.

Perusal of the German and Anglo-American literature reveals two different attitudes to digital image processing. Whereas a number of authors [4, 6, 11] see only advantages, others have expressed criticism [16, 19, 20, 23, 24]. When comparing X-rays, digital distortion is not an admissible means of postmortem reconstruction of intravital radiological parameters. Postmortem ray path reconstruction involves more complex procedures, as is impressively demonstrated by Homann et al. [12]. It must not be the objective of postmortem radiology to perform secondary digitization of poor quality postmortem X-rays and to manipulate them to such an extent that optimal or even misleading results are presented.

The claim by forensic experts that image manipulations could be detected at first glance on account of the poor quality ascribed to them was disproved once and for all with the report published by Visser and Krüger [24]. The authors presented 6 authentic and 6 manipulated X-rays to 39 specialist colleagues for their opinion and found that none was able to identify all manipulations as such.

This potential risk has been highlighted from the legal aspect. For example, Jung et al. [16] pointed out that it is a “document” and not an electronic data file which is demanded by the judge, so that special attention should be given to securing an original copy. When employing digital imaging techniques, the practitioner must bear in mind not only the practical aspects but also the medicolegal status, i.e. the probative value [19]. Any digital image is a subjective interpretation, not an objective document. The X-ray which was once seen as conclusive evidence will have to be subjected to greater scrutiny in the future. Schyma and Schyma [20] pointed out that the fundamental imaging conditions must always be taken into account when evaluating digital image material.

In conclusion, the digital imaging technique offers not only beneficial applications but also a number of opportunities for manipulation. From the aspect of clinical radiology, digital examination methods can be expected to find increasing use, with antemortem X-rays being available in the future only as a data file, a situation which may give rise to substantial legal problems. This is of special significance due to the widespread use of image processing software and hardware now readily accessible to the general public in the form of personal computers.

References

1. Anderson C (1994) Easy-to-alter digital images raise fears of tampering. Science 263:317–318
2. Bengel W (1984) Die Photographie in Zahnmedizin und Zahntechnik, 1. Aufl. Quintessenz Verlag Berlin
3. Benz C, Künzel A, Sonnabend E (1993) Neue Systeme zur elektronischen Anfertigung und Archivierung von Zahnröntgenaufnahmen. Quintessenz 44:1161–1169
4. Buitrago-Tellez C, Wenz W, Friedrich G (1992) Digitale Röntgenbildbearbeitung als Hilfsmittel in der Rechtsmedizin. Radiologe 32:87–89
5. Dunn SM, Kantor MJ (1993) Digital radiography. Facts and fictions. J Am Dent Assoc 124:39–47
6. Fitzpatrick JJ, Shook DR, Kaufman BL, Wu SJ, Kirschner RJ, MacMahon H, Levine LJ, Maples W, Charletta D (1996) Optical and digital techniques for enhancing radiographic anatomy for identification of human remains. J Forensic Sci 41:947–959
7. Gray JE (1983) Standardization in video and digital diagnostic imaging. Am J Roentgenol 141:837–838
8. Gray JE, Karsell PR, Becker GP, Gehring DG (1984) Total digital radiology: is it feasible? or desirable? Am J Roentgenol 143:1345–1349
9. Haberäcker P (1991) Digitale Bildverarbeitung, 4. Aufl. Hanser, München
10. Harms V (1987) Physik für Mediziner und Pharmazeuten, 10. Auf. Harms, Kiel
11. Helmer R (1998) Identifizierung unbekannter und unkenntlicher Leichen mittels bildtechnischer oder rekonstruktiver Verfahren. In: Leopold D (ed) Identifikation unbekannter Toter. Schmidt Römhild, Lübeck
12. Homann T, Riepert T, Schild H, Mattern R (1995) Computerunterstützte radiometrische Schädelidentifikation unter besonderer Berücksichtigung unterschiedlicher Aufnahmeparameter. Rechtsmedizin 5:78–81
13. Horner K, Brettle DS, Rushton VE (1996) The potential medico-legal implications of computed radiography. Br Dent J 180:271–273
14. Iscan MY (1993) Craniofacial image analysis and reconstruction. In: Iscan MY, Helmer R (eds) Forensic analysis of the skull. Wiley-Liss New York, pp 1–9
15. Jähne B (1993) Digitale Bildverarbeitung, 3. Aufl. Springer, Berlin Heidelberg New York
16. Jung T, Figgener L, Visser H (1996) Digitale Röntgenaufnahme und Dokumentationspflicht. Zahnärztl Mitt 86:760–763
17. Pfretzschner M (1997) Digitales Röntgen in der Praxis. Colleg-Magazin 3:104–108
18. Richardson ML, Frank MS, Stern EJ (1995) Digital image manipulation: what constitutes acceptable alteration of a radiologic image? Am J Roentgenol 164:228–229
19. Schmidt-Beck JR (1991) Rechtliche Aspekte der EDV-gestützten ärztlichen Dokumentation. NJW 44:2335–2337
20. Schyma C, Schyma P (1995) Videodokumentation in der forensischen Praxis. Arch Krim 196:93–104
21. Stamm T, Brinkhaus HA, Lenzen H, Bollmann F (1996) Computergestützte Weichteilprofilerkennung im Fernröntgenseitenbild. Dtsch Zahnärztl Z 51:8–10
22. Tai C, Blenkinsop B, Wood R (1993) Dental radiographic identification utilising computerised digital slice interposition: a case report. J Forensic Odonto-Stomatol 11:22–30
23. Visser H (1994) Ein einfaches Verfahren zur Digitalisierung von Zahnfilmen. ZWR 103:282–287
24. Visser H, Krüger W (1997) Can dentists recognize manipulated digital radiographs? Dentomaxillofacial Radiology 26:67–69
25. Welp U, David M (1997) Verbesserte zahnärztliche Röntgendiagnostik durch Scannen von Zahnfilmen und digitale Bildoptimierung. Dentalspiegel 17:30–31
26. Wood RE, Tai C, Blenkinsop B, Johnston D (1994) Digitized slice interposition in forensic dental radiographic identification. An in vitro study. Am J Forensic Med Pathol 15:70–78