Review

Drilling down into ethics: A thematic review of ethical considerations for the creation and use of 3D printed human remains in crime reconstruction

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ARTICLE INFO	ABSTRACT
Keywords: Forensic science Forensic anthropology Virtual anthropology 3D printing Ethics Human remains Cognition Decision-making Training	The existing literature contains some exploration of the ethics concerning human remains in forensic and virtual anthropology. However, previous work has stopped short of interrogating the underlying ethical concepts. The question of how people understand and apply these concepts in practice, and what it means to act ethically, remain underexplored. This thematic review explores the ethical considerations that contribute to the creation and use of 3D printed human remains for forensic purposes. The three main branches of ethical theory are outlined to explore how they may apply to forensic practice. Key themes relating to 3D printing human remains in forensic contexts were explored to better understand the ethics landscape, ethical challenges, and the current guidelines in place. Through this thematic review, nine ethics principles were identified as key principles for guiding best practice: anonymity, autonomy, beneficence, consent, context, justice, non-maleficence, proportionality, and transparency. It is suggested that these principles could be incorporated into adaptable guidelines going forward to support ethical practice. The findings also suggest that holistic ethics cognition training may have value in supporting forensic scientists in ethical decision-making, together with procedural and structural design that may promote best practice and reduce cognitive load.

1. Introduction

When seeking to create and utilise three-dimensional (3D) printed human remains in forensic science there are ethical considerations which need to be critically evaluated to foster ethical and transparent practice [1,2]. This is necessary to ensure that human remains, and their 3D prints are handled with integrity, the chain of evidence is protected, and there is transparency to what meets good ethical practice. 3D imaging and 3D printing techniques can be employed to create physical replicas of human remains, specifically skeletal material, that can form a visual or demonstrative aid in a court of law [3]. This use of 3D printed remains for crime reconstruction purposes falls within the field of 3D forensic science (3DFS) [4] which spans activities at the crime scene through to the utilisation of materials in court [5].

Establishing the perceived impacts of reproducing human remains from forensic contexts [6] is critical to achieving ethical best practice. Factors such as whether the subject is deceased or living, the beliefs of the subject and the beliefs of their next of kin, might all need to be taken into account when deciding to replicate remains [7]. Further, if using the prints as part of a public exhibition (such as in a court of law), the wider opinion of the public should also be considered to incorporate a broad range of views from different communities, and to address any competing ethical concerns [8].

Practitioners are required to follow various codes of practice or codes of ethics in their activities [9]. However, it is worth considering what it means to act ethically?, what does that mean in practice?, and is it possible to know whether a particular practice can be considered to be acting ethically? Existing published literature lacks an in-depth consideration of ethical theory and falls short of interrogating the underlying concepts that govern how people understand and apply ethics in real life situations [10]. This thematic review explores the underlying principles of ethics and ethical practice to assess the degree to which they are applicable to the context of 3D printing human remains for use in crime reconstruction.

This paper begins by exploring the framework for considering ethical concepts, understanding what these concepts are and the role that

cognition plays in applying ethics. Broad ethical dilemmas in forensic science are then considered, followed by specific considerations of forensic anthropology and the legislation guiding the treatment of human remains. The question of whether the public have an emotive connection to human remains is considered, and the ethical consideration when dealing with living subjects and modern remains are examined. The presentation of human remains in courts of law is also explored for potential emotive and ethical impacts. Finally, ethics in virtual anthropology and in 3D printing remains are considered along with the current guidelines and the question of whether 3D prints should have comparable ethical considerations to real human remains to provide insight into which ethical principles guide best practices and how these may be applied in practice.

2. A framework for considering ethics

2.1. Ethical concepts

Three aspects of ethics (metaethics; normative ethics; and applied ethics (Fig. 1)) offer a helpful framework for considering the ethics of forensic science practice [11]. Metaethics explores 'what is ethics?', normative ethics considers 'what should be ethical?', and, applied ethics address 'is this ethical?'.

2.1.1. Meta-ethics

Meta-ethics is an approach to consider the language, morals, and theory behind concepts such as right and wrong. It is important ot recognise that moral values are understood in specific contexts intrinsic to particular times and places. As such there will be differences both spatially in different cultures and jurisdictions as well as the potential for evolution of values over time. What may be considered ethical today in a particular society and geography, may not be considered ethical in past or future cultures (and vice versa). These aspects of meta-ethics address broad issues that form the foundation of, and the basis for adopting, normative ethics. Two major theories within *meta*-ethics are cognitivism (or realism), where ethical statements can be true or false, and, non-cognitivism (or irrealism), which states that ethical statements are not propositions [11]. Theories within *meta*-ethics offer philosophical foundations that are important for considering normative ethics, and thus applied ethics.

2.1.2. Normative ethics

Normative ethics captures and considers the principles, rules, and guidelines we follow [12], for instance, standards can be created through knowing what is right or wrong. Normative ethics can stem from transcendental bases such as religious beliefs or personal consciences, that are separate from reason and logic [12]. They can also stem from non-transcendental bases, that is from observable and tangible events [12]. Individual interpretations of how to apply ethical principles will be influenced by these transcendental bases and/or non-transcendental bases, these will affect decision-making at an individual level along with influence from colleagues, family, culture and laws, etc. [13]. Normative ethics offer a consideration of different ethical theories including: consequentialism/utilitarian ethics (doing the greatest good for greatest number of people); deontological ethics (people being treated with dignity and respect); and, virtue ethics (the virtues of good public decision-making) [14].

Utilitarian ethics is the most prominent theory within consequentialism, which stems from a desire to maximise good for the majority [11]. Utilitarianism judges the morality of actions through the consequences of those actions. Forensic strategy provides a useful example, where potential evidential value is maximised and prioritised during collection, sampling, and analysis of evidence, considering the need to protect evidential integrity and act in the pursuit of justice [15]. The identification of unknown remains could be seen as acting in a utilitarian manner, where analysis of the remains provides positive outcomes such as identification and repatriation. Therefore, remains *should* be analysed and efforts for identification made when possible. In contrast, actions could be seen as being unethical if they do not seek identification outcomes.

Rather than being applicable to different scenarios, deontological ethics offer distinct 'rights' and 'wrongs', such as not stealing or not cheating, and underpins the principle that human remains should be treated with 'dignity and respect', a reoccurring principle seen in texts and guidelines regarding the treatment of human remains in forensic practices (such as in Passalacqua et al. [16], Royal Anthropological Institute [17], INTERPOL [18]). Dignity, in this context, is a philosophical approach to considering the dead to have autonomy, as well as desires or wishes that should be respected [19]. Moon [20] advocates that the deceased have human rights given that the two main principles of 'dignity' and 'respect' recur throughout forensic codes and practices, and that it is these that underpin how the dead are treated in humanitarian contexts. The importance of these rights lies in the belief that individuals maintain the right to be treated with dignity and respect after death. However, the application of deontological ethics in practice can itself result in ethical dilemmas arising due to the lack of flexibility. For example, while practices should avoid using invasive or destructive methods on human remains, this could not be a universal principle as that would in turn warrant DNA analysis unethical, which in turn would be acting unethically (against utilitarian ethics, as above).

Virtue ethics considers how people use ethics, or how ethics are reflected in their character, for example with traits such as acting with
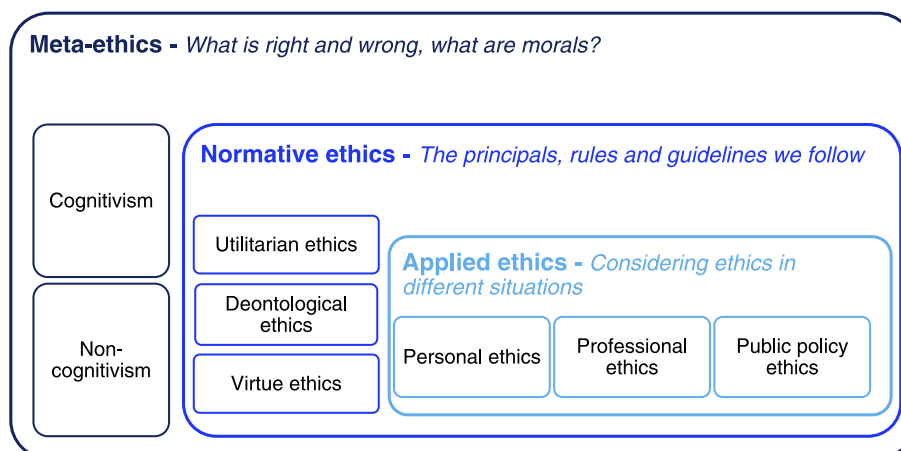
Fig. 1. Metaethics; normative ethics; and applied ethics.

honesty, loyalty, or integrity [11]. Virtue ethics often underpin forensic professional ethics, for example, the Code of Conduct for the Council of The Chartered Society of Forensic Sciences [21] (CSoFS) includes that members should *"conduct themselves honourably in the practice of their profession"*. Thus, someone can hold ethical traits, that will in turn guide them through ethical challenges. However, this understanding of ethics lacks specificity for differing situations that can require more nuanced thinking [15].

2.1.3. Applied ethics

Applied ethics, or applied normative ethics, is the consideration of ethical dilemmas in specific contexts and situations. While normative ethics address what is ethical in an abstract sense, applied ethics considers ethical actions in specific situations, or in practice [11]. Branches of applied ethics can be split into personal ethics, professional ethics, and public policy ethics [11] (Fig. 1). Professional ethics are particularly pertinent in forensic science, where forensic scientists are aiming to act for the greater good, or for justice and follow professional codes of practice. Ethics are important both to an individual and to a profession [9], given that individuals will have differing interpretations of *meta*-ethics and of normative ethics, there is inevitably room for different approaches to applying ethical considerations in practice. Therefore, incorporating the variability of individual interpretations to consider a broad range of perspectives is important for arriving at common ground.

Forensic scientists often have a duty to abide by regulatory bodies and follow relevant ethical guidelines as part of professional memberships [135]. For example, the Council of The Chartered Society of Forensic Sciences [21] (CSoFS), and the British Association for Biological Anthropology and Osteoarchaeology (BABAO) provide codes of conduct or of ethics for its membership [22]. Further, given the international work of many forensic anthropologists, Márquez-Grant et al. [7] additionally advises that forensic anthropologists should follow the most appropriate code of ethics for their country of practice. Moreover, how practitioners implement these guidelines in practice will vary depending on the contexts (personal, professional, policy, etc.).

To arrive at a holistic approach to considering ethical practice, all three concepts of ethics are important and must be considered together; for example, it has been said that forensic scientists should be aware of cultural and religious sensitivities about the handling, management and burial of the deceased [23]. This practice would encompass professional and legal guidelines (normative ethics), application of these in practice considering wider socio-cultural factors (applied ethics), in concert with acting morally and ethically (*meta*-ethics).

2.2. Ethics and decision making

Forensic scientists make decisions with ethical implications every day [24] and at every stage of the forensic science process [25]. To form ethical judgements in ethically challenging situations individuals will consider ethics and form judgements on ethical scenarios. An important aspect in making ethical decisions is being able to ask the pertinent questions and to engage with different views [13]. Schröder-Bäck et al. [26] developed a framework for teaching public health ethics that includes seven principles and recommended an 'inside-out' approach to learning through case-studies and problem-based learning. The seven principles of non-maleficence, beneficence, health maximisation, efficiency, respect for autonomy, justice, and proportionality were laid out as part of a 'toolbox' for professionals and offers one way of ensuring individuals have training in applying ethics in relevant situations and working more broadly in an ethical manner. Forensic scientists are asked to follow codes of ethics; however, it cannot be assumed that a knowledge of broad ethical considerations will always equip individuals to tackle specific ethical challenges appropriately or result in good ethical decisions in specific situations.

While training is clearly very important, forming ethical decisions in practice (for example, when considering whether to 3D print human remains) will be informed by both explicit and tacit knowledge. Ethics training can be used to embed 'good' ethical principles in learning environments, and to explore the application of those principles in case-study scenarios [26,27]. It is also important to acknowledge that training alone is not sufficient. Every case is different and will require nuance and an understanding of context within a broad framework of ethical principles. Decision making has both conscious elements as well as subconscious elements, and so there is value in creating structures that can aid decision making to consider ethical principles in real time, as decisions are being made.

Therefore, a framework to outline good ethical principles in forensic science, together with training in ethical problem-solving and structural processes that guide decision making, could provide a holistic approach for achieving ethical best practice. Such a holistic cognitive approach would need to be applied both in higher education training, and in continuing professional development training to ensure that practitioners know how to apply the ethical principles in different scenarios, and thus understand what could form good ethical practice in novel situations, such as with new technologies like 3D printing or new developments enabled by enhanced capabilities of biometric data utilisation. It would also need to be incorporated into structural decision infrastructure to support ethical best practice. For example, designing reporting forms that ensure key ethical attributes are recorded such as consent and anonymisation of images and materials could reduce cognitive load and increase the likelihood of ethical practices being followed. There is therefore value in considering not only the regulatory environment but also the way human actors learn and apply core principles in practice, as well as how they make decisions and how those decisions can be impacted by 'nudges' to holistically support ethical decision making.

3. Ethical challenges in forensic science

Challenging ethical situations can often occur when different interests intersect. Due to the nature of forensic science work, controversial ethical dilemmas frequently arise (Fig. 2), which can often lead to scientists drawing a distinction between ethics and morals, in order to avoid ethical dilemmas [28].

One approach to challenging ethical situations is to employ clear ethical frameworks such as those that exist for the use of biometrics, and DNA databases [29,30]. The issues that have been considered with these forms of science evidence that utilise directly individualising data form a useful comparative example for 3D printing remains which has similarly sensitive issues in terms of privacy, personal data of both the living and/or deceased. The nature and sensitivity of biometric data necessitate the provision of ethical frameworks to ensure that biometric data is not used beyond its original purpose. The implementation of a UK national DNA database has raised many potential ethical questions, where beneficence to society and the proportionality of actions aimed at securing criminal convictions could be used to balance concerns about individual rights [31]. Biometric data is intrinsically linked to the providing individual, in particular because the individual can be identified from the data. Ethical dilemmas in specific cases that involve the use of a DNA database can range from overreliance on DNA evidence, use of non-consented sampling, and the withholding of DNA evidence details during interviews [32]. New techniques such as DNA 'photo-fits' and biogeographic ancestry can also present ethical dilemmas as they have been used for applications that are not yet tested or accepted in the scientific community [33].

Ethical dilemmas in forensic genetics have developed from being case-specific to prompting wider societal concerns that can disproportionately impact on broad populations. For example, the use of forensic DNA phenotyping (has progressed from being used to compare DNA profiles to being capable of predicting external attributes such as eye, hair, or skin colour); forensic genetic genealogy (can be used to search for genetic relatives from DNA left at crime scenes using genealogy
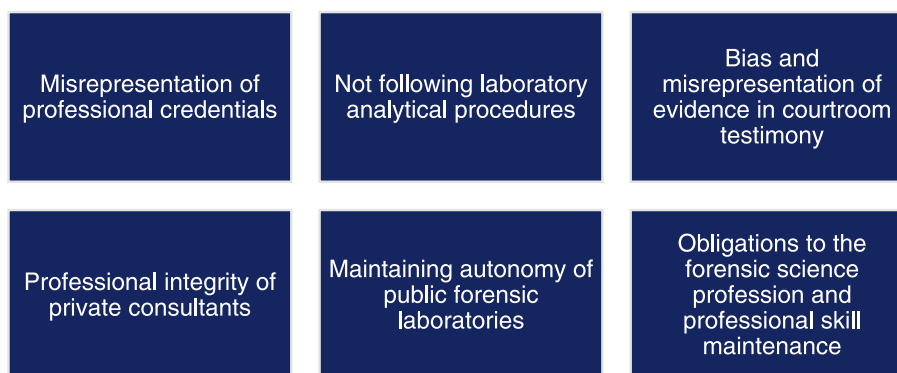
Misrepresentation of professional credentials	Not following laboratory analytical procedures	Bias and misrepresentation of evidence in courtroom testimony
Professional integrity of private consultants	Maintaining autonomy of public forensic laboratories	Obligations to the forensic science profession and professional skill maintenance

Fig. 2. Examples of sources of ethical dilemmas in forensic science [28].

databases, thus using genetic information from the public who may not have consented to such use in criminal investigations); and forensic epigenetics (can use DNA samples to 'predict intelligence' about lifestyle, such as drug or alcohol habits, body shape and size, exercise levels, and socioeconomic status) [24]. Such wide-reaching societal concerns warrant specific ethical guidance. Three ethical virtues of integrity (following legal, moral and ethical practices), trustworthiness (within the community), and effectiveness (balancing capabilities and claims of genetic technologies) have been put forward as a foundation for an ethos for forensic genetics that acknowledges wider societal and cultural values [33].

The sensitivity and associated ethical dilemma regarding biometric data was exemplified in the case of S and Marper v United Kingdom ECHR 1581 [34]. The European Court of Human Rights (ECHR) concluded that the retention of biometric data such as fingerprints, cellular samples and DNA profiles from persons suspected of crimes, but not convicted of crimes, should not be retained as this would be a violation of privacy. The Nuffield Council on Bioethics in their 2007 report, discussed how long-term retention of biometric samples goes beyond the original intended purpose and that report was referred to in the ECHR ruling [30]. The ECHR ruling found that by going beyond the original intended purpose, long-term retention of biometric data failed to strike a fair balance between the competing public and private interests. They raised the importance of individual concerns being considered in concordance with the wider community interests; explicitly, the principle of proportionality to find balance between the *objective* of the forensic actors (or the state), and the *impact* upon the individual.

Despite the definitive ruling by the ECHR, ethical challenges concerning the retention of biometric data are ongoing. For example, the use of facial recognition technology in police investigations and the retention of facial images was reviewed in the House of Lords [29]. The importance of managing ethical challenges concerning biometric data was reflected by the appointment of a National DNA Database independent Ethics Group in England and Wales [35]. Parallels can be drawn between the intrinsic sensitive nature of biometric data and human remains, particularly considering the retention of human remains beyond identification, or for teaching purposes, and the ability to identify the individual. Moreover, it is not yet established whether the retention of digital images from human remains (including 3D models and 3D prints) is an ethically sound practice, or whether this would reflect the unethical retention of identifiable data as seen with S and Marper v United Kingdom ECHR 1581 [34].

Technological advances and the generation of novel digital data types (including 3D printing) provide an evolving ethical and legal landscape. As a result forensic science also needs to be adaptable to cultural changes to be able to adapt with advancing science, ethical concerns, laws, and policies [35]. Cultural shifts may also inform better forensic science practice, such as enabling improvements in decision-

making and consideration of studies from context-specific scenarios [25]. Due to the dependence of *meta*-ethics on context (both temporal and geographical), the use of novel technologies (i.e., 3D printing) needs to be continually reviewed and deliberated to ensure guidelines are meeting current demands and applications in their associated contexts.

Forensic scientists are in a unique position to help inform judicial outcomes, but ethical challenges can arise at the intersection of science and the justice system [35]. For example in practices of 'designing out crime', environments are designed so that certain human behaviours are nudged towards 'pro-social' actions, which itself raises ethical questions [35]. The retention of sensitive biometric data for potential future intelligence information has also been raised as ethical issues, particularly in terms of proportionality, informed consent, liberty, autonomy, privacy and equality [30,35]. The use of genealogical databases for identifying criminal suspects raises some challenging questions [8] in terms of the potential to use data beyond its original intended purpose. Individuals who have uploaded their DNA profiles to privately owned databases generally did so to discover information about themselves and to seek information regarding familial links. In many cases they did not consent to further use of the biometric data which raises issues if there is unauthorised use of this data concerning whether there has been an undermining of human dignity. Another current debate in forensic science is the call for human taphonomy facilities (HTF), for example in the UK [36] and in Switzerland [37]. This is such a live topic for debate due to the issue of using human analogues (often pigs) in place of human cadavers for taphonomic research studies. While analogues are more readily available and ethically more straightforward to use in research [38] they have dissimilarities to human cadavers which may influence research outcomes and impact the applicability of those outcomes to the investigation and interpretation of human remains. However, the effectiveness of human facilities has been questioned given that such facilities can often only offer small sample numbers and may suffer from a lack of repeatability given the variability of environmental and antecedent conditions [39], issues which it has been argued can be addressed by analogues to provide more quantifiable research outcomes [38].

The retention of bioinformatic data highlights how the context influences the application of ethical principles and ethical judgements [30]. For example, how data were obtained can influence what applications may be considered to be ethically acceptable. It can be common practice in the US to create casts of bone specimens that may have evidentiary value prior to returning the bones to the body of the deceased [40]. However, while this may be common practice in forensic science settings, in humanitarian contexts this would be more problematic given the context of the work and the surrounding sensitivities between the families of the deceased and the local agencies [40].

4. Ethics in forensic anthropology

4.1. Ethical principles

Law and ethics both influence research and practice in forensic anthropology. Ethics dictate what work someone can morally conduct, whereas the law dictates what can legally be conducted. The two are intrinsically linked, but also independent; practice may be considered legal but not ethical, and vice versa. The Nuffield Council on Bioethics [30] report utilised the ethical values of liberty, autonomy, privacy, informed consent, and equality. Four chief principles for acting ethically are often presented as autonomy, non-maleficence, beneficence, and justice, for example for use in forensic activities [41], in clinical medicine [42], and in forensic anthropology [43]. A common principal for acting ethically suggests that any work should benefit society and also be carried out at minimum cost to the subject (beneficence) [43]. Given the considerable ethical considerations in play, researchers must consider if it is worth disturbing the dead even with imaging technologies [44]. A common theme is the argument that considers how to balance appropriate invasive research, and particularly repetitive invasive analysis [45]. For example, while imaging would be considered non-invasive, repeated radiological imaging could potentially damage DNA in tissues [45].

Passalacqua and Pilloud [10] set out ten ethical concepts that forensic anthropologists must follow in practice and research which centres around the need to act ethically; to follow requirements and professional guidelines and to not misrepresent self or findings (i.e., truth-telling); to act with respect, confidentiality, non-maleficence, transparency, integrity; to act within competency; and, to avoid biases. These concepts provide normative principles (such as non-maleficence and transparency) and some virtues (such as acting with respect or integrity). Further, confidentiality and truth-telling are deontological virtues that both reflect the ethical principle of autonomy [42]. It is important to distinguish between those principles that forensic scientists can *follow*, and those that scientists can *characterise*. The latter of which, is not easily changed or taught. Instead, normative values are those that can be followed using guidelines and codes of conduct, such as the seven normative principles provided by Schröder-Bäck et al. [26]. Similarly, the Nuffield Council on Bioethics [30] report discussed the ethical values of liberty, autonomy, privacy, informed consent, and equality. Liberty and equality are overarching societal values; however, privacy and informed consent can again be considered to stem from autonomy [42]. In forensic science, the principle of justice refers to the judicial system, not to wider societal justice considering civil liberty and equality [46].

Transparency ensures that it is possible to track actions during the collection, preservation, analysis, evaluation and reconstruction steps of the forensic science process [47,48], this in turn contributes to scientific integrity [16]. Transparency is also a recommendation specified by Squires et al. [49] when considering the ethical challenges of the utilisation of human remains. Hence, the process of generating a 3D replica bone ought to be fully documented to achieve transparency [50] not only in terms of how the print was created but also in terms of the decision-making that took place at each step of its production, and the interpretations that were reached from analysis of that print. Transparent reporting of crime reconstructions and decision-making is currently not explicitly required as a consequence of the novelty of 3D printing in forensic science [51], however, there is increasing recognition that transparency is critical and a means of achieving integrity of these forms of material [4].

4.2. Ethical challenges in forensic anthropology

Forensic anthropology has a history of problematic ethical treatment of remains such as the exploitation of historically marginalised populations, grave-robbing, and unauthorised anatomical dissection [50,52,53]. There has been increasing discussion of the colonial history of forensic anthropology and its related practices, methods, and teaching in recent years [53–55]. Likewise, there have also been debates addressing issues of representation in anatomical collections [56], and for repatriating human remains in museum collections. The latter discourse has become more widely considered [57,58], however there are often complex ethical or legal complications [59].

The current global (ethical) challenges, such as the migrant crises and unidentified human remains, have driven calls for forensic anthropologists to engage in humanitarian action and become advocates for such communities [60,61]. Indeed, humanitarian forensic action is ongoing with the recovery and repatriation of migrant populations [62] and conflict casualties [63]. However, the desire to trace the geographical origin of an individual and develop more appropriate and reliable ancestry estimation methods [64], has been contentious with the call for forensic anthropologists to cease using outdated ancestry methods in their advocacy for justice [53,54].

Given the sensitive and varied nature of their work, forensic anthropologists regularly encounter challenging ethical situations as outlined by Márquez-Grant et al. [7] in a consideration of challenges that can arise during scene attendance, laboratory analysis, research, and in dealing with next-of-kin of the deceased:

- Invasive autopsy versus non-invasive imaging
- Maceration of some or all remains
- Confidence in sorting comingled remains
- Suitability of training
- Presentation of research findings
- Sharing images of decedents
- Communication with families about decomposition
- Managing expectations around the identification process
- Legal rights of descendent
- Effectiveness of search procedures
- Ancestry estimation
- Age estimation on the living
- Religious or cultural considerations
- Ethical considerations of methods or technologies
- Implementation of guidelines

This highlights the need for guidance and oversight of ethical best practice in forensic anthropology. A major ethos in current forensic anthropology is that practices should always endeavour to preserve the dignity of the deceased and consider the rights of the families [16]. However, this position can often conflict with popular culture. For example, an increased fascination with death and deceased bodies in Western countries has been observed [9] as illustrated by newspaper and fictional literature using human skeletal remains as well as the high popularity of public exhibitions, such as the 'London Bodies exhibition', or 'Body Worlds'. Given the public appetite for death in popular culture, and the need to protect the dignity of the deceased in forensic anthropology, there is a balance to find in virtual anthropology applications between displaying the dead for 'entertainment' compared with for educational purposes. The context and provenance of human remains also bear important roles in the ethicality of their display [65]. Calls for the removal of remains from display have seen action towards removal, but these are often still reported alongside of images of those remains [66,67].

Ethics are the principles by which individuals or groups conduct their behaviour, and different cultures, societies and groups have different value systems [9,68]. An important consideration to belief systems are the sociocultural attitudes toward the deceased, as these are intrinsically connected to human/skeletal remains [9]. Therefore, when working with human remains, it follows that practitioners need to take the beliefs of the deceased (and the relatives of the deceased) into consideration.

4.3. Management of human remains

The management of human remains (including the recovery, analysis, retention, and display) presents many challenges at each stage, whether considering archaeologically or forensically derived remains [69], or in disaster scenarios [70]. Traditionally, teaching institutes would store anatomical or archaeological human remains long-term in boxes in storage rooms or on display, both to protect the dignity of the deceased and to protect the integrity of the remains [71,72]. However, more recently institutes and museums have been considering the importance of returning or repatriating existing human remains, and recent remains as soon as analysis is completed [58,65,73,74]. This is an example of the evolution of what is considered good practice and the shifting awareness and appropriate outworking of ethical considerations [75].

When dealing with human remains that contain soft tissues in forensic anthropology, traditional practice is to de-flesh or macerate the remains to expose the skeletal elements for analysis [76]. This practice is often discouraged for two reasons: first, as it can be considered as an unethical practice that irreversible destroys contextual material [77], and second, as digital imaging techniques largely negate the need for it [76,78]. Controversy occurred regarding the methods used to identify the deceased following the UK Marchioness-Bowbelle Disaster in 1989, where 51 people died in the fatal collision between the *Marchioness*, a pleasure steamer boat, and the *Bowbelle*, a dredger. Following recovery of the deceased, 25 of the victims had their hands removed for the purpose of fingerprinting and identification. Two years after the disaster, the families of the deceased learnt of the removal of the hands, which together with the fact that families were refused permission to view the bodies of the deceased brought about the need for a public inquiry [79]. The subsequent inquiry and report by Lord Justice Clarke provided recommendations for dealing with the identification of the deceased [79]. One of the recommendations stated that invasive procedures, disfigurement or mutilation of the deceased should be avoided wherever possible, and body parts only removed when absolutely necessary [80]. This principle was significant and has been carried forward into disaster victim identification (DVI) guidelines for handling dead bodies in the UK [81], and internationally through INTERPOL [18].

Significant advances in digital imaging mean that it should not be necessary to de-flesh remains (or remove body parts) in the majority of cases. Computed tomography (CT) scanning is possible even if metal is present and can also be used to find and identify injuries or objects that could be missed during a traditional autopsy. Medical device ID numbers can also be read from the CT images, and skeletal/dental examinations can also be performed from the digital scans, 3D models, or prints [80,82,83]. Additionally, certain faith groups forbid invasive procedures such as post-mortem autopsies on the deceased [80]. The UK DVI literature also details religious and cultural considerations in handling of the deceased for a number of different faith groups, including beliefs that address post-mortem examinations, storage, and burial [81].

4.4. Guidelines addressing human remains

Existing statutes regulate the use and storage of human remains in the UK. The Human Tissue Act [84] (HTA) was designed so that medical doctors could use all parts of the human body but with consideration for the wishes of the deceased, their relatives, and the need for the state to examine the deceased [43]. Following an inquiry into a scandal at Alder Hey Children's Hospital in Liverpool, UK, the Human Tissue Act [85] was amended to protect the rights of the deceased and the processing of their biological tissue and covers the removal (use and disposal of) of human tissue from both living and deceased individuals [86]. The HTA is limited in that it is does not address research material obtained non-invasively, such as photographs or radiographic imaging data,

however this is covered in the 2011 guidelines from the UK General Medical Council (GMC) [86]. The GMC guidelines state that permission from the subject is needed to obtain such images, unless the images can be anonymised [86]. Consequently, researchers are able access anonymised modern hospital imaging data which has opened avenues for research [87].

Further important pieces of legislation regarding human remains in the UK include the Anatomy Act [88] that regulates the examination of cadavers for anatomy teaching and requires individuals and institutions to obtain licences from the Home Office to be able to examine or store human remains [43]. Additionally, the Burial Act [89] governs the collections of archaeological remains, and the Human Rights Act [90] also played a part, consolidating English Law into EU law [43]. Importantly, the Theft Act [91] does not consider the human body to be property, but a landmark ruling in the Court of Appeal from R v Kelly and Lindsay 3 All E.R. 741 [92] established that any part of human remains may be classed as property if they have been altered due to skill [43]. Examples of altering remains by skill include applying preservations techniques (e.g., on Egyptian mummified remains), or carving designs into human bones (examples of which can be found online [93]). Despite this ruling, these latter commercial practices remain contentious among archaeologists and anthropologists and are often considered as unethical practice. For example BABAO released a *Statement on the Sale of Human Remains* and has a working group actively discouraging such behaviour [94].

The Declaration of Helsinki was formed by The World Medical Association Inc [95] to provide ethical principles regarding the use of human subjects in experimental research, Helsinki includes the need to respect patients in a clinical research setting, stating that the welfare of a subject takes precedence over scientific interests, and that ethical considerations preside over legal restraints [45]. However, Helsinki focuses on living patients and fails to clarify what this means for deceased patients [45]. Finally, there are strict laws in several countries with regards to culturally-sensitive research, for example the US Native American Graves Protection and Repatriation Act (NAGPRA) [96] and the Australian Aboriginal and Torres Strait Islander Heritage Protection Act (ATSIHP) [97 43].

To act 'ethically', professional organisations commonly produce a set of rules known as a 'code of ethics' to help practitioners work using 'best practice' [9]. There are few international forensic anthropology organisations with formal codes of ethics, but examples include the American Board of Forensic Anthropology (ABFA), The British Association for Biological Anthropology and Osteoarchaeology (BABAO) and the British Association for Forensic Anthropology (under the Royal Anthropological Institute), however these guidelines tend to be general and not specific to practice [9]. The Centre of Evolutionary medicine at the University of Zurich developed an internal 'code of ethics' that aims to help balance the rights of the deceased with scientific progress, this also provides guidelines for ethical invasive sampling as well as considerations on the transport and storage of human remains and data generation [45]. Institutes and museums may also have codes of practice, but local or smaller organisations are unlikely to have articulated codes, and most would be unlikely to refer to imaging or 3D printing.

4.5. Emotive connection to human remains

The link between the remains of a deceased individual (i.e., the body or the skeletal elements) and the individual that was living, does not always remain intact. This missing link is reported by Blau [9] who demonstrates that only half of surveyed students (n = 16) who excavated humans remains, considered the remains to be associated to a living person. In a similar study, the emotive opinion of Italian archaeologists was explored through a series of interviews by Rajala [98]. The attitude of the interviewees towards the dead was strongly towards neutrality (n = 7), or seeing the dead as 'objects of study' (n = 9), with only four interviewees responding with attitudes towards 'respect' and

three with 'emotions' [98].

The results from Rajala [98] did appear to be influenced by the sub-speciality of the archaeologist. However, the opinions regarding the objectification of human remains and maintaining neutral emotive opinions were also cited as aiding the archaeologists to be impartial, objective scientists [98]. Palop and Currás [19] describe this 'objectivity' when dealing with human remains, as 'dehumanising'. The topic of objectivity in forensic science is well debated and increasingly it is being recognised that scientists can never be truly objective due to both intrinsic and extrinsic factors that are in play [99]. It is possible to suggest that perhaps this attempt at 'dehumanising' is an ephemeral process whilst 'at work', to enable professionalism without becoming emotional.

These examples demonstrate the importance of having ethical practice guidelines to ensure that the dignity and respect of the deceased are being preserved. Moreover, given that skeletal remains can apparently lose their association with the living, this paradigm brings into question the link between 3D printed remains and the deceased. Can 3D printed remains be considered as meaningfully linked to the deceased, and thus to living individuals or communities? In addition, the coexistence of principles such as maintaining dignity and respect of the deceased, and incorporating cultural or religious awareness into applied ethics, may inevitably result in ethical dilemmas when ethics and practice coincide.

4.6. Considerations of living subjects or modern remains

When working with human subjects, an overarching principle guiding good practice is consent, which of course cannot be obtained from the deceased post-mortem [40]. While research on the living, via radiographic data, for example, can be carried out with informed consent and additional ethical considerations imposed on the data [40], there remains different considerations of the use of imaging data derived from living people and from donated cadavers. Particularly that informed consent can be received from the living subject or donor, thus providing their permission to use their data, something which can calm so-called 'ethical-anxieties' [100]. In a review of the case for the development of a HTF, the importance of donors providing informed consent is often cited as addressing potential ethical objections to such facilities [36]. Additionally, a review of the medico-legal issues of 'virtual body donation' (obtaining imaging data from hospitals) by Aso-Escario et al. [101], also concluded that 'virtual body donation' could be considered as ethically acceptable given that the data collection was non-invasive and was regulated by receiving informed consent from the living donors.

Living people can also advocate for the dead, whether they are a relative, genetic decedent, or connected by a socio-cultural identity [100]. This does bring about the question as to whether consent from the next of kin of a deceased victim should be sought prior to producing 3D models and prints of the victim. This notion is of course complicated by the fact that the next of kin may themselves be involved in the forensic investigation (e.g., as a suspect). Thus, the question of who could advocate for the deceased is often unclear. Considering the multiple actors involved (Fig. 3), further research and debate is required to determine who can provide consent for the printing of bones from a deceased individual in different legal settings.

The question as to who can provide consent for printing in forensic contexts is also intrinsically linked to who owns the imaging data. Autopsy photographs are held under strict rules in Florida, USA where only the relatives of the deceased are allowed to view their autopsy photographs and they are not permitted to be kept in public record [86]. This is an unusual exception, resulting from a case where the family of a deceased NASCAR driver wanted to prevent dissemination of photographs from the autopsy of the driver (known as the Earnhardt Family Protection Act) [86]. Generally, photographs and imaging data are permitted to be used in research in the US as long as they are
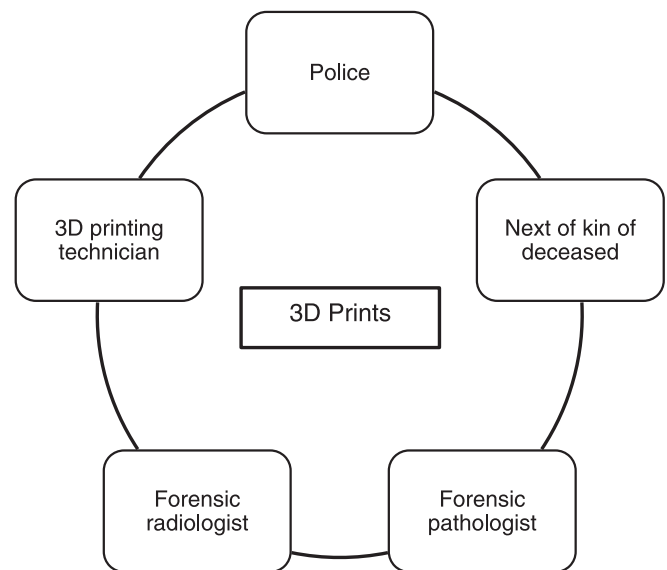

Fig. 3. The multiple actors involved who may hypothetically provide consent for the printing of bones from a deceased individual.

anonymised (with the exception of Florida), but while use of such research data is not necessarily illegal, it would be considered unethical [86].

Moreover, there is the potential for multiple actors to participate in the process of digitising and printing human remains [4], at each stage a different actor may take part and may therefore lay claim to any subsequent data. The concept of ownership of digital data from archaeological human remains (including copyright laws) is discussed by Hirst et al. [102], who conclude that at present it is not known who holds the right of ownership or copyright of digital data and 3D models. Further, the authors recommend the creation of data agreements before undertaking any digitisation of remains to avoid uncertainty and legal disputes. Researchers that are currently developing online repositories for digital models of modern remains are also unsure of the current ethical way to proceed, or how to protect the digital database and subsequent downloads from being used unethically [103]. Further guidelines are required to try resolve the complicated process involved in producing 3D printed remains and how they may be produced ethically.

4.7. Presentation of human remains in courtrooms

Human remains cannot be brought into UK courtrooms due to the risk that they would unfairly prejudice the jury against the defendant due to their confronting nature [104]. Certain types of evidence, such as emotional testimony by witnesses or gruesome photographs from the crime scene, can invoke an emotional response in a juror, which could then affect their judgement and decisions [105,106]. Further, they may be seen as inflammatory or prejudicial to the defence [107], although, according to Matsuo and Itoh [105] there is little empirical evidence to support this theory.

Photographs are especially emotive because of the relationship between the image and the subject (its realism). They also offer a special connection to their subject as they share the same view, lighting and spatial proximity of the subject as seen by the photographer [100]. Conversely, photographs can offer an alternative less-graphic visual aid for jurors, particularly if in black and white rather than colour [104]. There is some evidence that black and white photographs are less emotionally moving than coloured photographs [105]. Autopsy photographs in particular are often not admitted into UK courtrooms [108] usually because they are considered to be unnecessarily graphic [104]. Photographs showing severe gunshot injury or entomological activity

are most frequently rejected [109], thus demonstrating that the graphic nature of an exhibit needs to be careful considered. There are multiple factors to consider when submitting visual aids as evidence into a courtroom and a balance to strike between the probative value and any potential prejudicial impact [51,107,109,110].

Errickson et al. [104] has also suggested that virtual 3D models will be less emotionally disturbing to a juror than an autopsy photograph. More recent studies investigating the differences between courtroom presentation methods for skeletal evidence (e.g., photographs, 3D models, and 3D prints), have found 3D prints to be potentially disturbing or confrontational to mock jurors [106,111]. It is known that more realistic presentations can lead to a greater degree of involvement from a juror following a more intense perception (e.g. than written transcripts), and thus have a greater emotional impact and engage in a deeper understanding of the evidence [112]. Importantly, Eva Martín et al. [112] describe how these more 'realistic presentations' have led juries to have a greater tendency towards reaching guilty verdicts with a bias towards the prosecution, and notes that the type of presentation format employed should be considered for its potential to influence jurors and verdicts.

A study investigating the effect of emotional evidence on the decisions of mock jurors, found that both emotional testimony and gruesome photographs were needed for jurors to be influenced towards a guilty verdict [105]. The heuristic effects of different types of evidence on the emotions of jurors is a critical factor to consider and needs considerable research [105]. Judges must balance the significance of a courtroom visual aid against the potential negative impact it may have on proceedings [109]. In theory, the use of the 3D print could be considered as unethical practice if the 3D print was to have an unfair emotional or prejudicial impact on a juror. More research is needed to understand public opinion and reach consensus on the most proportionate way forward.

5. Ethics in virtual anthropology

5.1. Images and data

The ethical considerations in play in the consideration of the practice of virtual anthropology and 3D printing (of human remains) are under researched, possibly due to the recent development of digital imaging methods. While virtual anthropology was established in the 1990 s [113], there has been a lag in the development of suitable ethical considerations of the utilisation of 3D human remains. However, a recent shift has been seen with an increasing awareness of the importance of ethical codes of conduct [114] and published literature addressing ethics in virtual anthropology [102,115,116].

The use of images from donated cadavers is even now a growing issue [117] alongside the question of 'ownership' of body parts or digital data of human remains which has also been debated [86,102]. In the US, medical examiners have the right to remove body parts for medicolegal examination, but this does not necessarily mean ownership of the part, or of any ensuing digital data [86].

A significant challenge when considering ethical values and practice in virtual anthropology, is that digital imaging data or digital models from human remains are commonly available online with little or no associated information (e.g., information on acquisition, metadata, or consent). For example, a digitised human bone available online does not explain the provenance of the bone or give any mention of consent [118]. Similarly, there is also often no mention of the provenance of the 3D data (or the remains) used to generate 3D printed skulls for sale [119]. Without transparency surrounding the consent of the individual who was the source of the digital data used to create these skulls, it is considered to be unlikely that they would have consented to the reselling of replica skulls for commercial gain.

The ethical considerations pertaining to the use of virtual skeletal models/collections in teaching are gaining visibility [87,115,120].

However, anthropologists are being cautioned to avoid enforcing Western moral cultures and norms onto other groups by imposing rigid ethical guidelines [115]. Finding ethical frameworks that can offer a more flexible and culturally sensitive approach creates opportunities for online collections to be created and utilised in ways that incorporate access, a consideration of permission, a framework for the justification of their use, and ensuring and upholding anonymisation [115]. Thus, reflecting the ethical principles of beneficence, consent, non-maleficence, and autonomy.

5.2. Ethics in 3D printing bones

There are currently few sources that address the ethical considerations for 3D printed human remains. Cornwall [117] discusses 3D printing reproductions of medically donated cadaver body parts, and outlines how the rapid progression of 3D printing is impacting on society and creating new ethical issues that require consideration. It is noted that 3D printed body parts will require different considerations to traditional plastinated body parts, as prints are not 'actual' human tissue, which makes them easier to use and store - potentially *ad infinitum* [117]. McMenamin et al. [121] found that 3D printed teaching aids from cadavers fall under the Australian Human Tissue Act No. 9860 [122], and so can be reproduced ethically by citing a comparison of 3D images with 2D images of cadaver dissections. Currently there is little knowledge about what body donors find acceptable surrounding 3D printing of body parts [117], or regarding the use of digital data once human remains are repatriated or reburied [123]. This is a pressing gap that needs to be addressed to develop culturally appropriate guidelines going forward.

The ethics of the sale of human remains varies globally, trading in cadavers whether legal or illegal persists both nationally and internationally [124,125] and the sale of human remains in the UK is questioned [94]. It is noteworthy that parties are not permitted to make commercial gains from donated bodies in countries such as Australia and New Zealand, however whether this rule applies to 3D printed parts is unclear [117]. Further research into the ethical, social, and cultural considerations pertinent to 3D printing human remains is needed to facilitate 'good practice' across all disciplines [117].

The ethics governing virtual anthropology and 3D printed replicas are only beginning to be considered, and existing laws or ethics procedures do not always cover such novel technologies or their application [87,115,120]. Ethical practices are often subjective and a reflection of cultural, historic, and personal perspectives. Therefore, there is a need to seek views of different cultures and consult existing codes of practice to develop an informed and balanced view of ethical best practice that is translatable and that will help protect the dignity of the deceased in virtual anthropology applications.

5.3. Guidelines addressing 3D printed remains

In addition to the intrinsic ethical factors, (*meta*-ethics, Fig. 1), individual forensic scientists can have differing opinions regarding what constitutes ethical as opposed to unethical practice and this is where professional ethical codes of practice can help guide forensic scientists [28]. For example, a National Code of Ethics and Professional Responsibility for the Forensic Sciences (NCEPRFS) was published in the US following the 2009 NAS report National Academy of Sciences [114] to address a lack of ethical codes for forensic science practitioners [10]. It has also been suggested that the use of imaging techniques in forensic anthropology requires its own ethical considerations, which includes a consideration of the storage and data protection of digital images and imaging data [7].

There are various guidelines, legal obligations, codes of ethics, codes of practice and policy documents regarding the display of human remains [100,126]. For example, the recent 'BABAO recommendations on the ethical issues surrounding 2D and 3D imaging of human remains'

[127] states that 3D images and prints of human remains can be useful in minimising handling of remains, avoiding public exhibition of remains, and are useful for teaching and public outreach events. Further, the guidelines also reinforce that the context and authorisation behind the display of 3D remains must be considered and that 3D printing should only be used *"where research, education or public knowledge can be enhanced"* [127].

The BABAO guidelines do not provide any specific recommendations for the creation or display of 3D printed human remains beyond highlighting that professionals have a general responsibility to act ethically and justifiably (reflecting ethical virtues). This corresponds with the opinion that most forensic anthropologists do act ethically and comply with relevant codes of ethics set out by their professional organisations [86]. However, the ethics of professional practice often differ substantially between osteologists and forensic anthropologists, for example, in the case of forensic anthropologists, professional codes are focused on professional practice in casework and in courtroom testimony, they do not reach to cover ethical practice when conducting research [86].

Conversely, Passalacqua and Pilloud [68] note that there are individuals practicing forensic anthropology without the necessary qualifications or affiliations to professional bodies. Additionally, guidance aimed at osteologists is largely concerned with the display of human remains and issues regarding destructive sampling for research purposes [128]. Guidance will not cover all ethical dilemmas encountered in research or practice. For example, Dennis [27] asked digital archaeologists to consider whether the code of ethics from their professional organisations adequately covers digital ethics. France [86] also notes that the forensic anthropologist must respect the beliefs of the next of kin of a deceased individual, a notion that stems from the 2004 Human Tissue Act in the UK. Speaking to the next of kin of the deceased is something unlikely to pertain to osteoarchaeologists, given that they are working with historical remains. Ultimately, both disciplines share the common notion that the practitioner must always treat human remains with dignity and respect [17,128].

Ethical considerations of the use of 3D models and 3D prints are not yet covered in most guidance documents. For example, the UK Code of Practice for Forensic Anthropology does not mention the production of 3D models or 3D prints [17]. There is scope for professional organisations to consider 3D methods and develop protocols and guidance for their application in future professional practice more thoroughly.

A discussion by Jones [50] explored the use of 3D printing in recreating anatomy from donated cadavers, which points to several issues that deserve consideration when 3D printing models derived from the internet. Ethical considerations in this context include the source of the model, whether consent was received from the donor, the reason for printing, who will benefit, and whether the print will be commercialised [50]. These ethical considerations reflect the ethical principles of beneficence, context, and non-maleficence. Jones [50] also proposed that the following factors (paraphrased below) be considered in guidelines for ethical practice in 3D printing in anatomy:

1) Provision of informed consent during donation
2) 3D prints should not be identifiable as people
3) The link between the donor and the print should be maintained
4) Donor consent should be required for commercialisation of their prints
5) and thanks should be given to the donor for their contribution
6) Copyright violations and digital distribution of data
7) Proportionality can be used to consider using 3D prints or digital models
8) Generation of prints that do not follow anonymity (e.g., containing facial features) may be possible

Additionally, Backhouse et al. [129] investigated student perceptions of a 3D printed replica orbital bone (a partial crania model) on students learning and considered the ethical implications of 3D printing from donated cadaveric specimens. Previously it has been suggested that any aspect of 3D reproduction should be included in the donor consent form [117]. However, Backhouse et al. [129] argue that the prints in their study have been ethically created since the prints were made for teaching purposes, have not been made for commercial gain, are fully anonymised, and that some anatomical features (such as suture lines and missing teeth) were altered during production.

The notion that prints may be ethical if the features have been altered corresponds to the permissible sale of remains when altered due to a skill [92 43] (see section 4.34.3). Thus, given the labour that has gone into editing and creating 3D models/prints, they may now be classed as 'property'. However, this legislation is problematic and contentious among the relevant academic community who feel uncomfortable with the sale of any human remains [94], rather perhaps, the overarching principle of treating human remains with dignity and respect should take precedence over the technological aspect of how the prints were created.

Parallel to this debate about human bones being considered art, the objectivity of forensic photography has been questioned, with there being no definitive line between when a photograph shifts from being documentary to being creative art [104,109]. Similarly, it has been suggested that there is no clear boundary between when a 3D print becomes an interpretation of the user and when a print is a true reflection of the original object [130]. Moreover, Jones [50] argues that the modifications made to a 3D print, tip the print towards being an artificial object, rather than being 'part human'.

5.4. 3D printed human remains compared with 'real' remains

While public opinion is generally positive towards the display of human remains in museums [131], an issue remains as to whether 3D printed remains should be considered as 'real' human remains, and whether prints should therefore have the same (or different) ethical considerations. For example, the mode of a virtual autopsy means that it is considered distinct to traditional autopsies, in that they are non-invasive, non-destructive and thus are often tolerated by religious members who would otherwise oppose a traditional autopsy [132]. This distinct characterisation could also apply with 3D prints.

A review of ethical considerations regarding the use and display of 3D human remains by Smith and Hirst [116] highlights the current lack of ethical guidelines concerning 3D remains and advocates for greater consideration of the public display of virtual and 3D printed human remains. A noteworthy argument for how real and printed replicas may be distinguished, regards the public attitude towards children being able to freely handle printed human remains, a practice that would be deemed highly unethical with real remains [116]. This argument suggests that printed human remains can be considered to be distinct from 'real' remains in the public domain and are often treated as such. Additionally, museums are increasingly using 3D printed replicas for display of human remains, such as the prominent replica skeleton of King Richard III in Leicester, UK (Fig. 4). This display can be seen as an 'ethical alternative' that allowed for re-burial of the original skeleton while providing a less confronting specimen for public exhibition.

The public are often protected from seeing death in unexpected circumstances through practices such as the screening of crime scenes and archaeological sites from public view. This is partly and importantly, to protect the dignity of the deceased [100], but it also protects onlookers and affords them with the choice of seeing (or not seeing) the subject. Similarly, museum settings often afford human remains with separate zones so that the public are aware of their presence and can choose whether or not to view them [134]. If printed remains are to be considered real, then it could follow that prints may also be distressing to the public to view and/or hold as with real human remains or photographs of them. A study by Blau et al. [106] investigated the use of visual aids when presenting complex forensic medical evidence and importantly found that these visual aids may be confrontational. While

Fig. 4. 3D printed replica skeleton of King Richard III in a museum in Leicester, UK. Taken from ITV News [133].

colour autopsy photographs were found to invoke the highest confrontational response from participants, the use of the 3D print was also found to invoke some confrontational responses [106]. Similarly, Errickson et al. [111] suggests that 3D prints in courtrooms may evoke emotional responses from the jurors; which is comparable to the power of photographs (discussed in section 4.6).

The effect of the 3D print upon the jury and their decision-making is a field in itself that requires further research [106,111], nonetheless if these 3D prints are invoking emotional responses from jurors, then it follows that they must be linked to the human subject that they are derived from in a meaningful way. Conversely, it could be argued that 3D printed human remains are so far removed from the original subject that they are no longer connected to the subject and should not be considered as human remains at all, they are for example, not covered by the Human Tissue Act [85]. Importantly it is not known which of these conflicting interpretations are reflective of public opinion, perhaps it is the addition of the forensic injuries in the courtroom (and/or the connection of a juror as an advocate for the victim) that make the 3D prints emotive, rather than the fact that they are derived from human subjects.

6. Conclusion

The aim of this paper was to explore the themes shaping ethical considerations in forensic anthropology practice, with a particular focus on emerging techniques including the production and utilisation of 3D printed human remains. An exploration of ethical concepts provided understanding of the role of normative ethics and applied ethics in this context. This paper has addressed the complexity of the forensic science and forensic anthropology landscape and highlighted key challenges for developing ethically underpinned best practice. In summary, the key principles necessary for the development of an ethical framework for the creation and use of 3D printing of human remains in forensic science are anonymity, autonomy, beneficence, consent, context, justice, non-maleficence, proportionality, transparency.

Practitioners regularly question whether their actions are ethical and if they are working to best represent the dignity of the deceased. However, it is not sufficient to advise forensic actors to simply 'act ethically', there needs to be a consensus regarding what this means in practice, and how to make such decisions, in a way that is sensitive to the context whether that is regional, or case related.

The existing guidelines for ethical practice when printing remains for anatomy or archaeology purposes [50,127], do not include specific guidance for how to act ethically in forensic practices or how to determine if a practice is ethical. Furthermore, given the ongoing activities directed at addressing historic and present-day unethical practices in forensic science and forensic anthropology, it is clear that guidance on ethical best practice in general, and more specifically with regard to 3D printing human remains for forensic practices will be beneficial. Training that offers the opportunity to engage with a holistic framework of theory and exploration of best practice in specific scenarios is an important part of the pathway forward. To realise the potential of training, it should be delivered in combination with the design of approaches that embed and encourage best practice in structural practical settings such as methods of reporting that incorporate a documentation of the steps taken to address anonymity, consent, and autonomy in case work.

CRediT authorship contribution statement

Rachael M. Carew: Conceptualization, Supervision, Writing - review & editing. **James French:** Conceptualization, Supervision. **Ruth M. Morgan:** Conceptualization, Supervision, Visualization, 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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