J Forensic Sci, Nov. 2003, Vol. 48, No. 6
Paper ID JFS2003118_486
Available online at: www.astm.org

TECHNICAL NOTE

Michael J. Thali,[1,2] *M.D.; Marcel Braun,*[3] *Joachim Wirth,*[4] *Ph.D; Peter Vock,*[2] *M.D.; and Richard Dirnhofer,*[1] *M.D.*

3D Surface and Body Documentation in Forensic Medicine: 3-D/CAD Photogrammetry Merged with 3D Radiological Scanning

ABSTRACT: A main goal of forensic medicine is to document and to translate medical findings to a language and/or visualization that is readable and understandable for judicial persons and for medical laymen. Therefore, in addition to classical methods, scientific cutting-edge technologies can and should be used. Through the use of the Forensic, 3-D/CAD-supported Photogrammetric method the documentation of so-called "morphologic fingerprints" has been realized. Forensic, 3-D/CAD-supported Photogrammetry creates morphologic data models of the injury and of the suspected injury-causing instrument allowing the evaluation of a match between the injury and the instrument. In addition to the photogrammetric body surface registration, the radiological documentation provided by a volume scan (i.e., spiral, multi-detector CT, or MRI) registers the sub-surface injury, which is not visible to Photogrammetry. The new, combined method of merging Photogrammetry and Radiology data sets creates the potential to perform many kinds of reconstructions and postprocessing of (patterned) injuries in the realm of forensic medical case work. Using this merging method of colored photogrammetric surface and gray-scale radiological internal documentation, a great step towards a new kind of reality-based, high-tech wound documentation and visualization in forensic medicine is made. The combination of the methods of 3D/CAD Photogrammetry and Radiology has the advantage of being observer-independent, non-subjective, non-invasive, digitally storable over years or decades and even transferable over the web for second opinion.

KEYWORDS: forensic science, wound documentation, Photogrammetry, 3-D/CAD, forensic radiology, image fusion, image merging, virtual autopsy, virtopsy

Wound documentation and analysis in forensic medicine is progressing towards the use of high-tech methods. To document the body surface in 3D some forensic groups have started to use for example 3D Photogrammetry methods (1–4). In addition, there is the possibility to document the internal body morphology using modern Computed Tomography (CT) and Magnetic Resonance (MR) techniques (5,6). Radiology, especially CT and MR, had one of the greatest impacts in medicine in the last years. To reach a full output of the existing technology merging the different modalities is necessary and essential. Based on this knowledge, the goal of this study is to demonstrate how to merge 3D photogrammetric data with a 3D radiological dataset to reach full surface and internal body documentation for forensic analysis.

[1] University of Berne, Institute of Forensic Medicine, Buehlstrasse 20, 3012 Berne, Switzerland.
[2] Institute of Diagnostic Radiology, University of Berne, 3010 Berne, Switzerland.
[3] Scientific Forensic Service, Photogrammetry Division, Zurich City Police, Zurich, Switzerland.
[4] CARCAS Group, University of Basel, 4031 Basel, Switzerland.
Received 30 Mar. 2003; and in revised form 15 June 2003; accepted 15 June 2003; published 27 Aug. 2003.

Methods

The photogrammetric and radiological method is shown based on a muzzle imprint on the chest of a victim in a gunshot case (Fig. 1).

First, the injury site was marked with "radiological landmarks" (Multi-Modality Markers for CT and/or MRI, IZI Medical Products, Baltimore, MD), i.e., radiologically visible orientation markers, which serve in the photogrammetric and radiological data merging process.

Photogrammetric Documentation and 3D Analysis Process

Forensic, 3-D/CAD-supported Photogrammetry is the science of the measurement and 3-D reconstruction of the external surface(s) of patterned injuries, and their possible injury-causing instruments. The principles of the forensic 3D/CAD supported Photogrammetry (FPHG) was recently published in form of a step-by-step documentation guideline manual (2). FPHG is a method of recording and documenting the surface of objects, thus enabling a 3-dimensional image of objects in virtual space. The procedure allows the examination of (patterned) injuries for matching potentially incriminating instruments in shape, size, and angle. 3D recording of objects to be examined requires taking a series of photographs or scanning (Fig. 2). The computer system then calculates the position in space of specific points on the surface of the objects and subse-

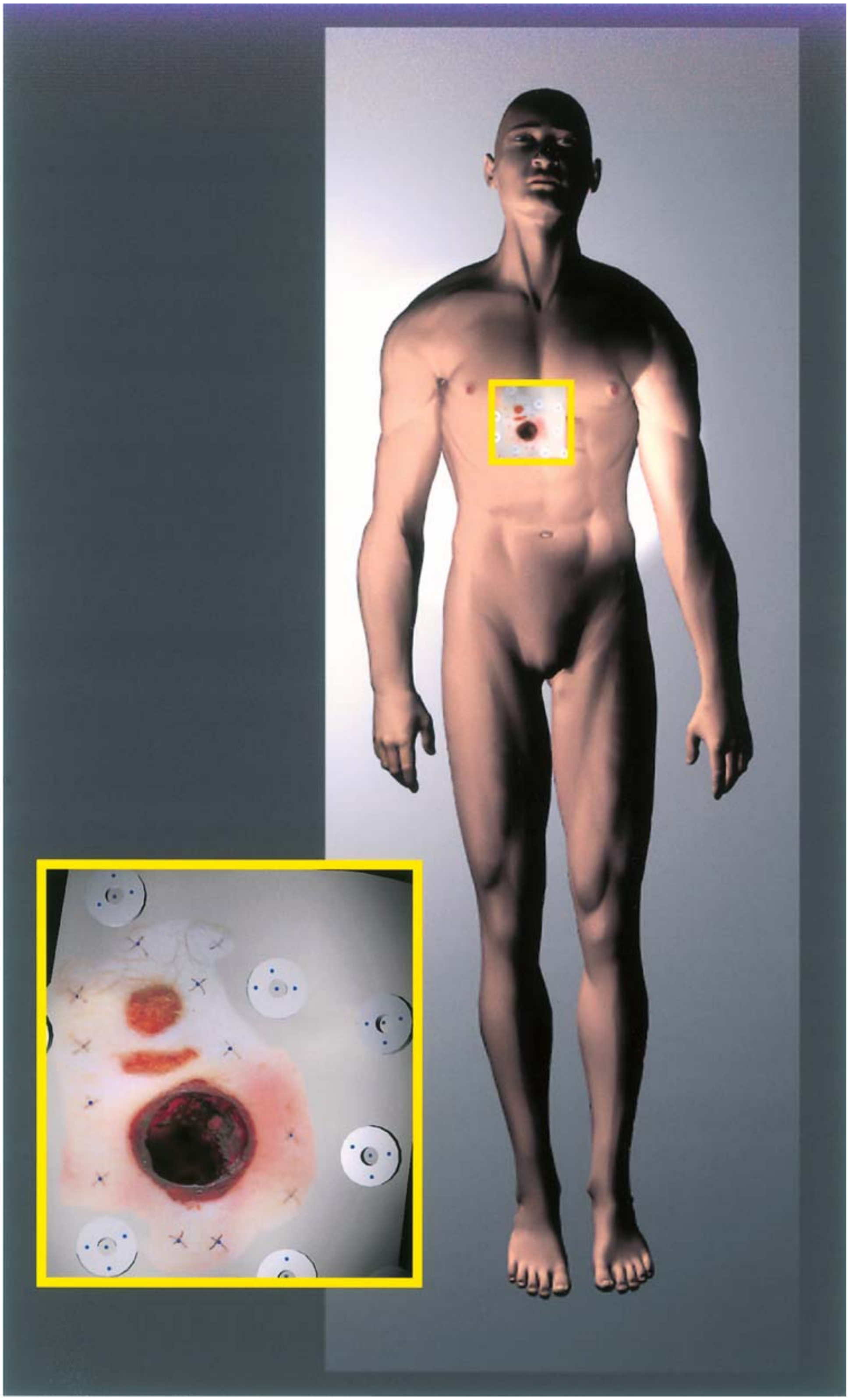

FIG. 1—*Shotgun entrance wound localized using Poser software and in a detailed view.*

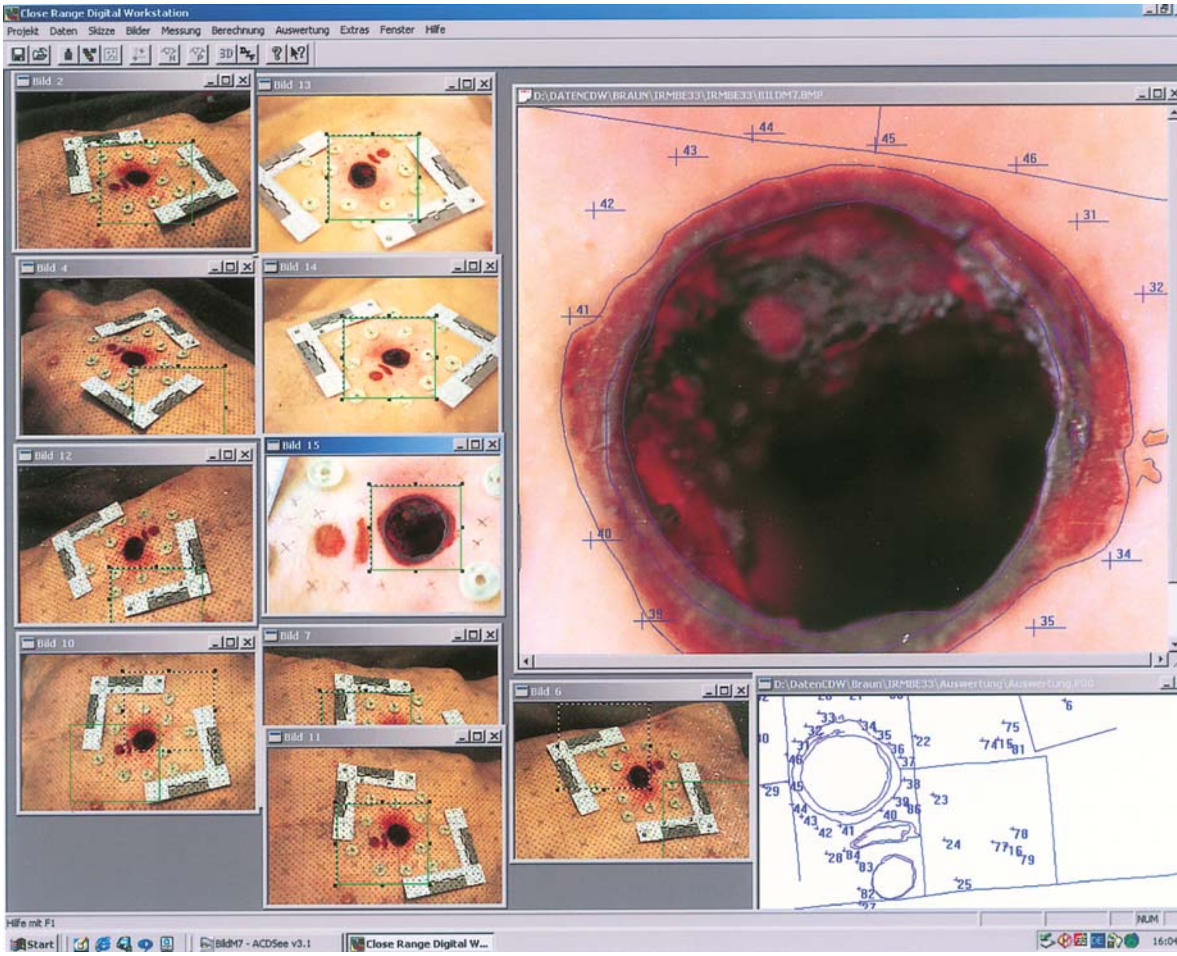

FIG. 2—*Pictures series of the wound for the photogrammetric documentation and analysis.*

quently produces 3D data models of the objects (Figs. 3, 4). Using a 3D/CAD program these data models are used to generate graphic, true-to-object volume models. The objects in question, for example the muzzle imprint and the barrel of the shotgun, can then be moved against each other arbitrarily, on the screen in 3D, for comparison, measurement and to possibly establish their congruence. These models could then be compared against one another in virtual space, to see if there were matching areas in size and shape (Fig. 5). The muzzle imprint and the shotgun were examined with respect to matching shapes, angles, and dimensions.

Radiological Documentation

The body was scanned by a multi-slice CT scanner with 4 detector rows (General Electric Medical Systems, Milwaukee, WI), using a high-resolution modus. The CT cross-sections and subsequent 3D CT reconstruction permitted the evaluation of the injury's sub-surface morphological details (7), which were not visible to the photogrammetric process (Figs. 6, 7, 8).

Image Fusion/Merging the Datasets

Using the "radiological landmark," new computer technology allowed the superimposition of the Photogrammetry dataset directly onto the contours of the radiological 3D CT model, rather like "coating" or merging the radiological dataset with the photogrammetric data (Figs. 9–12).

Results

The result was a Forensic Photogrammetric dataset of the external injury surface and a CT dataset of the internal volume (body) of the injury (Figs. 3–12).

Figure 3 shows the photogrammetric surface documentation, Fig. 5 shows the match analysis of the photogrammetric 3D surface of the muzzle imprint with the shotgun on the computer screen, and Figs. 6–8 demonstrate the result of the CT scans (cross-sections and 3D visualizations). Finally, Figs. 9–12 demonstrate the merged datasets of the Forensic, 3-D/CAD-supported Photogrammetry and the radiological CT data using the previously mentioned "radiological landmarks."

Discussion and Conclusion

A main goal of forensic medicine is to document and to translate medical findings to a language and/or visualization that is readable and understandable for judicial persons and for medical laymen. Therefore, in addition to classical methods, scientific cutting-edge technologies can and should be used. In this study we transformed our vision of image fusion to reality. We had postulated the idea of merging a 3D surface and a 3D internal body documentation already some years ago (4). Now the recent progress of technical development has made it possible to realize the idea using a real forensic case. High-tech technology like 3D Photogrammetry and cross-sectional radiology in combination with CAD software allow

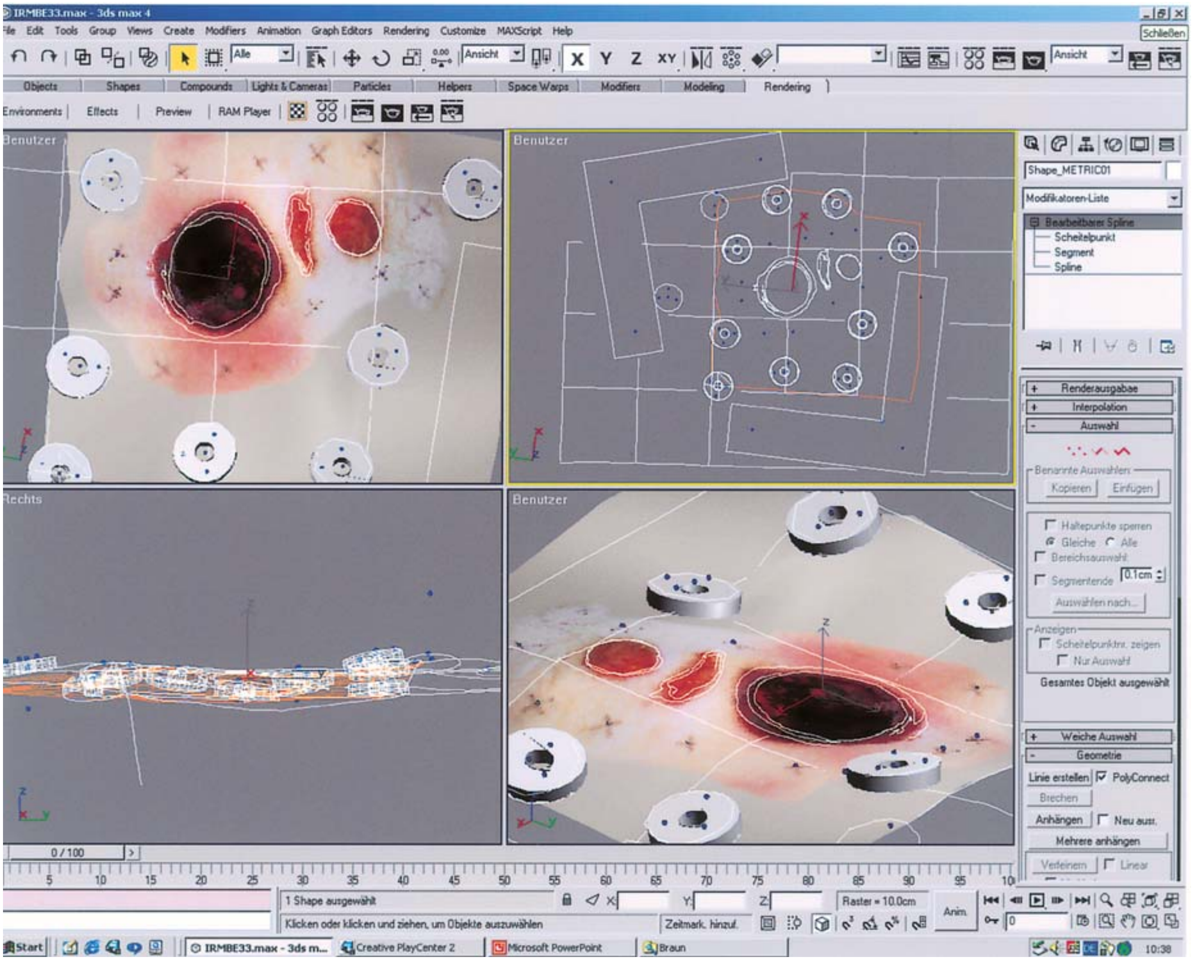

FIG. 3—*Photogrammetric visualization of the wound in 3D.*

FIG. 4—*Shotgun (bottom) and its 3D model on the computer screen.*

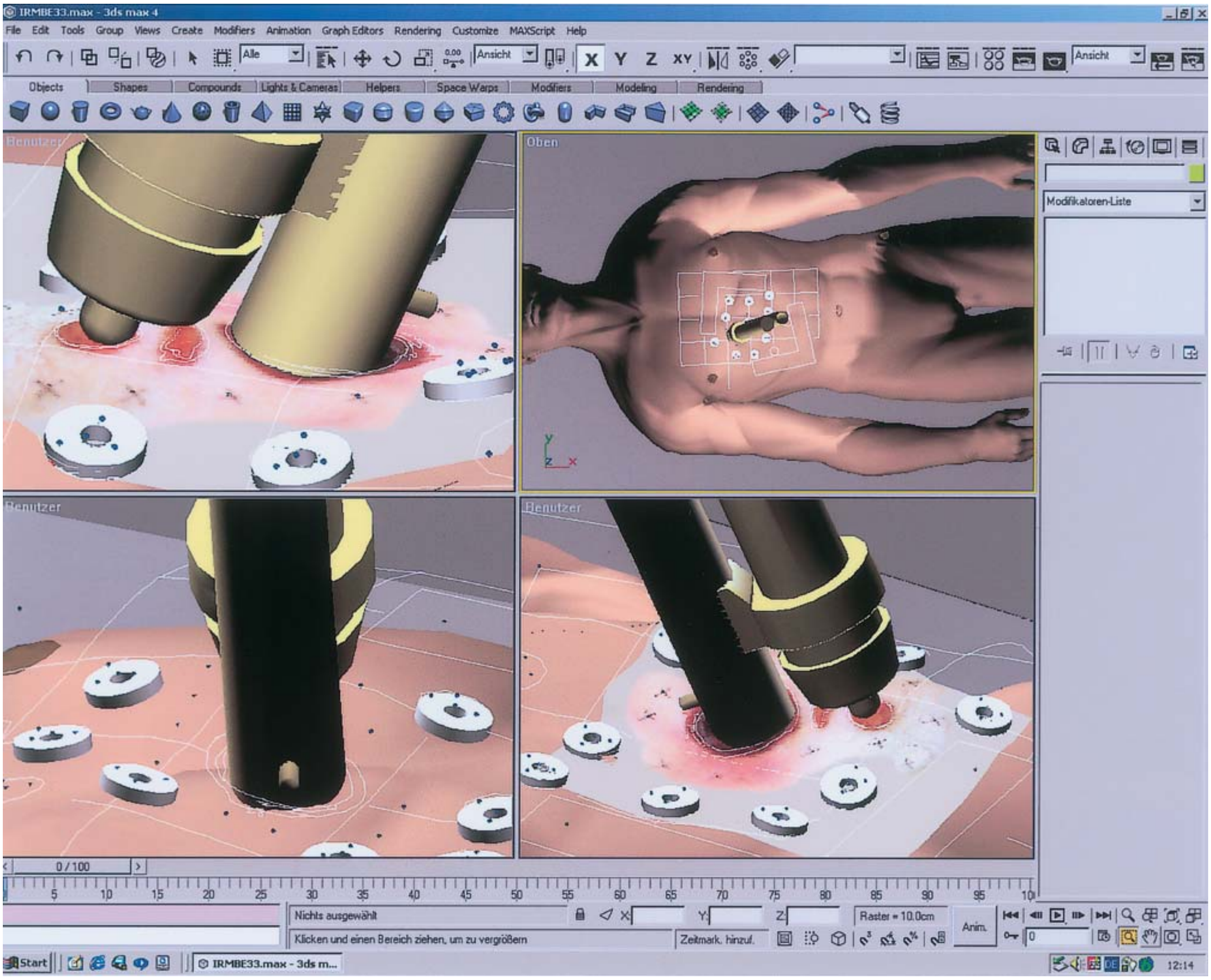

FIG. 5—*Photogrammetric attempt to fit-and-match the muzzle imprint with the weapon.*

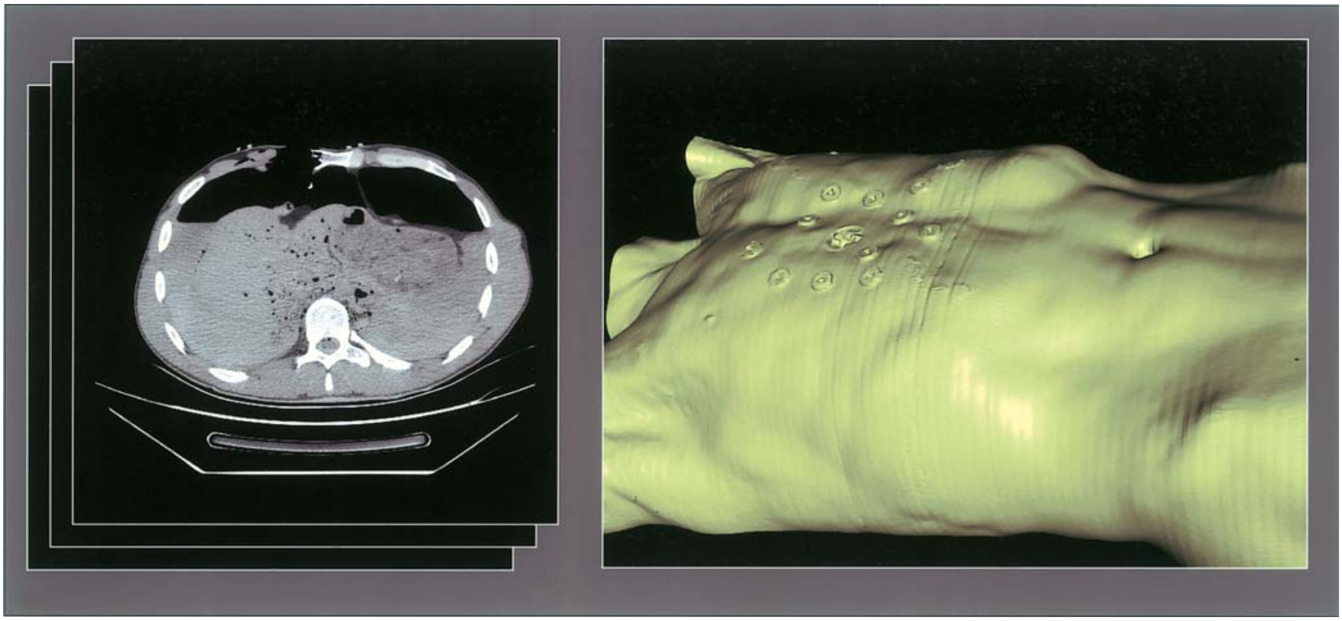

FIG. 6—*CT cross-section through the gunshot injury. 3D reconstruction of the body based on the CT cross-sections.*

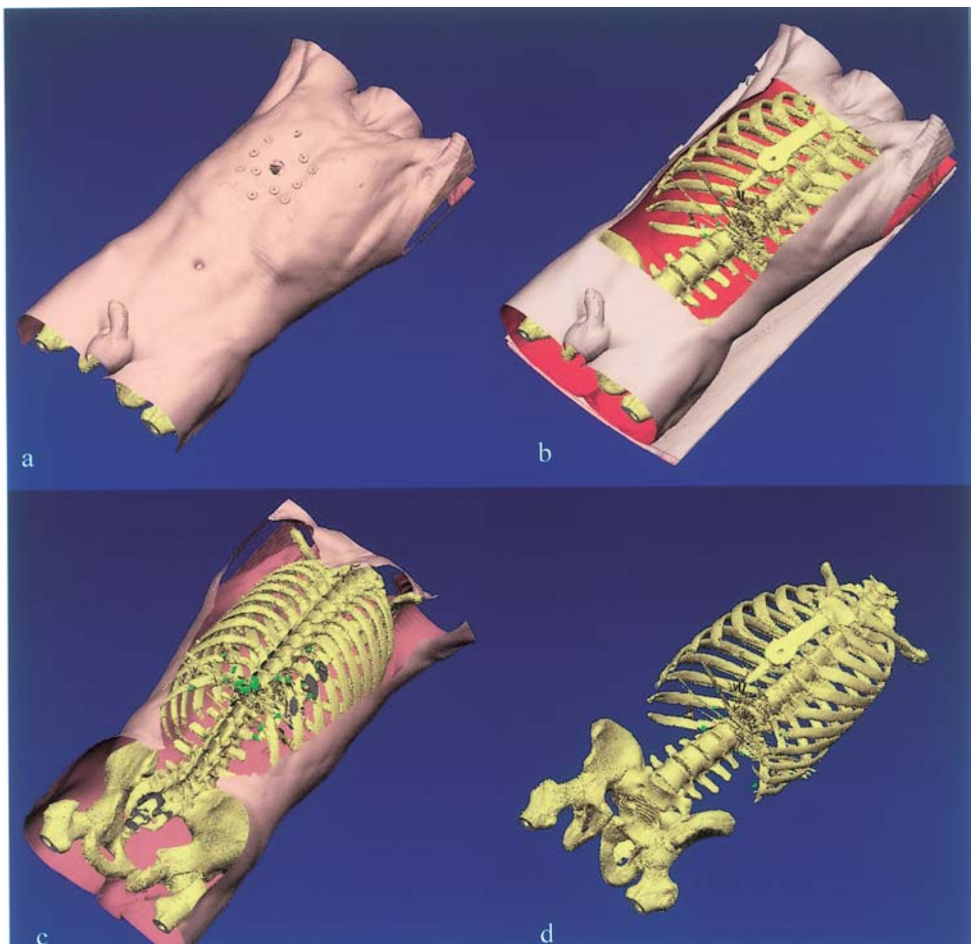

FIG. 7—*3D CT reconstructions demonstrate:* a) *Skin or soft tissue visualization of the body,* b) *virtual opening of the thorax and abdomen showing bullets (with some metal artifacts, seen as star patterns) in the body,* c) *dorsal view of image 7b,* d) *bone visualization.*

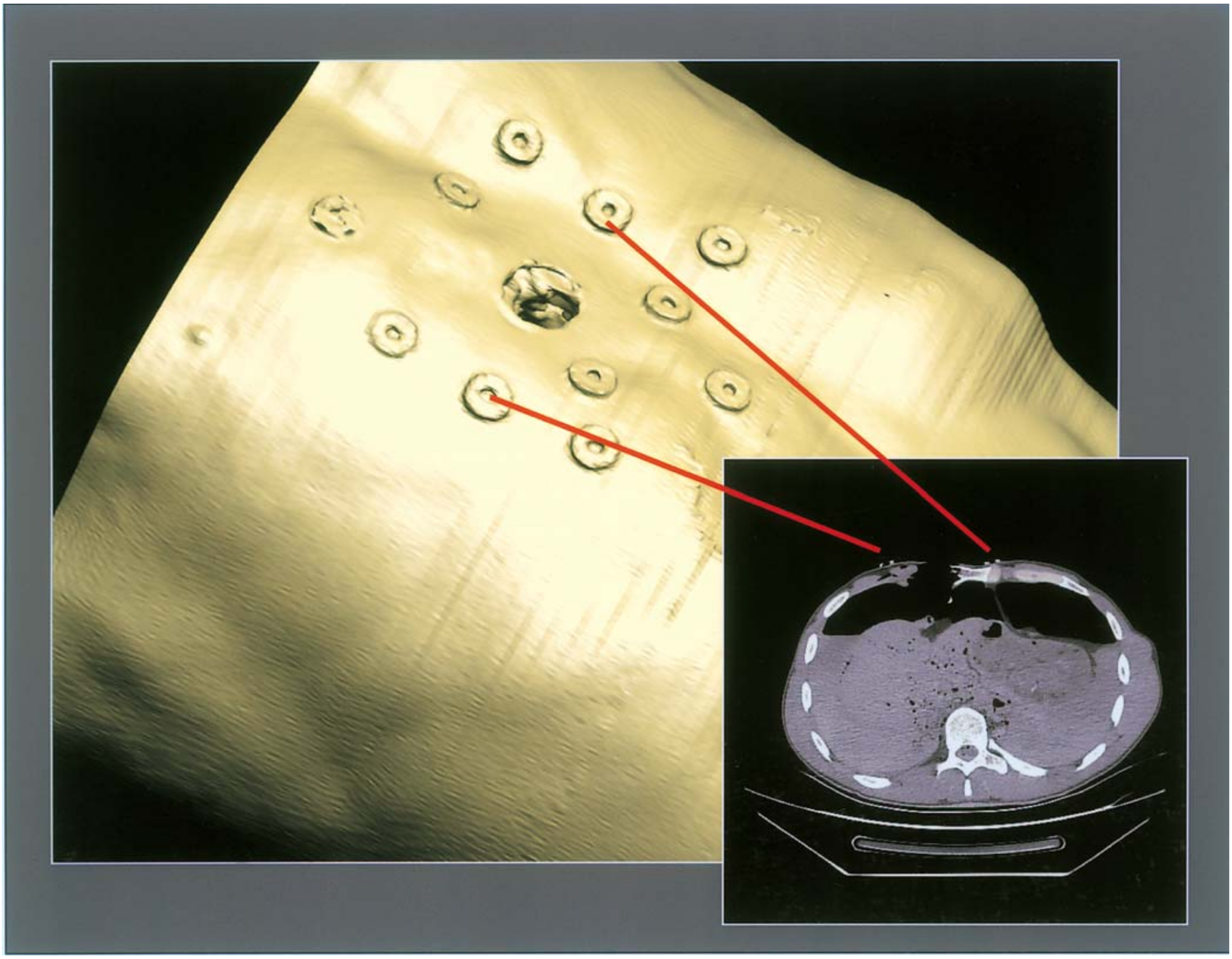

FIG. 8—*Radiological landmarks (Multi-Modality Markers) are used to give the local orientation between the cross-section and 3D reconstruction of the CT.*

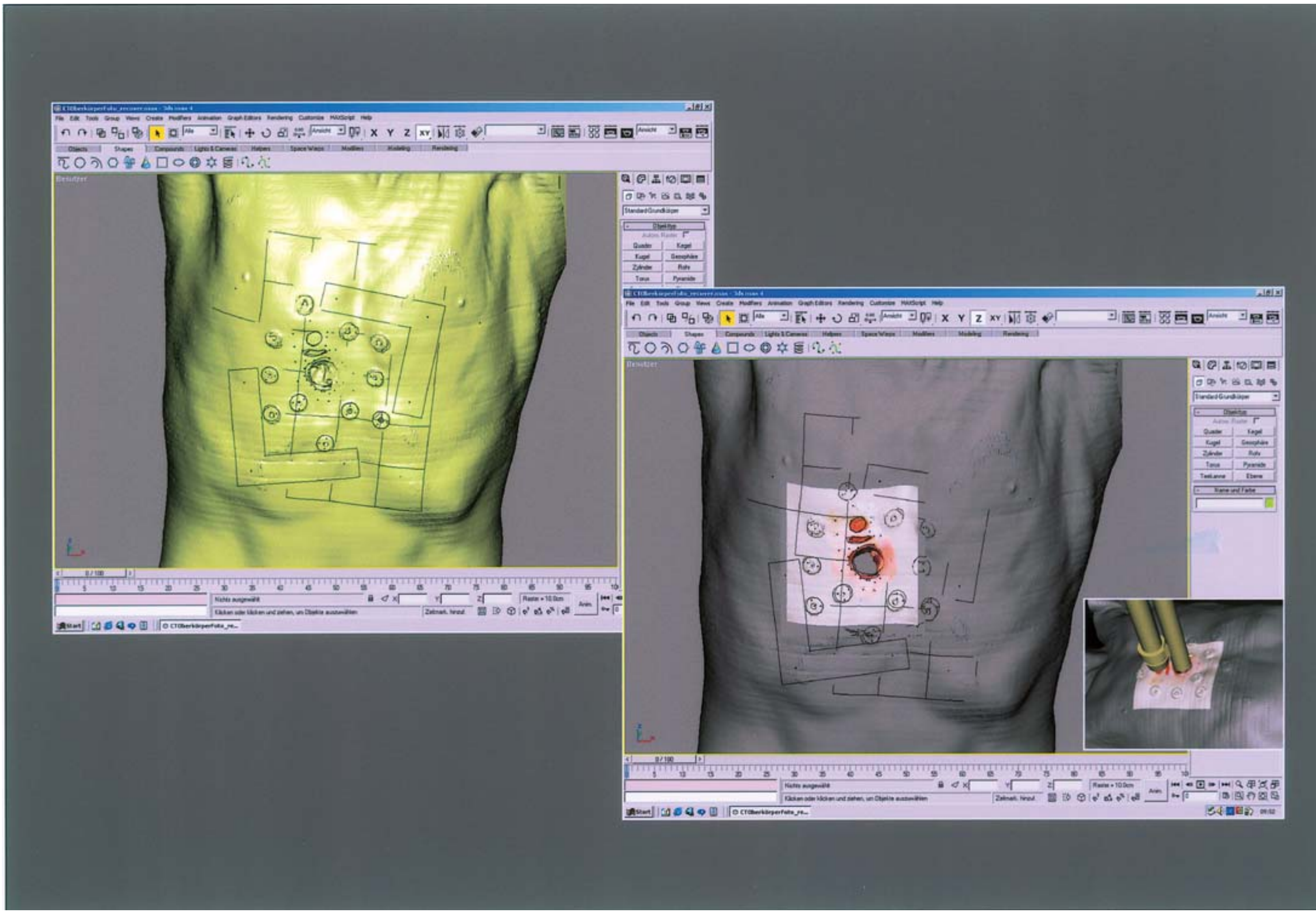

FIG. 9—*Radiological landmarks (Multi-Modality Markers) are helping to merge the photogrammetric with the radiological dataset and to analyze the match with the injury-causing weapon (see close-up view).*

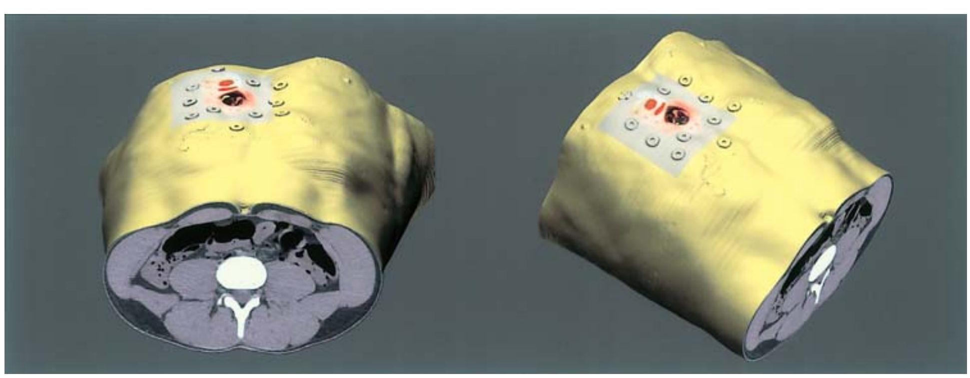

FIG. 10—*Merged photogrammetric and radiological 3D datasets with different views of the body surface and body inside.*

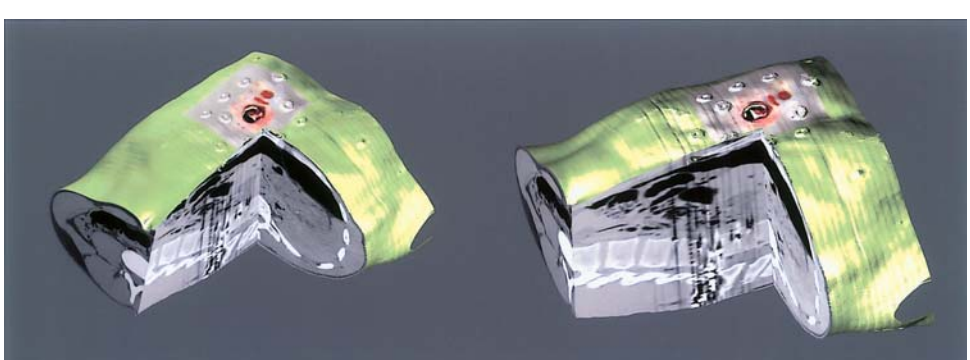

FIG. 11—*Virtual autopsy of the body. Note some streak artifacts of bullets as in Fig. 7.*

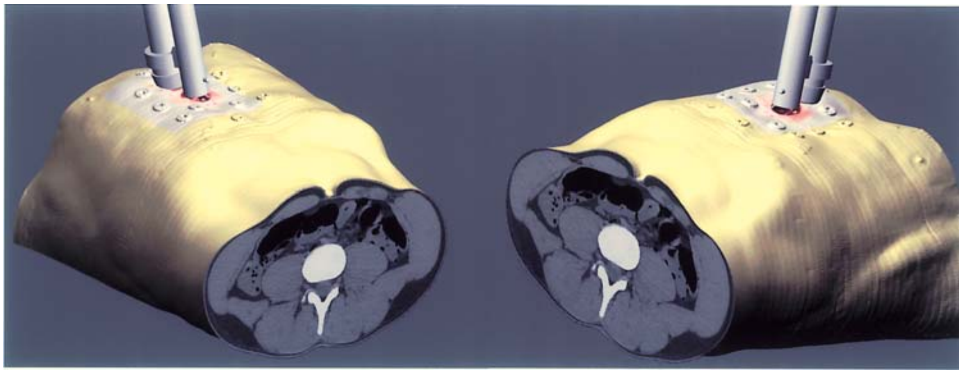

FIG. 12—*Merged photogrammetric and radiological 3D datasets with muzzle imprint visualization.*

for a comprehensive documentation of the outer *and* inner structures of (patterned) injuries of the human body.

Through the use of the Forensic, 3-D/CAD-supported Photogrammetric method the documentation of so-called "morphologic imprints" has been realized (3). Forensic, 3-D/CAD-supported Photogrammetry creates morphologic data models of the injury *and* of the suspected injury-causing instrument allowing the evaluation of a match between the injury and the instrument. In addition to the photogrammetric surface registration, the radiological documentation provided by a volume scan (i.e., spiral, multidetector CT, or MRI) registers the sub-surface injury, which is not visible to Photogrammetry.

This new, combined method of merging Photogrammetry and Radiology datasets creates the potential to perform many kinds of reconstructions and postprocessing of (patterned) injuries in the realm of forensic medical casework. The real advantage to other visualization software programs (for example POSER etc., Fig. 1) is that our approach is presenting the real 3D models of the case. So the 3D visualization is not artificially created, it is real because it is based on the original datasets of the forensic case instead of a pre-fabricated model out of a software program toolbox. At present, these techniques are not readily available in every forensic institute due to the high costs of the necessary instrumentation and manhours. However, this approach opens the way for a new 3D body surface and body volume documentation and the effort will prove to be worthwhile for the future evaluation of forensic cases, especially when a detailed 3D geometrical documentation is required.

As mentioned earlier, (4) the combination of the single methods of 3D/CAD Photogrammetry and Radiology has the advantage of being observer-independent, non-subjective, non-invasive, digitally storable over years or decades, and even transferable over the Internet for second opinion.

Using this merging method of colored photogrammetric surface and gray-scale radiological internal documentation, a great step towards a new kind of reality-based, high-tech wound documentation and visualization in forensic medicine is made.

Acknowledgments

Stephan Bolliger, Roland Dorn, and Urs Koenigsdorfer for the support during the injury documentation; Naseem Malik for the preparation of the manuscript.

References

1. Brueschweiler W, Braun M, Fuchser HJ, Dirnhofer R. Photogrammetrische auswertung von haut- und weichteilwunden sowie knochenverletzungen zur bestimmung des tatwerkzeuges; grundlegende aspekte Rechtsmedizin 1997;7:1976–83.
2. Brueschweiler W, Braun M, Dirnhofer R, Thali MJ. Analysis of patterned injuries and injury-causing instruments with forensic 3D/CAD supported photogrammetry (FPHG): an instruction manual for the documentation process. Forensic Sci Int 2003 Mar 27;132(2):130–8.
3. Thali MJ, Braun M, Brueschweiler W, Dirnhofer R. Morphological imprint: determination of the injury-causing weapon from the wound morphology using forensic 3D/CAD supported photogrammetry. Forensic Sci Int 2003 Apr 8;132(3):177–81.
4. Thali M, Braun M, Kneubuehl B, Brueschweiler W, Vock P, Dirnhofer R. Improved vision in forensic documentation: forensic, 3D/CAD-supported photogrammetry of bodily injury external surfaces, combined with volumetric radiologic scanning of bodily injury internal structures to provide more leads and stronger forensic evidence. 3D visualization for data exploration and decision making, SPIE Vol. 3905, 2000;213–21.
5. Thali MJ, Yen K, Plattner TH, Schweitzer W, Vock P, Ozdoba C, Dirnhofer R. Charred body: virtual autopsy with multi-slice computed tomography and magnetic resonance imaging. J Forensic Sci 2002 Nov;47(6):1326–31.
6. Thali MJ, Yen K, Schweitzer W, Vock P, Boesch C, Ozdoba C, et al. Virtopsy, a new imaging horizon in forensic pathology: virtual autopsy by postmortem multislice computed tomography (MSCT) and magnetic resonance imaging (MRI)—a feasibility study. J Forensic Sci March 2003.
7. Wirth J. Rapid modeling—gegenständliches CAD für die begreifbare produktgestaltung. München: Hanser, 2002.

Additional information and reprint requests:
Michael Thali, M.D.
Institut für Rechtsmedizin
Universität Bern
Bühlstrasse 20
CH-3012 Bern
Switzerland
E-mail: michael.thali@irm.unibe.ch