UTILIZATION OF 3D SCANNING IN BURN ANALYSIS AND IDENTIFICATION

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Abstract

Effective burn scar treatment requires objective measurement of burn severity and progression, and 3D scanning technologies could offer a valuable alternative to the current clinical assessments. This article discusses the use of 3D scanning to determine the area and extent of burns. The study involves a comparison of twelve burns in six patients using two CAD software. The article deals with the methodology of scanning burns, and subsequently describes in detail the methodology of determining the area of burns from a 3D scan. Methodologies for burn scanning and determining burn area from 3D scans were detailed, emphasizing the innovation's potential in surpassing traditional assessment methods like the Rule of nine and Palm method estimation. Twelve burns were scanned at least twice, allowing comparison of the burn area before and after a certain period of healing. The study revealed that 3D scanning provides an accurate approach to measuring burn areas, with minimal differences observed between software. Meshmixer software emerged as the preferred tool due to its intuitive features, underscoring the potential of 3D scanning to improve burn assessment and treatment planning. This approach enables the use of 3D scans to determine individual treatment according to the progression of healing, and at the same time opens up the possibilities of using 3D scans to design burn orthoses.

Keywords

3D scanning, burn analysis, burn identification

Introduction

Measurements of the wound surface represent a relevant indicator of the dynamics of its healing. There is a wide variety of methods for quantifying wound dimensions, from traditional methods such as the use of a ruler, which are quick and economical, but their accuracy can be affected by the irregular shape of the wound, to sophisticated computer algorithms that offer high accuracy but are associated with significant costs and time requirements [1]. For practical use in clinical practice and research, it is critical that the wound measurement method would be time and financially efficient, easy to control and should minimize discomfort for the patient. The percentage of re-epithelialization of the wound plays a key role in evaluating the effectiveness of treatment of acute burns [2]. It is important to remember that wounds are three-dimensional, and when measuring on a curved or more extensive body surfaces, a two-dimensional photograph may not adequately capture its complex shape, which may affect the accuracy of the measurement [3].

The Rule of Nines is commonly used to estimate the total body surface area (TBSA) affected by the burn, which is crucial for determining treatment and fluid resuscitation needs. Additionally, tools like the Lund and Browder chart offer a more precise assessment, especially in children, where body proportions differ from adults. Finally, the Burn Severity Index (BSI) is used to evaluate the overall severity and guide clinical decisions. The Palm Method is another technique used to estimate the total body surface area (TBSA) affected by burns, particularly for smaller burns. In this method, the patient's palm (including fingers) is considered to represent approximately 1% of their TBSA. This method is especially useful in emergency settings when quick estimations are needed, or when the burn areas are irregularly shaped or small. It’s a simple and practical tool for initial assessment, particularly in resource-limited environments or when more detailed tools are unavailable [4].

3D scanning enables visualization of an object as a virtual 3D entity, which can be manipulated and observed from any angle, as if it were in the examiner's hands. This is achieved by the 3D scanner, which

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records the 3D coordinates of an object's surface, usually in the form of a dense cloud of points [5]. This data can then be processed, typically using specialized software, into a 3D surface model. The latest innovation in 3D scanning is the non-contact, portable, handheld optical scanner. This type of scanner was chosen for the study due to its ease of use and ability to be used in a clinical setting [6].

The aim of the study is to investigate the efficacy of 3D scanning in accurately determining the area and extent of burns, compare the results obtained from two different software tools, and explore the potential of 3D scans in guiding individualized treatment strategies and modelling burn orthoses.

Methodology for determining the extent of burns from a 3D scan

To obtain patient data, ethical approval was first secured, and informed consent was obtained from each patient. The study was approved by the Ethics Committee of AGEL Hospital Košice-Šaca (Slovakia) under the number 17-2023. In addition, a set of questionnaires was developed for doctors and nurses, which covered a wide range of information. The questionnaire for doctors included questions about the gender of the patient, the extent of the burn determined by traditional methods, the degree of the burn and the possible need for surgery. A separate questionnaire was prepared for the nurses, focused on information about bandages, methods of conservative treatment, and photo documentation was also obtained. This cooperation was established with the Department of Burns and Reconstructive Surgery in the AGEL Hospital Košice-Šaca (Slovakia), which ensured access to relevant clinical data and created a solid basis for scientific research. Such a comprehensive approach to data collection and collaboration with the clinical environment provided an important framework for subsequent analysis and interpretation of results.

Methodology of scanning the affected area

The first step is 3D scan obtainment of the burned area using a suitable 3D scanner. An Artec Eva (Artec 3D, Senningerberg, Luxembourg) 3D scanner was used, which can capture details with high surface accuracy (<0.1 mm) and create a digital model with the texture of the object. Burn scanning was performed except on the day of admission after a certain period of healing if the physician noted a significant change in the extent of the burn.

When scanning a burn patient, it is important to ensure adequate training of the patient and any helping hospital personnel. The patient is informed of the need to remain as still as possible and to minimize movement during the scanning process. Before the actual scan, it is essential to thoroughly examine the burns and the areas of interest. If several areas are affected, it is crucial to plan the scanning process in such a way that the least possible movement around the patient is necessary and that he/she is in the most comfortable position during the procedure. If staff assistance is required, it is essential to provide instruction during the scanning process to eliminate the need for procedure repeating and minimize patient discomfort and burned tissue exposure time.

Before scanning, it is essential that the wound is thoroughly exposed, clean, and free of any remaining dressing material. This is necessary for accurate diagnosis and assessment of the extent of the burn.

At the same time, it is necessary to prepare the space around the patient, since most 3D scanners that are suitable for scanning the human body operate with a working distance from the patient in the range of 0.4–1.0 m.

This fact requires that the space around the patient is free and without any obstacles that could limit the scanning process and cause loss of tracking of the object in the surrounding space, which would require re-scanning. When scanning extensive burns involving multiple areas of the patient, it is essential to provide 360° accessibility around the patient. This means that the patient should be placed in a surrounding where it is possible to move around him from all sides without obstacles. However, the patient must be in sufficient proximity due to the connection of the 3D scanner to the computer via USB cable that ensures the collection and processing of the scanned data.

During the 3D scanning process, it is necessary to ensure that not only the burned but also the undamaged tissue is scanned to a sufficient extent, so that it is possible to precisely define the borders of the burned area. To precisely define the borders of the burn, we chose the necessary minimum margin of healthy tissue of approximately 2 cm around the edge of the burn.

Methodology for identifying burns from a 3D scan

The principle of marking burns involved delineating the damaged tissue caused by burns from the healthy tissue, based on the texture and relief of the skin on 3D scans. For a specific example, the left upper limb of the patient was selected with a burned part from the arm, through the forearm to the shoulder. The region was scanned using an Artec Eva handheld 3D scanner. The scanned point cloud was converted into a specific 3D model in Artec Studio 13 Professional (Artec 3D, Senningerberg, Luxembourg) software. Since the model needs to have textures to be able to determinate the burns, it must be exported in OBJ (Object File Format) format. This OBJ model was subsequently imported into the relevant CAD (Computer Aided Design) software. As part of this study, a comparison of methods for determining the area of the burn was

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performed using two freely available CAD software, Autodesk Meshmixer (Autodesk Inc., San Francisco, CA, USA) and Blender (Blender Foundation, Amsterdam, Netherlands). Both mentioned software are suitable for free-form 3D modelling and 3D objects editing. In Meshmixer software, the "Select" function was used to mark the burned tissue, which allows precise marking of the desired burn area using an adjustable brush tool. This is possible due to the displayed texture of the 3D model.

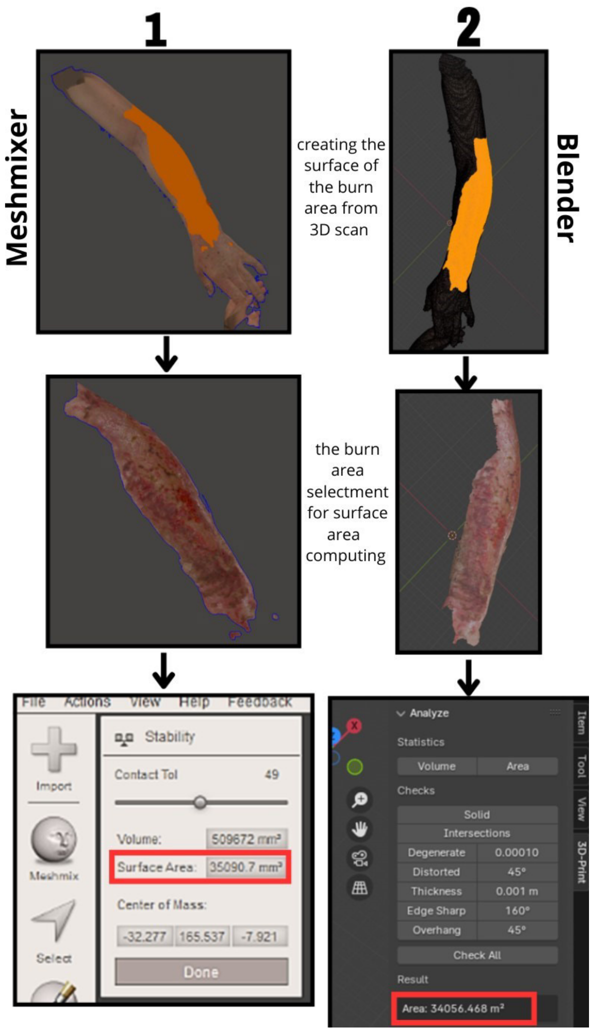

Fig. 1: Similarity of the surface determination process in Meshmixer and Blender.

After the creation of the surface, the area is separated and then evaluated using analytical tools using the "Stability" function, which calculates the total area of the marked burn area. Subsequently, the software evaluates and displays the value in the "Surface Area" value, which represents the extent of the burn. The process of identifying burns using the Blender software begins with marking the surface, where it is necessary to switch the mode to "Editing" and then use the marking tool to select the entire burn area. After the marking, it is necessary to remove the unnecessary part of the area of interest, and then it is possible to display the calculation of the area of the burned tissue using the "3D-Print Toolbox" extension. Blender utilizes a different unit of measurement compared to the majority of 3D modelling software; while the area is typically displayed in m^2 but in this case it is in mm^2 (Fig. 1).

Results

Table 1: The difference between the determined burn area on different parts of the body by Meshmixer and Blender software.

Patient No.	Burned area	Period (days)	Relative difference (mm^2)	Relative difference (%)
1.	Thigh	0	74.17	0.87
		15	17.43	0.28
2.	Right leg	0	195.27	0.56
		10	1268.47	4.44
	Left leg	0	58.46	1.17
		10	13.04	4.08
		15	1.35	0.74
3.	Face	0	243.15	3.59
4.	Right upper limb	0	3.83	0.04
		2	110.81	1.48
		7	57.80	3.58
		10	97.26	7.95
	Left upper limb	0	768.54	1.64
		2	1034.23	2.95
		7	122.85	0.46
		10	1300.53	5.23
	Thigh	0	335.93	1.80
		2	557.32	2.99
		7	79.08	0.55
		10	39.80	5.92
5.	Ankle	0	74.29	5.92
		2	6.11	0.89
	Forearm	0	27.66	0.19
		2	197.13	1.59
	Arm	0	638.45	0.86
		2	2192.94	3.19
6.	Left upper limb	0	152.57	0.85
		2	388.81	2.21
	Right upper limb	0	531.53	2.73
		2	491.75	2.98

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The obtained values were compared, after the marking and determination of the burned tissue area in the two software. Using these values, the differences in the burn size were subsequently calculated (Table 1), both in mm^2 and in percentage.

From the results of the data collection and processing we can state that there is only a slight difference in the marked area between the sampling in both programs. The mean difference was 371.02 mm^2, representing 2.25%, and the median was 195.27 mm^2, representing 1.8%.

The healing process and its description using 3D scans

This table (Table 2) provides information on the extent of burns in different patients and their change over time. Each patient is identified by the number and location of the burn. The information also includes the period (in days) from the onset of the burn and the change around the burned tissue in mm^2 and in percentage, compared to the first date of the 3D scan obtainment. Furthermore, it also displays the percentage of the burn, representing the severity of burns on specific body parts, under the assumption that the skin area measures between 1.5–2.0 m^2. For this estimation, information from the Institute for Quality and Efficiency in Health Care (Cologne, Germany) was used, that human skin has an average of 1.5–2.0 m^2 [7]. This allowed us to create a range that estimates the approximate extent of the burn in percentage. Table 2 is divided according to individual patients and their burns, while the values of the change around the tissue and the extent of the burn in different time intervals are given. This information serves to monitor the development of the extent of burns over time and provides important data for evaluating the effectiveness of treatment.

The obtained data show that burned tissues start to heal and shrink after only 2 days from their occurrence (Table 2). How quickly the burned area will shrink depends mainly on the place where the burn occurred, its depth and its size. The data shows that small burns heal faster than those whose area is significantly larger. The change in the size of the wound can also be seen from 3D scans (Fig. 2).

Table 2: The difference of the burn area of individual patients for a certain healing time by the burn area on different parts of the body and the total extent of the burn with respect to the total surface of the skin by Meshmixer software.

Patient No.	Burned area	Period (days)	Change of burned tissue area (mm^2)*	Change of burned tissue area (%)*	Extent of burn (%)**
1.	Thigh	0	–	–	0.42–0.56
		15	2240.74	26.50	0.31–0.41
2.	Right leg	0	–	–	1.74–2.33
		10	7649.20	21.88	1.36–1.82
	Left leg	0			0.24–0.32
		10	4595.57	93.49	0.01–0.02
		15	99.90	95.52	0.01–0.02
3.	Face	0	–	–	0.34–0.45
4.	Right upper limb	0	–	–	0.49–0.65
		2	2261.03	23.18	0.38–0.50
		7	5936.64	84.04	0.08–0.10
		10	331.98	87.45	0.06–0.08
	Left upper limb	0	–	–	2.35–3.13
		2	11905.1	25.33	1.76–2.34
		7	8198.70	42.77	1.35–1.79
		10	2000.30	47.03	1.25–1.65
	Thigh	0	–	–	0.93–1.24
		2	589.60	3.15	0.90–1.20
		7	3722.20	23.10	0.72–0.95
		10	5787.30	31.00	0.64–0.86
5.	Ankle	0	–	–	0.06–0.08
		2	565.40	45.08	0.03–0.04
	Forearm	0	–	–	0.72–0.96
		2	2116.80	14.75	0.61–0.81
	Arm	0	–	–	3.70–4.93
		2	7596.90	10.26	3.32–4.42
6.	Left upper limb	0	–	–	0.89–1.19
		2	697.90	3.90	0.86–1.14
	Right upper limb	0	–	–	0.95–1.26
		2	2953.40	15.58	0.8–1.06

* The change is compared to the date of the first 3D scanning (day 0).
** The extent of the burn of an individual part of the body, provided that the skin has a size of 1.5–2.0 m^2 [7].

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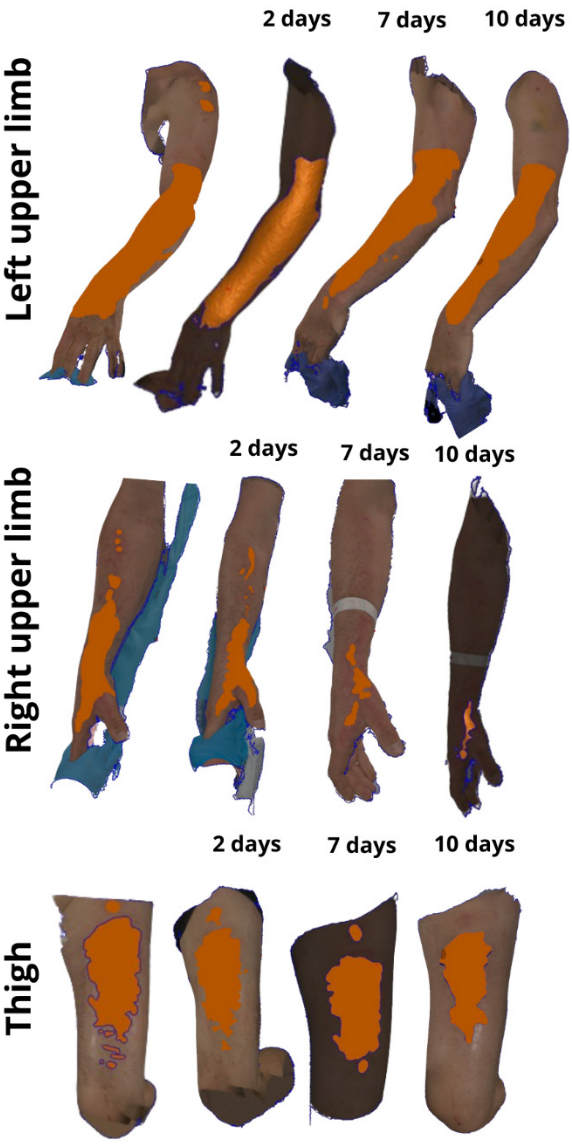

Fig. 2: Graphic representation of the healing of burns caused by hot oil of patient no. 4 by individual periods and at individual locations from 3D scans.

After calculating the extent of all burns per patient, we found that the highest extent reached a value between 4.48% and 5.96% of the total body surface area. This detected value indicates that according to the classification of the severity of burns, this range could be included in the categories of light and small burns. We can consider burns for adults as light when their area is less than 15% of the total body surface, according to the classification mentioned above [8].

Discussion

The utilization of 3D scanning in burn tissue analysis and identification presents a significant advancement in the field of burn medicine. This innovative approach offers numerous advantages over traditional methods, particularly in terms of speed, accuracy, and comprehensive data acquisition [9, 10]. One of the key benefits of employing 3D scanning is its ability to assess rapidly and precisely burned areas within minutes, facilitating efficient data collection without subjecting patients to the discomfort associated with traditional data assessment techniques. Moreover, the digital nature of the scan results allows for easy archiving and analysis, enabling healthcare professionals to access and evaluate patient information without exposing wounds, thereby minimizing the risk of infection.

Furthermore, the detailed marking and calculation capabilities afforded by 3D scanning enable more accurate diagnosis and treatment planning. By accurately quantifying the percentage extent of burns, healthcare professionals can make informed decisions regarding patient care, leading to improved treatment outcomes. This method could only help healthcare professionals in the management of burn treatment, but the treatment and its effect always depend on many factors that can only be assessed by the attending physician. Additionally, the visualization of skin texture provided by 3D scans allows the comparison of color changes during the healing process, providing valuable insights into treatment progress and efficacy [11, 12].

The study has several limitations that should be considered when interpreting the results. Mainly, the small sample size of six patients with twelve burns limits the generalizability of the findings and may not represent the full range of burn types and healing responses seen in a broader patient population. Additionally, the use of a single type of 3D scanner and only two software tools may restrict the applicability of the results, as variations in scanners or software could affect accuracy and usability. Lastly, the research was conducted within a single clinical setting, which may limit the broader applicability of the findings to other healthcare environments. These limitations suggest that future research should involve larger and more diverse samples, explore various scanning technologies and software, and extend the follow-up period to better assess the long-term benefits and generalizability of 3D scanning in burn management.

Conclusion

Detailed and accurate information about the surface, structure and texture of human tissue provides information that can be used in the treatment of patients who have suffered a burn injury. 3D scanning makes it possible to create 3D models of burned areas and track their evolution over time, providing important data for comparing the effectiveness of different treatment methods.

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In conclusion, our data analysis revealed only a minimal difference in the marked burn area between analysis using the Meshmixer and Blender CAD software, suggesting that software choice in this case has little impact on the outcome. However, Meshmixer emerges as the superior choice for burn tissue marking due to its specialized features and user-friendly interface, which is particularly beneficial for beginners. While Blender excels in its versatility for 3D modelling, its interface may be overwhelming for novice users and less efficient for specific tasks like burn tissue marking. Therefore, Meshmixer's streamlined workflow, and intuitive interface makes it the preferred option for precise and efficient burn tissue marking and analysis.

Future research should be directed towards expanding the clinical applications of 3D scanning in burn tissue management. This could involve investigating its utility in monitoring wound healing progression, guiding surgical interventions, and assessing treatment outcomes over time. Additionally, exploring the feasibility of using 3D scans to customize and fabricate patient-specific burn orthoses would be valuable for improving treatment efficacy and patient comfort.

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