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Three-dimensional identification of knife with a thickened tenon edge in solving the issues of modern forensic practice

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ABSTRACT

Objective of the research: To apply the technique developed by us for the methods of photogrammetry with subsequent creation of 3D models and their research in space of the graphic editor "3DsMax" concerning elements of the wound channel formed by knife with a thickened tenon edge. The research was carried out of the series of 15 experimental and practical cases of stab injuries. To make experimental wound channels caused by piercing-cutting objects with one-sided sharpening of the blade and thickened tenon edge, alginate impression mass with rubber-like effect «Hydrogum 5» (firm «Zhermack», Italy) was used. During examination and measuring injuries of 3D models by means of a graphics editor «3ds max» linear dimensions of certain morphological parts of the wound channel were obtained to within 0.001 cm, which is indicative of the possibility to identify fine-resolution of both separate elements and a sharp traumatic object on the whole. Considering reliable results obtained in the experiment, the method was applied during forensic expertise of a stab wound of the cardiac muscle, which enabled to identify the object causing the injury among other piercing-cutting objects presented for expertise. The results obtained are indicative of high information value of the three-dimensional identification methods used to find a knife with a thickened tenon edge by means of spatial reconstruction of the wound channel fragments, which provides an high level of accuracy in solution of applied tasks in modern forensic practice and science of criminal law.

Keywords: a knife with a thickened tenon edge, 3D reconstruction, forensic expertise.

1. INTRODUCTION

Practical work of expert in forensic medicine is directed to expertize, first of all in cases of violent death or when it is suspected, and in differentiating violent death from non-violent one. Expertize of a dead body begins with the stage of

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crime scene investigation or the place of body detection. A lot of information should be documented at this stage: body position, cadaver bed, disposition of the body with other surrounding objects, bodily injuries in sight, traces of biological and non-biological origin etc. At the same time, one should understand that the more information must be documented at the crime scene, the higher is probability of human error in the form of neglect of fine detail description, which can play an important role in the formation of forensic expert's conclusion. In this respect the use of 3D methods of modeling crime scene or body detection have become more and more essential, since these methods enable to relatively rapidly digitize all the details available with high accuracy at the scene of the crime. It allows 3D models to be kept during unlimited time, to carry out their repeated or additional investigations in the course of expertise in cases when additional questions arise on the part of investigating bodies, and in its turn it promotes formation of the most objective expert's report (Raneri et al., 2018; Komar et al., 2012).

Moreover, up-to-date methods of 3D modeling have been widely used for presentation of the digital evidence data base of 3D models during sitting of the court, and jury trial in particular, which passes a sentence. The jury trial is formed with men and women of various ages and occupations, therefore, the mechanism of injury, real evidence or other important details should be demonstrated as clear and understandable as possible, since in every particular case they can play a crucial role in passing a verdict (Errickson et al., 2020; Carew et al., 2020; Ebert et al., 2011). During court sessions not only digital 3D models are reasonable to be demonstrated, but those volumetric models of anatomical structures printed on 3D printers as well (Baier et al., 2018). Methods of 3D modeling with further printing of models enable to obtain lost bone fragments, draw a conclusion concerning a number of aggressors and criminal instruments (Wo`zniak et al., 2012; Baier et al., 2018; Mitsouras et al., 2015). It should be noted that printed volumetric models of anatomical structures are highly accurate, and in addition to simple visualization it enables to identify instruments causing injury (Carew et al., 2018; Carew et al., 2020; Jani et al., 2021). Today the methods of 3D modeling are applied in forensic odontology, during identification of dead bodies in the areas of mass mortality (Johnson et al., 2019).

In our previous researches the method of 3D-reconstruction of the wound channel formed by a piercing-cutting object with acute injury of the soft tissues and parenchymal organs was developed (Kyshkan et al., 2020). According to this method 3D modeling of the experimental wound channel and a practical case of a stab wound of a victim's kidney was performed (Kyshkan & Savka, 2021). On the assumption of it, the issue concerning possible use of a three-dimensional spatial reconstruction of the wound channel caused by a piercing-cutting object with specific parameters to identify the instrument causing injury becomes reasonable.
Objective of the research was finding possibilities to reproduce parameters of a piercing-cutting traumatic object with a thickened tenon edge (a knife blade with specific parameters) by means of the use of up-to-date computer programs and methods of three-dimensional spatial reconstruction of bodily injuries in the space of graphics editor «3ds Max» on the basis of photogrammetric method.

2. MATERIAL AND METHODS

The experimental and practical parts of our research were carried out with the use of our patented methods (Patent of Ukraine №145645, dated 28.12.2020; Patent of Ukraine №145646, dated 28.12.2020; Patent of Ukraine №145647, dated 28.12.2020). Fifteen experimental wound channels were made by means of alginate impression mass with rubber-like effect «Hydrogum 5» (firm «Zhermack», Italy), which becomes hard rapidly, remains elastic after polymerization and allows impresses to be obtained with an extremely smooth surface. Possessing high thixotropic properties the alginate mass glides with pressing while taking an imprint made by a sharp traumatic object. It most precisely reconstitutes the properties of an experimental knife blade with a thickened tenon edge. To make experimental injury a new piercing-cutting object was used – a knife with one-sided sharpening of the blade and thickened tenon edge, its blade was 9.53 cm long, 2.7 cm wide in the point of its biggest thickening, and the tenon edge 0.42 cm thick. These sizes of the piercing-cutting instrument were obtained by means of sliding calipers with the error ± 0.03-0.15 cm. Every fragment of the wound channel was contrasted with a dye using 1% brilliant green alcohol solution. All the fragments of the wound channel were opened parallel to its length and were placed on a rotary table located in a light cube to provide adequate illumination and photos were taken. The digital camera SONY RX 10 II was used for shooting, the object of shooting was labeled with a number, a fragment of a plotting scale 1.0 cm long was placed on it to calibrate the scale and control the sizes of the object examined in computer programs.

The photos obtained in JPEG format were loaded into the computer program «Agisoft Photoscan», and 3D textured models of a wound channel fragment were created in it. The model obtained and the texture was exported in «OBJ» format. The next stage of the work was to transfer 3D models obtained into the graphic space of «3ds max» program, where the scale of the model was calibrated. After that the wound channel can be reconstructed in the graphics editor by means of 3D models of the wound channel fragments.

3. RESULTS

To compare differences between classical and new methods at first linear dimensions of injuries were measured by means of a ruler which enabled to get the results presented in Table 1. Whereupon the depth of the wound channel consists of three main fragments according to the method of measuring the depth of the wound channel in the dead body by means of putting together of its separate parts according to the knife blade immersion and passing in the body of the victim (in the skin and subcutaneous tissue with muscles, the wall of the thoracic cavity and in it itself, and in a certain internal organ (in our particular case it is the heart)).

The width of the wound channel and the distance between the angles from the side of the tenon edge were accurately registered at different levels. These measurements illustrate how thick the blade is and how long separate fragments are, which in their turn reproduce the width of the blade of a sharp traumatic object.

Table 1 Linear dimensions of damage to experimental wound channels, obtained using a ruler (x ± Sx, n=15).

Parameter	MIN	MAX	M±m	SD
Depth of the 1st fragment of the wound channel	3.1	3.6	3.25 ± 0,04	0.14
Depth of the 2nd fragment of the wound channel	3.3	3.8	3.54 ± 0.03	0.13
Depth of the 3rd fragment of the wound channel	2.5	3	2.81 ± 0.04	0.14
Depth of the wound channel	9.6	9.6	9.5 ± 0	0
The width of the inlet in the middle part	0.2	0.2	0.2 ± 0	0
Width of the 2nd fragment of the wound channel in its middle part	0.2	0.2	0.2 ± 0	0
Width of the 3rd fragment of the wound channel in its middle part	0.2	0.2	0.2 ± 0	0
The length of the inlet	2.7	2.7	2.7 ± 0	0
Length of the 2nd fragment of the wound channel	2.6	2.7	2.7 ± 0,01	0.04
Length of the 3rd fragment of the wound channel	2	2.3	2.14 ± 0.02	0.09
The distance between the corners from the side of the back of the blade on the inlet	0.4	0.4	0.4 ± 0	0
The distance between the corners from the side of the back of the blade of the 2nd fragment of the wound channel	0.4	0.4	0.4 ± 0	0
The distance between the corners from the side of the back of the blade of the 3rd fragment of the wound channel	0.3	0.3	0.3 ± 0	0
Pt	< 0.05	< 0.05	< 0.05	< 0.05

The next stage in our research was to examine and get linear dimensions of injuries by means of up-to-date technologies using

3D models with the help of the graphics editor «3ds max». This computer program enabled to get the above results with a higher accuracy to 0.001 cm. The results of the dimensions obtained are presented in Table 2.

Table 2 Linear dimensions of damage to experimental wound channels, obtained with the help of a computer program for 3D modeling «3ds max» ($x \pm Sx$, n=15).

Parameter	MIN	MAX	M±m	SD
Depth of the 1st fragment of the wound channel	3.042	3.586	3.233 ± 0.036	0.139
Depth of the 2nd fragment of the wound channel	3.272	3.784	3.524 ± 0.033	0.127
Depth of the 3rd fragment of the wound channel	2.489	3.018	2.776 ± 0.037	0.142
Depth of the wound channel	9.529	9.538	9.533 ± 0.001	0.002
The width of the inlet in the middle part	0.221	0.228	0.223 ± 0.001	0.002
Width of the 2nd fragment of the wound channel in its middle part	0.209	0.214	0.212 ± 0.0003	0.001
Width of the 3rd fragment of the wound channel in its middle part	0.201	0.208	0.204 ± 0.001	0.002
The length of the inlet	2.705	2.708	2.706 ± 0.0003	0.001
Length of the 2nd fragment of the wound channel	2.637	2.695	2.673 ± 0.004	0.017
Length of the 3rd fragment of the wound channel	2.005	2.278	2.150 ± 0.019	0.073
The distance between the corners from the side of the back of the blade on the inlet	0.421	0.425	0.422 ± 0.0003	0.001
The distance between the corners from the side of the back of the blade of the 2nd fragment of the wound channel	0.384	0.397	0.393 ± 0.001	0.003
The distance between the corners from the side of the back of the blade of the 3rd fragment of the wound channel	0.326	0.334	0.331 ± 0.001	0.002
Pt	< 0.05	< 0.05	< 0.05	< 0.05

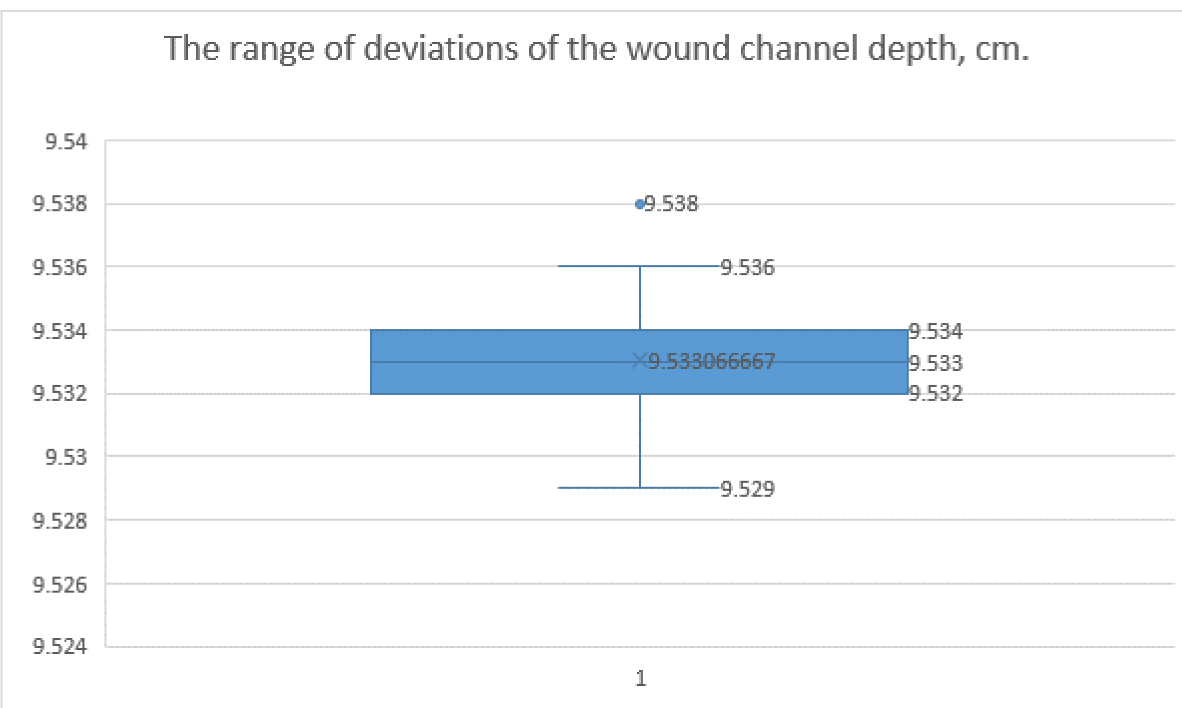

Figure 1 The range of deviations of the wound channel depth.

4. DISCUSSION

The results of measuring presented in Tables 1-2 were analyzed and compared. In this way we tend to determine similarity between dimensions obtained by means of classical methods and those obtained by means of examination of 3D models of the same damages. Meanwhile, it should be noted that dimensions obtained by means of computer «3ds max» program were by far more accurate. Examination of the range of depth of the wound channel (Fig. 1) obtained by means of «3ds max» program, which appeared to be 9.533 ± 0.001 cm, found the range of absolute relative deviation in this case to be 0.03.

The inlet length is rather valuable diagnostic element of a stab wound. This dimension reflects the width of the blade in its widest point where it was immersed into the body and enables to draw relative conclusions concerning the depth of immersion of a traumatic object. The inlet length in the experiment (Fig. 2) is 2.706 ± 0.0003 cm, and the range of its absolute relative deviation is 0.23%.

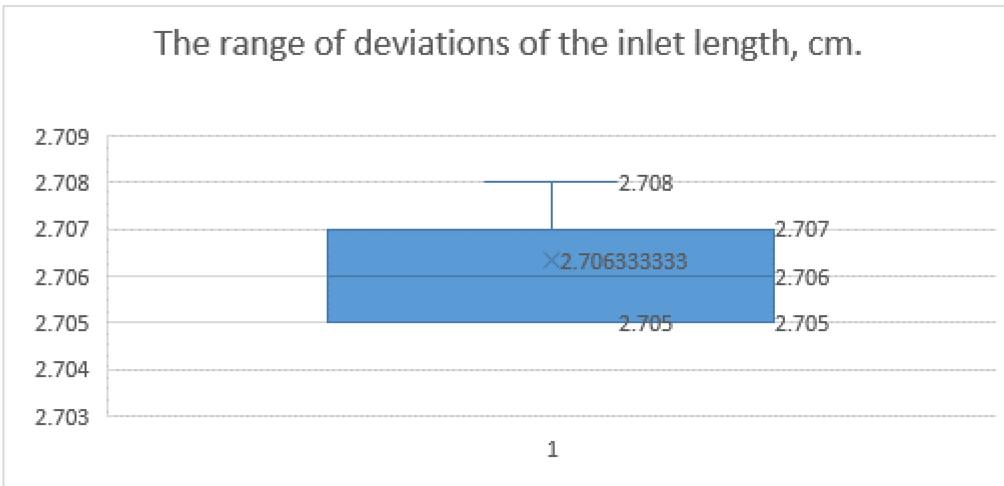

Figure 2 The range of deviations of the inlet length.

The parameter of the inlet width illustrates the measurement of the blade thickness in its middle part and dimension in the experiment were 0.223 ± 0.001 cm. The range of absolute relative deviation were 1.48% (Fig. 3).

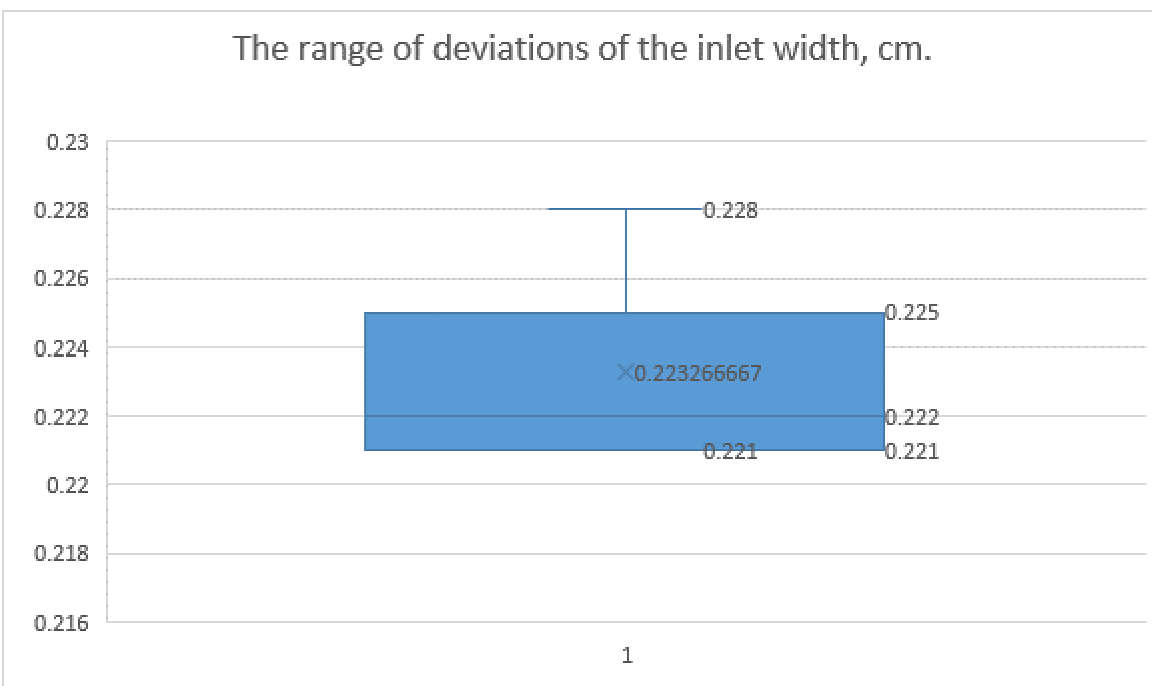

Figure 3 The range of deviations of the inlet width.

The distance between the angles from the tenon side possesses still more important identifying value (Fig. 4), since this dimension allows a conclusion to be drawn concerning specific features of the blade of a traumatic sharp instrument and its thickened tenon edge available. In our case as illustrated in Figure 4, the mentioned dimension is 0.422 ± 0.0003 cm with the range of absolute relative deviation of 0.52%.

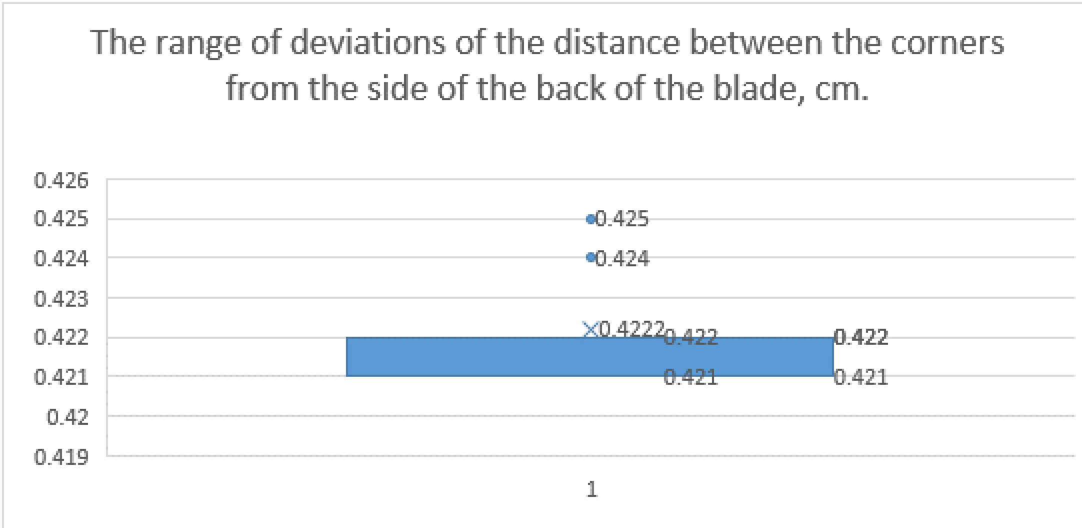

Figure 4 The range of deviations of the distance between the corners from the side of the back of the blade.

Considering high accuracy of the linear dimensions obtained in the experiment, this method was applied during forensic expertise on the base of the Municipal Medical Establishment "Regional Bureau of Forensic Medicine Expertise" (Chernivtsi, Ukraine). In the course of examination of a dead body keeping to the current legislation order the method of photogrammetry was applied followed by further 3D modeling of the wound channel elements made by a piercing-cutting instrument. First of all, 3D modeling of the skin wound was performed (Fig. 5). The next stage was formation of volumetric models of the wound channel fragments (Fig. 6).

Figure 5 Skin wound with visual inlet caused by a piercing-cutting instrument, followed by formation of 3D model, expertise №862, citizen P.)

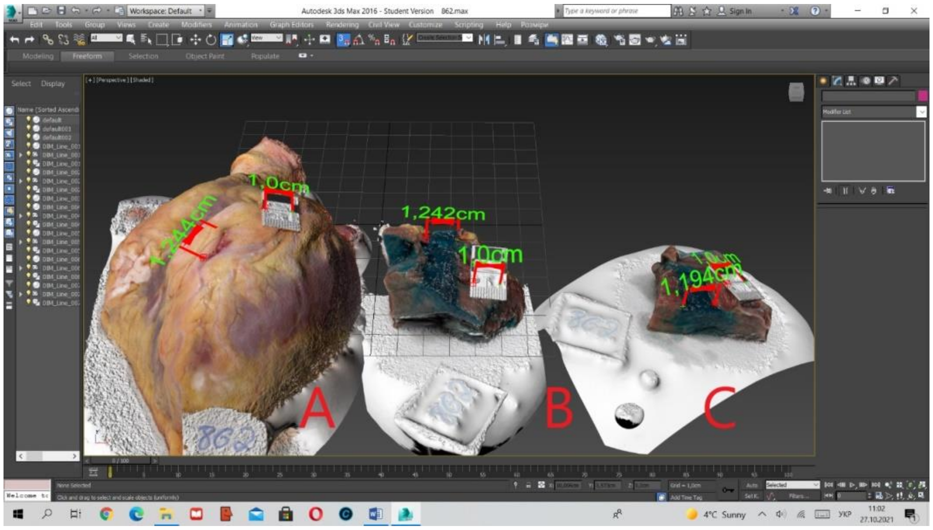

Figure 6 3d models of the wound channel fragments according to the expertise №862, from right to left: 3D model of the heart with visual stab wounds – A; left ventricular anterior wall - B; left ventricular posterior wall - C.

Due to the fact that the object causing the damage was not found by the investigation bodies on the crime scene, 3D modeling of a piercing-cutting object fragment was carried out on the basis of available morphological features of bodily injuries (Fig. 7). The volumetric fragment of a traumatic object obtained was made in the space of graphics editor «3DsMax». It can be printed on 3D printer and used as one of the instruments to identify the object/instrument causing the wound (Fig. 8).

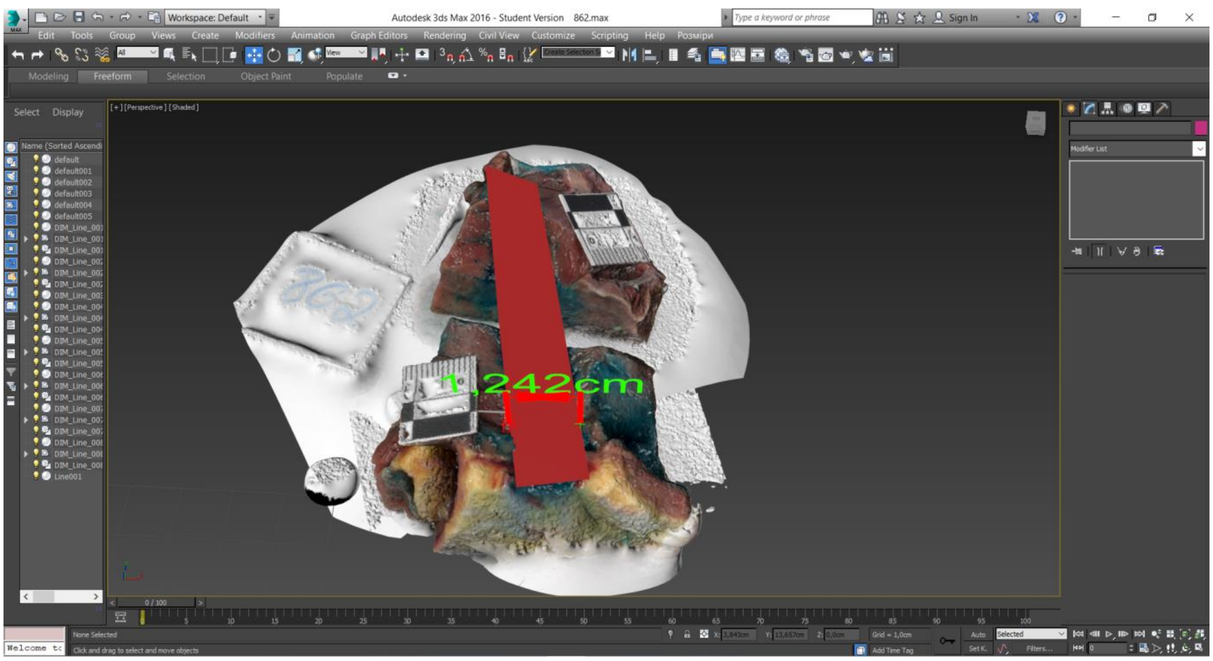

Figure 7 Making 3D reconstruction of a traumatic object fragment on the basis injuries available.

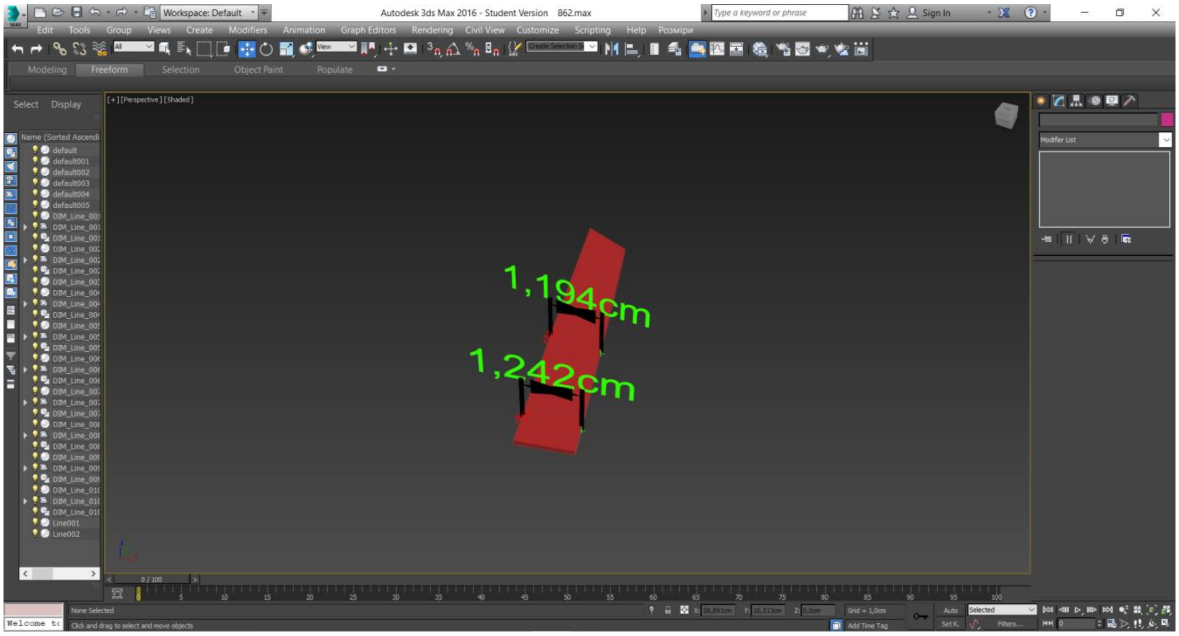

Figure 8 3D model of a piercing-cutting object fragment.

Therefore, due to three dimensional identification of a piercing-cutting object which use resulted in the death of the victim, special features of its blade were determined. The expert's report prepared for the investigation bodies included information about the traumatic piercing-cutting object and its parameters on the level of its immersion into the body: the tenon edge was no more than 0.2 cm; the blade in the point of passing thought the external surface of the left ventricular anterior wall was 1.242 cm long; the blade in the point of passing through the internal surface of the left ventricular posterior wall was 1.194 cm long.

5. CONCLUSION

The results obtained are indicative of high information value of the three dimensional methods to identify a traumatic piercing-cutting object with specific parameters by means of a spatial reconstruction of the wound channel fragments, which provides high accuracy in solving applied tasks in modern forensic practice and criminal law science.

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Author Contributions

All the authors contributed to the research and/or preparation of the manuscript.

Informed consent

Written & Oral informed consent was obtained from all individual participants included in the study.

Ethical approval

The study was approved by the Medical Ethics Committee of Bukovinian State Medical University (Protocol No.2 dated 21.10.2021).

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Conflict of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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