Editorial

ANNALS OF MEDICINE & SURGERY

OPEN

Limitations of using 3-D printing in postmortem computed tomography: roadblocks and the way forward

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Dear Editor,

The burgeoning body of evidence surrounding the potential of the 3-dimensional printing (3DP) technology has unfurled a wide array of avenues, and forensic science is no exception to this. This has facilitated the use of 3DP in tandem with techniques such as postmortem computed tomography (PMCT), which is widely accepted for routine forensic investigations[1]. Conventionally, PMCT has been accepted for detailed imaging of skeletal injuries, deformities, and foreign substances, which would otherwise be difficult to reproduce during an autopsy[2]. Thus, PMCT aids in the identification, characterization, and reconstruction of gunshot wounds, burns, and accidents, among other forensic investigations[2,3]. Furthermore, advanced techniques, such as contrast-enhanced PMCT, can aid in the visualization of blood vessels and the identification and investigation of vascular anomalies and/or injuries[4,5]. The potential of both PMCT and PMCT-3DP has been widely reviewed and would be beyond the purview of this article.

Limitations of employing 3DP in PMCT

With ongoing studies and growing empirical evidence, there have been several limitations flagged for the PMCT-3DP technology. This article aims to explore, underscore and classify these limitations.

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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Annals of Medicine & Surgery (2024) 86:2393–2394

Received 5 January 2024; Accepted 2 March 2024

Published online 12 March 2024

http://dx.doi.org/10.1097/MS9.0000000000001942

Imaging-related limitations

The 3DP technology relies on the data obtained from PMCT scans. Subsequently, the images are segmented, processed, and transformed into a 3D mesh-like structure, which forms the standard tessellation language (STL) file format. Consequently, while PMCT is precise in detecting traumatic injuries and determining the cause of mortality, it often fails to characterize specific pathologies and/or subtle injuries[4].

Additionally, a major concern that limits the utility of PMCT-3DP is that the reconstructed 3D images may not be well-suited for detailed and comprehensive analysis. In most cases, the images only provide reconstructed images, and their accuracy depends vastly on the scan parameters, the presence of metallic particles, and other artifacts and foreign bodies[6].

Furthermore, the insufficient contrast resolution of PMCT impedes its utility in the replication of soft tissues such as organs and muscles[7].

Moreover, pre-clinical research underscores the numerous challenges in the imaging of spinal cords, despite extensive pre- and postprocessing of the images[8].

Despite recent advances in 3D surface scanning and the mapping of postmortem 3D-to-2D fingerprint imaging, the technology is still in its nascent stages.

Printing-oriented limitations

To render precise and reliable 3DP reconstructs suitable for courtroom presentations and comprehensive investigations, it is imperative to understand the limitations of 3DP modeling across various forensic cases.

While various 3DP techniques have been used extensively in nonmedical applications, the printing of intricate details of the human body, as well as the replication of small specimens, presents a daunting task[7]. Although there has been a satisfactory level of agreement between PMCT scans and their 3DP models, issues such as fracture lines[9] and excess support material are commonly reported.

Generally, the choice of material, process, and thus the curing and post-curing times are major determinants in 3DP models. Following printing, an adequate post-curing time is imperative for defining the mechanical properties of the models[10]. While some studies have suggested a post-curing time of at least an hour[10], there is a paucity of scientific evidence across a spectrum of materials. Furthermore, factors such as material composition, layer thickness, duration of exposure, intensity, and nature of the curing beam could also adversely affect the mechanical properties and color of the reconstruction[10]. In addition, it is onerous to achieve homogenous polymerization in both the deep and superficial layers of the model, which further leads to anisotropic characteristics[10]. Consequently, it affects the mechanical stability, durability, and reliability of these constructs, which is of paramount importance in comprehensive forensic investigations.

While 3DP technology is renowned for its precision, empirical evidence suggests that limitations in manufacturing methods similar to those discussed above often result in lower precision. In addition, this may precipitate inconsistencies in the surface finishing and quality, leading to surface roughness. This may necessitate additional expenditure on post-treatment methods, such as laser post-treatment[11]. These factors negatively impact the reliability and precision of the anatomical structures and artifacts, which are intended to be replicas of the original structures.

Conclusion and outlook

In conclusion, there is enormous potential for the utilization of PMCT-3DP technology in forensic sciences, especially in the replication of injuries or impacts on skeletal tissue. The utility of the technique can be extrapolated to the replication of evidence, forensic investigation, courtroom presentation, and planning of autopsies. Although the use of hyphenated or tandem techniques brings together the best of both worlds, it may also invite unforeseen problems presented by their limitations. However, it is of paramount importance to consider the aforementioned limitations and eliminate them using adequate strategies. It is also advisable to understand and seek professional support for the identification of appropriate techniques and materials during the printing process. In addition, no hard-and-fast printing parameters have been indicated for ideal print results. Thus, it is imperative to methodically and systematically trial the parameters to tailor the process to the needs of the individual, institution, and/or organization. With necessary amendments, the process can benefit the fields of forensic medicine and forensic sciences across a wide range of trauma cases.

Ethics approval

Not applicable.

Informed consent

This is an *Editorial* article that provides a clinical presentation on the pioneering study on postmortem computed tomography in tandem with 3D Printing technology. It is not a research study/ clinical trial/systematic review, and therefore does not require any patient data or thus did not solicit any Informed Consent.

Sources of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contribution

H.A., V.V., R.V., FI: conceptualization, formal analysis, writing original draft, writing review, and editing; R.V., F.I.: data curation and supervision; all authors commented on subsequent revisions and provided references.

Conflicts of interest disclosure

The authors declare that there is no conflicts of interest.

Research registration unique identifying number (UIN)

1. Name of the registry: Not applicable/Not required [Please note that this is an *Editorial* article which provides a clinical presentation on the pioneering study on postmortem computed tomography in tandem with 3D Printing technology. It is not a research study/ clinical trial/systematic review, and therefore does not require any Registry number.]
2. Unique Identifying number or registration ID: Not applicable/ Not required.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): Not applicable/Not required.

Guarantor

Harsh Anchan (first author).

Data availability statement

The data in this *Editorial* article is not sensitive in nature and is accessible in the public domain. The data is therefore available and not of a confidential nature.

Provenance and peer review

Not commissioned, internally peer-reviewed.

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