



An ethical framework for the creation and use of 3D printed human remains in crime reconstruction[☆]

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ABSTRACT

There is currently a lack of clear guidance setting out ethical best practice in 3D forensic science broadly, and for 3D printing human remains specifically. This paper presents nine ethical principles identified by Carew et al. [4,7] that provide a foundation for establishing ethical practice. The relevance of the nine key normative ethics principles (justice transparency, proportionality, beneficence, context, non-maleficence, anonymity, consent, and autonomy) is outlined, and a hierarchical ethics framework is presented that sets out a synthesis of these nine principles at societal, case, and task levels. This framework sets out key principles to be considered at different stages in the forensic science process and in operational planning, as well as identifying the accountability of key decision makers at each stage. The hierarchical ethics framework provides an adaptive tool that forensic actors can use in practice, to take each ethical principle into consideration and develop best ethical practice, that ensures 3D printed human remains are created and used in an ethical manner.

1. Introduction

The National Academy of Sciences' 2009 report called for a connection between ethics and codes of practice to lay the foundation for establishing a framework to guide practices towards being ethically beneficial to the discipline and profession of forensic science, rather than for self-interests [1]. Each forensic science domain has its own ethical considerations and guidelines that have been developed in response to the distinctive nature of each domain. Codes of ethics exist in disciplines working with human remains [2,3], however, the ethical considerations for creating and using virtual anthropology and 3D printed replicas are rarely considered in existing codes and guidelines [4].

The most recent guidelines that outline recommendations on the ethical issues surrounding 2D and 3D digital imaging of human remains that were set out by the British Association for Biological Anthropology and Osteoarchaeology (BABAO) [5] did not conclude with any specific recommendations for the creation or display of 3D printed human remains, but did highlight that professionals have an obligation to act with an ethical responsibility that is justifiable. This lack of specific codes of

practice suggests that research is needed to reach a consensus as to what constitutes best ethical practice concerning the 3D printing of human remains, and how to develop and use prints justifiably. This becomes even more pertinent and pressing to set in place when the remains are derived from modern forensic casework, where the deceased may have living relatives.

This paper presents an ethical framework for the production and utilisation of 3D printed human remains for medico-legal purposes in the field of 3D forensic science (3DFS) [6].

2. Key principles

Following a thematic review of 3D printing human remains in crime reconstructions, nine normative deontological ethics principles of best practice were identified by Carew et al. [4]. These nine principles included justice (acting fairly and following best practices), transparency (in print production), proportionality (balancing competing ethical concerns or probative value against potential prejudicial impact), beneficence (for the deceased, society, or criminal justice), context (e.g., the background of the case, or circumstances of death),

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non-maleficence (treating remains and printed remains with dignity and respect), anonymity (prints not being identifiable), consent (from the victim or next of kin), and autonomy (respect for the beliefs of the victim/deceased) [4]. A survey of public perceptions of using 3D printed human remains (n = 400 respondents) further identified public support for the use 3D prints in courts of law to help juror understanding and identified several preferred practices as well as concerns [7]. The nine key principles lay a foundation for considering ethical best practice and drawing on these principles and insights of the public perception of what constitutes ethical best practice, this paper presents a hierarchical framework to offer a foundation for establishing ethical best practice for the creation and use of 3D prints of human remains.

2.1. Justice

The overarching principle when considering ethical practice for the creation and utilisation of 3D prints of human remains is the pursuit of justice. The integrity of case materials is a key part of this [8] and this was also identified to be important to the public, particularly when considering how a 3D print may be used and then disposed of after its use in an investigation or court proceedings [7].

2.2. Transparency

Transparency is an important principle underpinning every stage of the forensic science process [9,10]. Enhancing transparency in practice can contribute to best ethical practices by ensuring it is possible for methods and interpretations to be scrutinised. Members of the public were generally in favour of full transparency in terms of how a print was created and in how accurate or true a representation the print is of the original material [7]. It is generally agreed that forensic anthropologists should be as transparent as possible in their work [2,8], and it follows that in order to achieve transparency, the 3D replication process should be fully documented [11].

2.3. Proportionality

The ruling from *S and Marper v United Kingdom* ECHR 1581 [12] was predicated on proportionality and sought to find a balance between (sometimes) competing public and individual interests regarding biometric data storage. Similarly, the debate concerning the use of genealogy databases in forensic investigations has often centred on balancing threats to public safety with invasions of privacy [13]. Balancing the possible benefits of having a print as a visual aid with the potential ethical concerns of printing human remains is a major underlying issue. It was found that 73% of survey respondents agreed that a 3D printed model would help them to understand forensic evidence better than a photograph [7], which indicates that there is a willingness amongst the public for the use of prints in courtrooms with appropriate safeguarding. Presently there is general consensus that when 3D prints are created there should be a consideration of their probative value and any potential prejudicial impact or ethical concerns [14-17].

2.4. Beneficence

The importance of printed human remains having beneficence to the deceased or wider society is an important issue for the public [7]. It has been identified that there is much less support for creating prints when there is no clear beneficence for the deceased, such as the selling of the prints which could be an act of a self-interest (53% in favour), compared to their use in teaching that can be of benefit to society (99% in favour) [7]. Striking the balance between beneficence and maleficence when sharing images of human remains continues to be an important consideration. For example an instance of online images of a 3D skull model from an individual who died on board the *Mary Rose* being publicly displayed with little contextual information raises issues in

terms of how to achieve that balance, and whether the sharing of a 3D skull differs from sharing an image of the original bone [18]. Clearly the intent of the creator of the model and the interpretation of intent by the end-user is an important consideration and this needs to be incorporated into a judgement about the beneficence in a particular context alongside considering how to maximise beneficence [19].

2.5. Context

Context has been identified as being a critical principle to establishing best ethical practice. The BABAQ guidelines outline that 3D printing can be used “*where research, education or public knowledge can be enhanced*” [5], and in so doing this guidance ensures that the principle of utilitarian ethics (doing the greatest good for greatest number of people) is incorporated into practice. Distribution of printed remains online or for teaching needs to be considered within the context of the case and whether consent has been obtained from the deceased (or next of kin where this is possible) [7] or from other relevant actors involved in a case [4]. This application of the prints goes beyond the original intended purpose of demonstrating evidence in court, and thus warrants specific consideration to determine best practice that is mindful of the specific attributes of the case, and as transparent as possible.

2.6. Non-maleficence

Non-maleficence appears in wider forensic science and medical frameworks. For example, the Hippocratic Oath in medicine to “*First do no harm*”, is a premise that is also recommended for use by forensic anthropologists when practicing [8,20]. In accordance with related disciplines, the ethical principle of non-maleficence should also be applied in the context of forensic 3D printing. It is not always clear who retains ownership of a print once produced, except when a print is logged as courtroom evidence. The creator of the print may maintain an aspect of intellectual property [21]. Survey respondents indicated that the creator ought to retain the connection to the deceased and treat the print with dignity and respect [7].

2.7. Anonymity

The need for anonymity has been underlined in many reports [8,22,23]. Indeed, in general forensic science settings there have been recommendations for the anonymity of forensic samples to be irreversible and that data used for research purposes must be anonymised [24]. When considering 3D prints more specifically it has also been suggested that the anonymity in place for 3D prints speaks to the ethical creation of those prints [25]. The public perception of what constitutes ethical best practice for prints also highlights the importance of maintaining anonymity [7].

The principle of anonymity can be found in similar forensic applications, such as the Data Use Agreement for an online decedent database which includes a clause that researchers must not attempt to identify a participant, or reconstruct a recognizable face for public viewing [26]. With the exception of cases of rare disease or alternations, prints of skeletal elements are arguably anonymous. In contrast, prints containing soft tissue features of the face would not be anonymous as they could be identified and as such ought not to be created without explicit permission from the individual who is being printed (or from their next of kin). Anonymity is important to consider in line with the wider context or application, for example if a print were to be used in a forensic investigation or court case, the identity of the victim or deceased would be known as part of the case details, reflecting the utilitarian ethical theory of doing the greater good i.e., the demonstration of injuries in a forensic case in pursuit of justice. Moreover, the issue of anonymity could be more pertinent with prints created for uses other than courtroom use, such as for teaching or public display.

2.8. Consent

Whether or not consent has been received from the deceased (or the next of kin) is a very important consideration for the public when deciding whether different applications of a 3D print signified good ethical practice (with 94% of respondents indicating that they felt that permission should be sought from a next of kin) [7]. Permission has also been identified as an important factor when dealing with living subjects or modern remains [23].

When considering the issue of consent for the creation and utilisation of 3D prints, the beliefs of the deceased and their next of kin need to be taken into consideration. The next of kin should be informed about the creation of the 3D print where possible especially if the print is to be used for demonstration purposes in a courtroom (where the next of kin may be present). Consideration should also be given to the preference of the next of kin regarding disposal or re-purposing of the print after use [7]. There is naturally no straightforward answer as to who can provide consent for the deceased, this will depend on the individual circumstances of a case, however, consent is a key attribute of good ethical practice.

2.9. Autonomy

Autonomy, in this context, refers to the deceased having wishes that should be respected [27,28]. A smoking ban in public places is an example of how wider interests need to be considered alongside individual interests, together with a consideration that the burden of proof for demonstrating the need for autonomy lies with the advocates [19]. Members of the public have also indicated that consent is an important factor to consider when producing 3D prints from deceased individuals so that the deceased may retain some autonomy over subsequent 3D prints [7]. While there is a balance to find that may well vary according to specific contexts, at the very least autonomy should translate to the prints being treated with dignity and respect.

It is important to appreciate that the consideration of each principle should not be undertaken independently of a consideration of the other key principles. There is a need for a holistic and nuanced approach that takes each principle into account. To this end, a framework that seeks to bring these principles together is presented in Section 3.

3. Hierarchical ethics framework

The value of guidelines to advise robust and transparent ethical practice is clear. As such, a hierarchical framework is presented here that incorporates these nine key ethics principles that offer a guide for considering the ethical creation and use of 3D prints of human remains. As outlined in Fig. 1, this framework offers a scaled approach that identifies three levels that broadly address societal (macro scale), through to casework (meso scale), and then task (micro scale) considerations.

3.1. Societal level

Justice, along with **transparency**, **proportionality**, and **beneficence** are the four overarching principles that underpin ethical best practice at a broad societal level (Level 1, Fig. 1). Incorporating these principles into practice promotes overarching ethical practices which could include the manner of reporting and maintaining evidential integrity. In this framework, justice is the ultimate aim to be achieved (i.e., through a forensic investigation or court case). The remaining eight principles are intrinsically necessary contributing principles to achieving justice through ethical practice. If proportionality and beneficence are not incorporated in practice, justice will be impacted. For example, if a 3D print was used in court in a manner that did not effectively represent the associated forensic science evidence, then this could be misleading (and not beneficial to the victim), and result in a misinterpretation of the evidence. In some cases this could lead to mistrial or grounds for appeal, and impact both the process of justice as well as broader public trust in the justice system.

These societal level principles are broad and overarching and should be incorporated into general best practice of every aspect of the creation and utilisation of 3D prints, rather than being principles that require specific consideration in a specific case. For example, a forensic reporting template may include a section to detail 3D capture details, to ensure that the transparency of reporting data has been addressed. Similarly, standard operating procedures could require a statement for the justification of producing or using a 3D print to demonstrate the proportionality of this approach that balances the pursuit of justice with the resources deployed and impact of a 3D print.

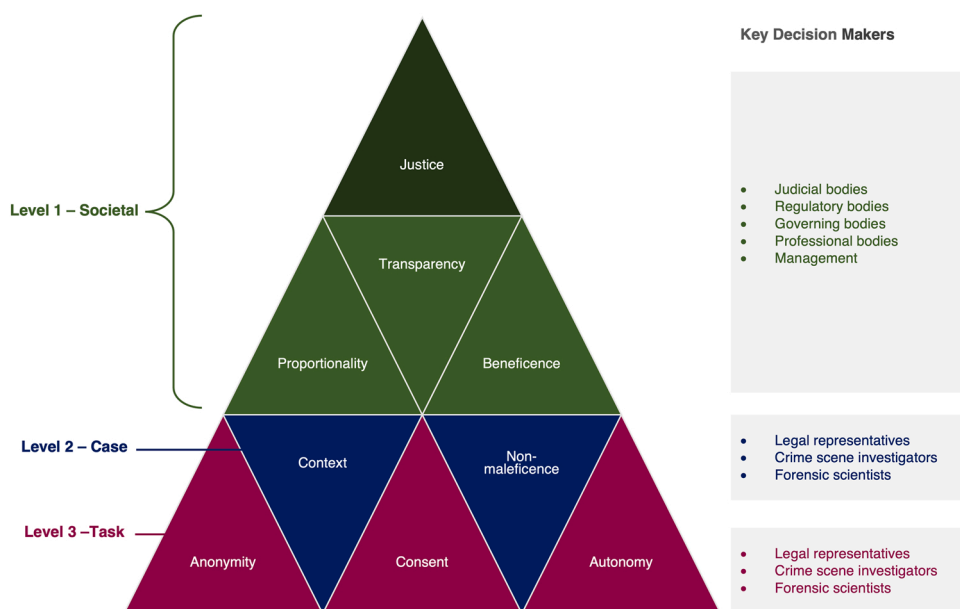


Fig. 1. Hierarchical ethics framework representing nine key deontological ethics principles that need to be addressed to achieve good ethical practice with 3D printed human remains at the societal level, case level and specific task level.

3.2. Case level

The principles of **context** and **non-maleficence** are values that need to be incorporated when considering ethical best practice in an individual case. The context and what may constitute non-maleficence will vary depending upon key factors of a specific case. The context of each case will be distinctive in terms of what has happened, how it happened, where it has happened, and what type of crime has been committed. Every case will also have many distinctive variables such as the demographics of the victim; type and number of injuries; skeletal element involved; acquisition method; visualisation required, etc. In addition, both the provenance of the human remains (such as the time, location, or socio-cultural affiliations), and the application of a 3D print in an investigation needs to be considered on a case-by-case basis. Similarly, ensuring non-maleficence may result in different actions in specific cases as how best to treat human remains and the printed remains with dignity and respect is navigated. In addition to assessing how to preserve and protect the evidence (the remains and any contextual evidence or trace materials) in an appropriate way for the case in hand. In every case it will be necessary to provide valid reasoning for producing printed remains based on the case background that can offer a demonstrable contribution to justice and thus wider society. The context of a case will always be an important and intrinsic consideration that will also influence the degree to which maleficence is harmful to an individual or case and how proportionality is assessed given that specific actions and outcomes will vary depend on the case context.

A valuable example is provided in the case presented by Baier et al. [29], where micro-CT scanning was performed on remains found in a suitcase. In such cases, the process for visualising and/or removing the remains requires specific thought to maximise evidential value, and preserve multiple types of potential evidence (e.g., DNA, toolmarks, and environmental traces). By scanning and 3D printing the remains, it was possible to create a physical replica that could be inspected and used for physical fit analysis without disturbing the human remains themselves. This could be an example of acting in an ethical manner driven by the principle of non-maleficence in the context of a specific case. Ensuring a consideration of context and non-maleficence also contributes to the societal level principles.

3.3. Task specific

Anonymity, autonomy, and consent are the three principles that need to be addressed most specifically in the operational tasks that are employed to create and use 3D prints within the pursuit of justice (Fig. 1).

With respect to anonymity, 3D printed remains should be anonymous and not identifiable. However, the degree to which this is possible will be highly dependent on the context of the case, the remains themselves and the specific tasks or actions undertaken during the investigation of the crime or its hearing in court. For example, the process of including/excluding names and identifiable features will be decided by the forensic actors involved in the case and in the creation of the 3D print. Such tasks could include the decision to remove distinctive features from a print to make it less relatable or potentially less emotive for use in a courtroom.

Consent will be achieved by the actions of forensic actors involved in a forensic case. Procedures to ensure consent may be built in at a (quality) management level, they may also be case specific, but they will require individual thought and consideration as specific tasks based on the context of a case. Consent may not be suitable or applicable in certain cases, for example, when the pursuit of justice overrides concerns from next of kin who may also be suspects in a case (establishing this incorporates a consideration of proportionality). However, consent will still need to be given consideration at the task level.

Autonomy is provided to the victim or deceased through considering the wishes of the victim or deceased (e.g., through their next of kin) and

in how 3D printed remains are handled and stored. For example, a forensic actor may contact the family of a victim to communicate their intention to create a 3D print for use in a court of law (as noted, linking with transparency) and seek consent, but at the same time they can also establish the wishes of relatives in terms of the use, storage, and disposal of the print and in so doing ensuring efforts to respect the dignity of the victim/deceased. In cases where the decedent is unidentified, it could be the responsibility of those advocating for their justice (i.e., the forensic pathologist) to determine what is ethical best practice or in the interest of the deceased.

It is important to recognise the foundational importance of anonymity, autonomy, and consent because if any of these principles at the task level are not achieved it will be difficult to achieve the principles at both case and ultimately societal level. For example, if appropriate consent is not gained, this will impact the ability to demonstrate that transparency, proportionality, and beneficence have been upheld.

3.4. The application of this framework

This framework incorporates nine key principles that have order and levels, but which also interact with each other. It is important to recognise that nuance will often be required to identify best practice that will ensure that the case specific and task specific principles are upheld. These nine principles can inform good practice that can be applied in individual cases. Experience and expertise will be important in identifying best practice that can be sensitive to specific contexts underlining the value of holistic ethics training to support tacit knowledge development, as well as problem-based learning to instil a culture of appropriately applied ethical best practice in different scenarios [4]. Considering normative principles further illustrates the need for having ethical guidelines that are built into management systems so that good ethical practice is embedded into practice structurally.

These ethical principles will be relevant at different times in the process of creating and utilising 3D prints. For example, societal level considerations tend to occur before a case is investigated and can be built into operational systems in advance. The principles particularly relevant in case specific situations can be incorporated into the allocation of casework, considering case budgets, staffing, and wider requirements. Task specific considerations occur during an active investigation addressing the decisions that need to be made and at what point (during an investigation or during system planning). At each level there will be key decision makers (as outlined in Fig. 1) who will be responsible for delivering ethical decisions.

This hierarchical framework has been produced specifically to address ethical considerations for creating and using 3D printed human remains in the context of forensic science/anthropology. However, it may have relevant applications beyond 3D prints to wider 3D visualisation methods in forensic investigations, such for body mapping or even digital forensics (e.g., CCTV presentation) as well as broader contexts that involve human remains such as forensic medicine or bio-archaeology. It is clear that while this framework offers a practical approach to ethical best practice, wider considerations are still critical to achieving it. For example, legislation regarding intellectual property and privacy may need to be considered in different jurisdictions. Consideration is also warranted for the use of 3D prints following the closure of court proceedings, including the sharing, or selling of material for teaching or research purposes.

4. Conclusion

A hierarchical framework is presented that sets out nine key principles for ethical best practice. Level 1 addresses societal level considerations (justice, transparency, proportionality, and beneficence) which are comprehensive and can be built into the management and oversight of casework. Level 2 incorporates two case specific principles (context and non-maleficence) which need to be considered before incorporating

task or operational level considerations in level 3 (anonymity, autonomy, and consent). The nine principles are dynamic and synergistic yet by setting out a hierarchical structure it becomes clearer where forensic decisions are being made, at what level, at what time, and potentially by who, which can inform systemic management and incorporate best practice insights into operational infrastructure. In combination with a holistic cognitive learning approach [4], it is hoped that this framework can guide ethical decision-making and ensuring that individuals are treated with dignity and respect.

CRediT authorship contribution statement

Rachael M. Carew: Conceptualization, Project administration, Writing – original draft, Writing – review & editing. **James French:** Conceptualization, Supervision, Writing – review & editing. **Ruth M. Morgan:** Conceptualization, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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