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To Replicate, or Not to Replicate? The Creation, Use, and Dissemination of 3D Models of Human Remains: A Case Study from Portugal

Francisca Alves-Cardoso [1,2,*] and Vanessa Campanacho [1,3]

[1] LABOH—Laboratory of Biological Anthropology and Human Osteology, CRIA—Centro em Rede de Investigação em Antropologia, Faculdade de Ciências Sociais e Humanas, Universidade NOVA de Lisboa, Av. Berna 26, 1069-061 Lisboa, Portugal; vcampanacho@gmail.com
[2] Cranfield Defense & Security, Cranfield University, Bedford MK43 0AL, UK
[3] Department of Anthropology, American Museum of Natural History, New York, NY 10024-5102, USA
* Correspondence: francicard@fcsh.unl.pt

Abstract: Advancements in digital technology have conquered a place in cultural heritage. The widespread use of three-dimensional scanners in bioanthropology have increased the production of 3D digital replicas of human bones that are freely distributed online. However, ethical considerations about such 3D models have not reached Portuguese society, making it impossible to assess their societal impact and people's perception of how these models are created and used. Therefore, Portuguese residents were asked to take part in an online survey. The ratio of male to female participants was 0.5:1 in 312 contributors. The age ranged between 18 and 69 years. The majority had a higher education degree. Only 43% had seen a 3D model, and 43% considered the 3D replicas the same as real bone. Also, 87% would be willing to allow their skeleton and family members to be digitalized after death, and 64% advocated the controlled dissemination of replicas through registration and login and context description association (84%). Overall, the results suggest agreement in disseminating 3D digital replicas of human bones. On a final note, the limited number of participants may be interpreted as a lack of interest in the topic or, more importantly, a low self-assessment of their opinion on the subject.

Keywords: ethics; biological anthropology; three-dimensional scanning; three-dimensional modeling; human skeletons; heritage; public opinion; Portugal

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1. Introduction

The digital revolution is here to stay, having conquered a place in cultural heritage preservation and display. The advancements in digital technology include 3D scanning, 3D modeling, photogrammetry, virtual reality, and augmented reality, to name a few [1,2]. Some technologies are also applicable to intangible cultural heritage preservation [3]. These all have wide applicability, involving data collection and documentation, reconstruction, preservation, conservation, and dissemination in academia and non-academic contexts. The European Commission has also embraced these, promoting the conservation of European Cultural Heritage via digital technologies, leading to the signing of a declaration of cooperation on advancing the digitization of cultural heritage in 2019 by 27 European Countries. This declaration focuses on three major areas, which are: a pan-European initiative for 3D digitization of cultural heritage artifacts, monuments, and even entire archaeological and historical sites; secondly, cross-sector and cross-border enhancement of cooperation, and capacity building in the sector of digital cultural heritage; and thirdly, fostering a broader citizen engagement in digital technologies applied to cultural heritage, its innovative use, and bridging to other sectors [4]. The COVID-19 epidemic has emphasized the importance

of "making" cultural heritage digital and available online. On a side note, it is also important to highlight that the digital revolution is not limited to cultural heritage; its relevance to the medical sciences has also been well established [5–9].

Digital advancements have allowed the creation of replicas of organs, limbs, and tissues (including bones), artifacts, and other elements recovered in archaeological contexts. They have also promoted the commodification and dissemination of these replicas for teaching and research purposes in various disciplines ranging from the medical sciences to the social sciences and humanities. Three-dimensional imaging technology has allowed the democratization of a wide range of data and elements, having a massive impact on the access to human remains, their study and display, and associated ethical issues. Squires and colleagues' [10] book, *Ethical Approaches to Human Remain,* assembled a noteworthy contribution on these and other matters, contributing to a discussion on the access, use, and display of human remains in research, teaching, and as cultural heritage to be displayed as any other artifact. For additional works on this issue, see [11–17].

The Digitalization and Creation of 3D Replicas of Human Remains

One of the strongest arguments for implementing 3D replicas of human remains is that of preservation—using 3D replicas of human bones prevents bone damage from frequent handling. Human osteological collections can be damaged and lose elements over time, especially in collections heavily used in teaching and research, such as documented collections [18–21]. The use of 3D has also become popular in research and teaching and will undoubtedly continue to be so since it has become embedded in popular culture via television programs, e.g., *Meet the Ancestors, To the Ends of the Earth,* and *Secrets of the Dead* [20] (p. 140), as well as in popular science magazines such as National Geographic. Additionally, three-dimensional technology can be valuable for outreach and teaching, especially in universities with small anatomical and/or osteological collections [21,22] and research associated with rare and/or pathological cases such as exemplified by the project Digitized Diseases (http://www.digitiseddiseases.org/alpha/, last accessed on 9 June 2022). The Digitized Diseases project was built with digitalized human bones available online in open access. It represents a collective of digital replicas of bones, exemplifying disease-related bone changes (e.g., traumatic, infectious, degenerative, metabolic) that can be viewed and downloaded by anyone, anywhere, with a smartphone, computer, or tablet.

With a 3D print, bones can be examined and measured as many times as necessary, minimizing damage and maximizing their observability and revisitation for re-analysis. However, it is also necessary to acknowledge that replicas cannot wholly replace a bone with pathological changes. In some cases, 3D models/prints do not replicate small features observed in disease-related bone changes, such as "woven bone," and minor osteolytic lesions essential, for example, in the paleopathological assessment of neoplasias [23]. Nonetheless, 3D prints are optimal, for example, for assessing bones' overall shape and size.

One major issue related to digitalization and the creation of 3D replicas of human remains is that of consent. Although consent issues are rooted in the acquisition of the bones themselves (for more details, see [10,18]), except for cases where remains are donated, the majority of human remains in museums and institutions were collected from archaeological digs and/or amassed as collections without consent from those the remains had belonged to, their relatives, or their extended communities. Hence, when addressing 3D replicas of human remains, the consent issue persists and cannot be ignored. Moreover, the issue of consent is even more pressing since many 3D replicas end up being commercialized online. Some questions related to 3D printing have already been voiced by Jones [24,25], who asks: What parts of the body are being 3D printed? What is the reason for 3D printing? Who will use and benefit from the 3D printed material? Additional provocative questions may include: would one consent to have one's, or one's relatives, body/bones 3D printed? Would 3D digitization of human individuals who passed away for over 100 years be viewed as more acceptable than that of recently deceased individuals? Responses to these questions may vary between populations for various reasons, including religious beliefs,

social and cultural contexts, education, and many others. Aiming to build a viewpoint from a population at large, this paper explores the context of 3D creation, access, and dissemination of human remains in Portugal.

The ethical discussion on the use of human remains, for research and teaching, in Portugal is only in its early stages [26]. This is despite the fact that Portugal houses a significant number of osteological collections and that the Portuguese scientific community has, over the years, gained a significant profile on publications related to (and using) human remains [18]. Hence, ethical discussion on the use, creation, and access to 3D models of human remains is in its infancy, making it impossible to evaluate peoples' societal impact and the actual perception of how these models are created, used, and disseminated. This research is the first survey conducted on this topic and aimed to explore the opinion on the 3D creation, access, and dissemination of human remains in Portugal. Furthermore, based on the assumption that the exhibition of human remains is a sensitive issue to some people, we hoped to pinpoint specific issues that the creation, use, and sharing of 3D digital replicas of human bones may have in the near future.

2. Materials and Methods

2.1. Survey

The information used in the paper was collected via an online survey. The survey was composed of twenty questions and was initially built using Google Forms (Supplementary Materials). The survey was available online on several e-platforms (mentioned below) between July 2018 and July 2019. The participation was voluntary, and no question was mandatory allowing people to answer only the questions they felt comfortable with and/or were willing to address. The survey was divided into three main parts:

1. Part 1: addressed participants' engagement with visualization and creation of 3D digital replicas of human bones
2. Part 2: addressed participants' opinions on the creation, use, and dissemination of 3D models of human skeletal remains
3. Part 3: collected demographic information, e.g., gender, age, education, occupation (here a reference to a professional occupation), relation religion (since this may affect how one treats and perceives the body, and bodily remains), and citizenship, to profile the survey participants. The participants' anonymity was guaranteed.

The survey included a description of a 3D digital replica of a human bone (Supplementary Materials) and how the model could be created. Including the description of what a 3D model is, meant to help those participants who had never seen a model. An online 3D model was not associated with the survey so that participants could base their response on previous knowledge of the topic and not bias their opinion via data presented with this survey since the survey's first question addresses if people have ever seen a 3D model.

The survey was shared on social media (i.e., Facebook, Twitter, and LinkedIn) and in a news article showcasing the current study, in which we appealed for participation [27]. The survey was sent via mailing-list (with consent) associated with the Laboratory of Biological Anthropology and Human Osteology (LABOH: a research laboratory of the Center for Research in Anthropology—CRIA: Portugal), and disseminated in 211 Facebook groups, comprising a community with a wide range of interests, specifically: 3D technology (n = 5); anthropology (n = 8); archaeology and history (n = 32); arts and literature (n = 30); business (n = 2); cemeteries and churches (n = 3); DIY (Do It Yourself) and beauty (n = 10); education (n = 25); medical sciences (n = 9); natural sciences (n = 9); nature and traveling (n = 10); other social sciences (n = 26); places and cities in Portuguese (n = 23); science and knowledge (n = 16); spiritualism (n = 2); women's group (n = 1).

2.2. Statistical Analysis

Frequencies and percentages were calculated for each specific question. Not all questions had the same total number of individuals since participants could opt out of answering, and some questions had multiple options of choice. A binary classification was used to

cluster the participants according to their occupation, dividing the sample into (a) *specialists* and (b) *non-specialists.* Those grouped as specialists included individuals more likely to engage and/or be exposed to handling, sharing, and producing 3D models of bones during their occupation and/or training. These included archaeologists, anthropologists, biologists, health and health-related professionals, and 3D designers. Grouped as non-specialists are all the individuals that could access and/or be exposed to 3D models of human remains by chance, curiosity, or other motives. Not all participants disclosed their occupation, and some were vague about their current and/or former occupation (e.g., retired, non-specified researcher, and unemployed): these were classified as having a non-specific occupation and were not included in the analysis.

A Chi-square test was used to infer if a significant difference in opinion existed in the sample demographic profiles, i.e., between gender, occupation, education, and religion. In addition, a Mann–Whitney U and a Kruskal–Wallis one-way analysis of variance was undertaken to infer if a difference of opinion existed according to participants' age was significant. Age assessment only used individuals who identified as male or female as very few identified themselves as non-binary male/female (n = 6). Results are presented according to the survey PART I, PART II, and PART III. First, an overview of all data is presented per each section, followed by results related to gender, age, occupation, education, and religion. The statistical significance level was set at $p \leq 0.05$ for all the tests, and the statistical analysis was performed with Excel 2010 and JASP 0.12.2.0.

2.3. Social Media Comments

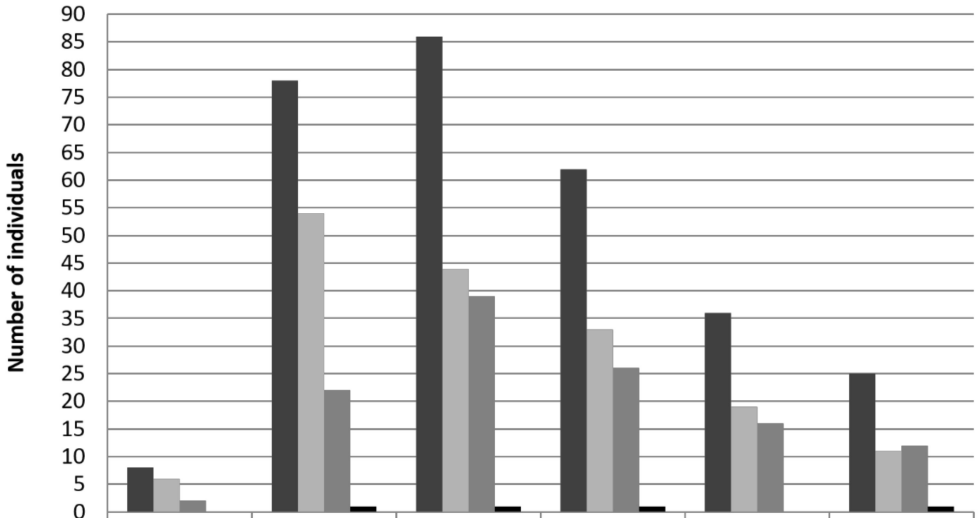
Comments on social media that related to the survey were also considered since they informed the participants' viewpoints. No biographical information was disclosed when reporting specific comments. Similar comments (e.g., relevance to scientific knowledge) were clustered together as representative of the same opinion and discussed as such. The authors opted not to reply to any comments made on social media to avoid influencing participants.

3. Results

3.1. Participants' Demographical Profile

Three hundred and twelve people participated. All were residing in Portugal at the time of the survey. It is essential to highlight, once again, that the number of participants per analysis will vary per question answered since none was mandatory, and some were of multiple options. Consequently, some participants may have provided information on age but not on gender (and vice versa). The same applies to the other sub-samples of the demographic data (i.e., education, occupation, and religion).

- Citizenship results. Most participants were Portuguese (n = 280, 95%). Additional citizenships included Brazilian (n = 12, 4%); two (1%) Spanish; and one (0.3%) Belgium. Nineteen participants had more than one citizenship: 10 European (two identified their second citizenship as Portuguese); five Brazilians, three Africans; and one American. Seventeen individuals did not disclose their citizenship.
- Gender results. Three hundred participants disclosed their gender information on the survey. Most individuals identified themselves as feminine (n = 172, 57%), with the second-largest number of participants identifying themselves as male (n = 122, 41%). A smaller percentage of individuals ascribed their gender as LGBT+ (n = 6, 2%). LGBT+ participants identified themselves as queer (n = 1), male transgender (n = 2), and "Other" (n = 3).
- Age results. Only 295 participants stated their age at the time of the survey, with seven individuals reporting only their age but not their gender. The age distribution of participants can be found in Figure 1. Participants were between 18 and 75 years old and, on average, had 39 $\pm$ 13.10 years old (median age = 38 years). Age descriptions per gender are represented in Table 1.



	18—20 years	21—30 years	31—40 years	41—50 years	51—60 years	61+ years
Total	8	78	86	62	36	25
Female	6	54	44	33	19	11
Male	2	22	39	26	16	12
LGBT+	0	1	1	1	0	1

Figure 1. Participants' age distribution for the total sample and per gender.

Table 1. Descriptive statistics of age distribution in years of the participants in the survey according to gender.

Gender	N	Mean	SD	Median	Minimum	Maximum
Female	167	38	12.96	36	18	70
Male	117	42	12.94	40	19	75
LGBT+	4	42	17.35	39	25	65

Legend: SD is the standard deviation.

- Educational results. Most participants had a higher education degree (n = 261, 85%-bachelor's or undergraduate degree: n = 83, 27%; post-graduation or master's degree: n = 125, 41%; doctorate degree: n = 53, 17%). Age distribution for individuals with a higher education diploma: mean = 39 ± 12.73 years; median = 38 years; minimum = 20 years; maximum = 75 years. Only 45 (15%) participants had a high school diploma or lower (elementary graduate: n = 4, 1%; high school graduate or equivalent: n = 41, 130%). Age distribution for high school diploma or lower: mean = 39 ± 15.13 years; median = 40 years; minimum = 18 years; maximum = 69 years. Discrimination of participants' academic degree per gender can be found in Table 2. Six participants did not disclose their academic degree. Eleven participants did not reveal their gender and twelve their age but disclosed their academic degree.

Table 2. Distribution of participants per academic degree and gender.

Gender	High School Diploma or Lower		Higher Education Degree	
	N	%	N	%
Female	20	45	151	60
Male	23	52	95	37
LGBT+	1	3	5	1

- Religious results. One hundred and ninety-five participants (69%) did not follow a religion, with 58% females (n = 110), 39% males (n = 75) and 3% LGBT+ (n = 5). On average,

the participants without a religious belief were 38 ± 12.85 years (median = 37 years; minimum age = 18 years; maximum age = 75 years). For the non-religious participants, 15.98% (n = 31) had a high school diploma or lower and 84% (n = 163) a higher education diploma.

Eighty-seven participants (31%) hold a religious belief. The majority were Christians (n = 75, 88%). Other religious beliefs included Buddhism (n = 3, 4%), New Age (n = 5, 6%), Theosophy (n = 1, 1%), and Umbanda (n = 1, 1%); 59% were females (n = 50), 40% males (n = 34) and 1% LGBT+ (n = 1). The group of participants with religious beliefs was on average 41 ± 13.17 years (median = 40 years; minimum age = 20 years; maximum age = 69 years). Regarding academic achievements: 12% (n = 10) had a high school diploma or lower and 88% (n = 76) a higher education diploma. Thirty participants did not disclose if they hold religious beliefs.

- Occupation results. Twenty-nine participants did not give information on occupation, and 89 did not specify their profession properly; consequently, they were not allocated to occupational groups. The specialist group was composed of 109 participants (56%). The majority were female (n = 68; 63%). Thirty-seven were male (34%) and 3 were LGBT+ (3%). The specialist group's mean age was 34 ± 12.10 years (18–70 years; median age = 32 years). The majority were non-religious (n = 71; 70%), while only 30 (30%) followed a religion. The non-specialist group was composed by 85 individuals (44%), with a similar percentage for females (n = 41, 50%) and males (n = 40; 49%). Only one individual (1%) identified themselves as LGBT+. Non-specialists were 21 to 75 years (mean age = 40 ± 12.78 years; median age = 39 years). Most non-specialists were non-religious (n = 49; 62%), while 30 non-specialists (38%) followed a religion.

3.2. Results PART 1: Visualization of Three-Dimensional Models of Skeletal Remains

A summary of the frequency and percentage of the results in the visualization of 3D models of human remains can be found in Figure 2. Participants replied similarly throughout the questions, regardless of gender, education, religion, or occupation, with minor percentual changes. For example, most participants had seen a three-dimension (3D) model of human bones online (question 1); the majority had never created, nor shared, a 3D digital model of human skeletal remains (questions 2 and 3).

For those that had shared a 3D model, there was again a consistency with most participants informing us that the images of skeletal remains seen and/or shared online were that of an individual(s) that passed away more than 100 years ago, or they simply did not remember which image had been seen and/or shared (question 5). The question with the broadest diversity in responses addressed how the online source in the model had been seen (question 4): all the options presented, e.g., news website, social media, museum website, university and/or research center website, and 3D model online repositories had similar responses.

Although responses tended to be homogenous within and between groups, when responding to whether (or not) participants had visualized a 3D model of human remains, some associations have statistical significance (Table 3). Significant differences were found for gender and occupation groups regarding the question—*Have you ever seen a 3D model of human skeletal remains online?* Gender differences highlighted how male individuals accounted for the major number of people that had seen a model (n = 66; 54%; χ^2 = 13.845, df = 2, $p < 0.001$) (Tables 3 and 4). The other significance was found in occupation, as those classified as specialists had seen more 3D models of bones than non-specialists (n = 63; 58%; χ^2 = 18.427, df = 2, $p < 0.001$), while most non-specialists had seen 2D images of human remains (48%) (Tables 3 and 4).

Question and options	Total		GENDER						EDUCATION				RELIGION				OCCUPATION			
			Female		Male		LGBT+		High School diploma or lower		Higher education		Religious		Non-religious		Specialistic occupations		Non-specialistic occupations	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1 - Have you ever seen a 3D model of human skeletal remains online?	312	100	172	100	122	100	6	100	45	100	261	100	87	100	195	100	109	100	85	100
Yes	133	43	60	35	66	54	2	33	17	38	111	43	35	40	84	43	63	58	23	27
No, I have only seen two-dimension (2D) pictures of human bones online	119	38	68	40	42	34	3	50	18	40	100	38	33	38	73	37	32	29	41	48
No, I have never seen 2D or 3D images of human bones online	60	19	44	26	14	11	1	17	10	22	50	19	19	22	38	19	14	13	21	25
2 - Have you ever created a 3D digital model of human skeletal remains?	130	100	59	100	64	100	2	100	17	100	108	100	35	100	83	100	61	100	23	100
Yes	14	11	4	7	8	13	1	50	2	12	12	11	3	9	10	12	8	13	1	4
No	116	89	55	93	56	88	1	50	15	88	96	89	32	91	73	88	53	87	22	96
3 - Have you ever shared a 3D digital model of human skeletal remains online (e.g., repository, news article, institutional website)?	131	100	60	100	64	100	2	100	17	100	110	100	35	100	84	100	63	100	23	100
Yes	32	24	9	15	18	28	1	50	1	6	29	26	8	23	21	25	14	22	4	17
No	99	76	51	85	46	72	1	50	16	94	81	74	27	77	63	75	49	78	19	83
4 - In which online source have you seen and/or shared a model of human skeletal remains?*	123	—	55	—	61	—	2	—	17	—	102	—	34	—	78	—	60	—	21	—
News website	27	22	9	16	16	26	0	0	3	18	23	23	5	15	19	24	11	18	5	24
Social media (e.g., Facebook, Twitter)	43	35	19	35	20	33	0	0	3	18	37	36	13	38	26	33	22	37	5	24
Museum website	45	37	20	36	23	38	1	50	3	18	41	40	12	35	31	40	20	33	7	33
University and/or research centre website	53	43	24	44	25	41	0	0	3	18	47	46	14	41	34	44	23	38	5	24
3D models online repository (e.g., SketchFab, Morphosource)	51	41	14	25	32	52	2	100	7	41	41	40	11	32	34	44	20	33	12	57
Not listed	13	11	2	4	4	7	0	0	3	18	9	9	5	15	6	8	7	12	2	10
5 - Which 3D images of skeletal remains did you saw and/or shared online?*	125	—	56	—	63	—	2	—	17	—	104	—	32	—	81	—	60	—	22	—
Human skeletal remains of individual(s) that have passed away more than 100 years ago	76	61	34	61	37	59	1	50	6	35	66	63	21	66	46	57	37	62	8	36
Unknown human skeletal remains of individual(s) that have passed away less than 100 years ago	26	21	14	25	11	17	0	0	2	12	23	22	7	22	17	21	12	20	2	9
Identified human skeletal remains of individual(s) that have passed away less than 100 years ago without disclosing identity. By known identity we mean that the name, age and sex is available	19	15	11	20	7	11	0	0	1	6	17	16	4	13	14	17	7	12	1	5
Identified human skeletal remains of individual(s) that have passed away less than 100 years ago with disclosed identity	3	2	0	0	3	5	0	0	0	0	3	3	1	3	2	2	1	2	0	0
I do not recall	37	30	15	27	21	33	1	50	9	53	27	26	6	19	29	36	16	27	11	50

Figure 2. Descriptive statistics of *PART 1: Visualization of three-dimensional models of human remains* per gender, education, religion, and occupation. Figure legend: */—: 100% was not attributed since participants could choose more than one option; N = frequency; % = percentage; SD = standard deviation. Questions 2 to 5 were only responded to by participants that had seen a 3D model of human remains (i.e., replied YES to question 1).

Table 3. Chi-square test results for the questions about visualizing three-dimensional models of human remains.

Group	Question	χ^2	df	*p*
Gender	Have you ever seen a 3D model of human skeletal remains online?	13.845	2	**<0.001**
	Have you ever created a 3D digital model of human skeletal remains?	1.141	1	0.285
	Have you ever shared a 3D digital model of human skeletal remains online (e.g., repository, news article, institutional website)?	2.968	1	0.085
Education	Have you ever seen a 3D model of human skeletal remains online?	0.419	2	0.811
	Have you ever created a 3D digital model of human skeletal remains?	0.006	1	0.937
	Have you ever shared a 3D digital model of human skeletal remains online (e.g., repository, news article, institutional website)?	3.423	1	0.064
Occupation	Have you ever seen a 3D model of human skeletal remains online?	18.427	2	**<0.001**
	Have you ever created a 3D digital model of human skeletal remains?	1.342	1	0.247
	Have you ever shared a 3D digital model of human skeletal remains online (e.g., repository, news article, institutional website)?	0.238	1	0.626
Religion	Have you ever seen a 3D model of human skeletal remains online?	0.284	2	0.868
	Have you ever created a 3D digital model of human skeletal remains?	0.304	1	0.582
	Have you ever shared a 3D digital model of human skeletal remains online (e.g., repository, news article, institutional website)?	0.062	1	0.804

Legend: bold *p*-values are indicative of statistical significance; df = degrees of freedom.

Table 4. Descriptive statistics of participants' age per question answered (questions 1 to 5).

Question and Options	Age (Years)					
	N	**Mean**	**SD**	**Median**	**Min**	**Max**
1-Have you ever seen a 3D model of human skeletal remains online?	—	—	—	—	—	—
Yes	122	38	12.99	36	18	75
No, I have only seen two-dimension (2D) pictures of human bones online	115	40	13.24	39	20	70
No, I have never seen 2D or 3D images of human bones online	58	42	12.85	40	20	69
2-Have you ever created a 3D digital model of human skeletal remains?	—	—	—	—	—	—
Yes	11	33	6.69	33	22	41
No	108	38	13.10	36	18	75
3-Have you ever shared a 3D digital model of human skeletal remains online (e.g., repository, news article, institutional website)?	—	—	—	—	—	—
Yes	25	39	13.00	36	21	62
No	96	37	12.71	36	18	75
4-In which online source have you seen and/or shared a model of human skeletal remains? *	—	—	—	—	—	—
News website	24	42	12.54	39	24	70
Social media (e.g., Facebook, Twitter)	36	38	9.81	37	21	58
Museum website	43	40	14.17	37	20	75
University and/or research centre website	47	36	11.32	36	18	67
3D model online repository (e.g., SketchFab, Morphosource)	45	34	9.91	32	19	62
Not listed	11	38	13.28	39	21	67
5-Which 3D images of skeletal remains did you see and/or share online? *	—	—	—	—	—	—
Human skeletal remains of individual(s) that have passed away more than 100 years ago	67	39	13.10	37	18	70
Unknown human skeletal remains of individual(s) that have passed away less than 100 years ago	24	36	10.60	35	18	62
Identified human skeletal remains of individual(s) that have passed away less than 100 years ago without disclosing identity. By known identity we mean that the name, age and sex is available	17	32	8.45	32	18	44
Identified human skeletal remains of individual(s) that have passed away less than 100 years ago with disclosed identity	3	38	17.62	33	24	58
I do not recall	35	37	12.54	33	20	75

Legend: */—: 100% was not attributed since participants could choose more than one option; N frequency; % = percentage; SD = standard deviation; Min = minimum age; Max = maximum age. Questions 2 to 5 were only responded to by participants that have seen a 3D model of human remains (i.e., replied YES to question 1).

The assessment of the age of the participants on the various questions, per group, showed that the participants' age profile was alike. The average age of all participants (that disclosed their age) was 38-years old. These data align with the no response patterns that were found within the groups, i.e., both older and younger individuals gave similar responses. The breakdown of the descriptive statistics per group is shown in Table 4. For example, the average age of participants that had seen/or not seen a 3D model (question 1) varied between 38 and 40/41 years of age (Table 4). Although the descriptive data suggest an absence of bias towards younger/older age, statistical significances were tested. The Kruskal–Wallis test inferred if significant differences existed in question 1: they did not ($H = 4.121$, $df = 2$, $p = 0.127$). The assessment of question 2 (Mann–Whitney $W = 461.000$, $p = 0.224$) and question 3 (Mann–Whitney $W = 1258.000$, $p = 0.713$) also failed to show any age bias with significance. Overall, no major differences existed between participants who created and/or shared 3D models. Most participants (with percentages ranging from 94%

to 50%) had not created, nor shared (percentages ranging from 50% to 94%) a 3D model. This is transversal to all groups under analysis (Figure 2).

3.3. PART 2: Opinion of Portugal Residents over the Creation, Use, and Sharing of Three-Dimensional Models Online

A summary of the frequency and percentage of the results on the opinion of residents of Portugal concerning the creation, use, and sharing of 3D models online are shown in Figure 3. The responses were very similar in the overall sample, between and within groups. For example, most participants (>86%) would be ok with the digitalization of one's skeleton and that of a family member (question 6)—this is observed in the overall sample, between and within groups. Also, the majority of respondents were concurrent on displaying 3D models for education, and research purposes, and on which e-platform the remains should be displayed (questions 8 and 9). There was a general agreement that some control should exist when accessing and disseminating 3D models (question 10). Furthermore, consensus exists in including a description/contextual information on the 3D models (question 13). However, some heterogeneous patterns of reply were found. For example, participants were divided as to whether 3D models should be considered to be the same as the original bone, and thus with the same ethical considerations regarding their display online (question 7): 42% agreed it was the same as a human bone, and 42% as being different. Differences of opinion were also diverse in the agreement on the online availability of 3D models for personal use (question 12).

Although the pattern of responses tended to be similar in the overall sample, except for the cases above mentioned, some levels of significance ($p < 0.005$) were found (Table 5), i.e., some responses were more likely to be given depending on the participants' gender, education and religion. These were specific to gender and religion. Male and especially LGBT+ participants were more likely to be ok with the digitalization of one's skeleton and that of a family member (question 6) ($\chi^2 = 13.845$, df = 2, $p < 0.001$). The LGBT + participants were also those that considered the 3D models to be the same as human bone, and deserving of the same ethical concerns (question 7) ($\chi^2 = 10.842$, df = 4, $p = 0.028$); advocated, as well as female participants, for some sort of control over the dissemination of 3D models (question 12) ($\chi^2 = 5.946$, df = 1, $p = 0.015$); and strongly disagreed with the use of 3D models for personal use, reinforcing their value within science only (question 12) ($\chi^2 = 17.543$, df = 4, $p = 0.002$). However, it is necessary to remember that the number of participants self-classified as LGBT+ was very small. The other major sub-set of gender participants, male and female individuals, exhibited a similar pattern of replies to questions.

The other question where a significance level was found was question 13, in which the non-religious participants were the majority of respondents advocating the need for contextual information being displayed in association with 3D models ($\chi^2 = 11.113$, df = 4, $p = 0.025$).

The average age of all participants (that disclosed their age) was 40-years old. The breakdown of the descriptive statistics of age per group is shown in Table 6. No significant age differences were found among participants who were okay or not okay with having their skeleton digitized (Mann–Whitney W = 5402.000, $p = 0.103$). Nor regarding the online dissemination via registration and login (Mann–Whitney W = 8916.500, $p = 0.687$); the download of 3D models for personal use by the greater public (Kruskal–Wallis = 4.171, df = 4, $p = 0.383$); or the expressed need for a description/context associated with the 3D models (Kruskal–Wallis = 7.138, df = 4, $p = 0.129$). Age assessment results show the absence of bias research pattern, i.e., both older and younger individuals gave similar responses, except for question 7—*Should 3D digital replicas be considered the same as the original human bone and thus with the same ethical considerations regarding their display online?* In this case, older participants opted not to express an opinion (Mean age = 46) or tended to disagree strongly (Mean age = 41) with viewing 3D models as bones and worthy of the same ethical observations (Kruskal–Wallis = 17.131, df = 4, $p = 0.02$), with participants without an opinion on the matter being older than the other participants.

Question and options	Total		GENDER						EDUCATION				RELIGION				OCCUPATION			
			Female		Male		LGBT+		High School		Higher		Religious		Non-religious		Specialistic		Non-	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
6 - Would you be ok with your skeleton and those of family members being 3D digitized after death?	310	100	170	100	122	100	6	100	45	100	259	100	86	100	194	100	109	100	84	100
No	39	13	22	13	14	11	0	0	3	7	35	14	12	14	18	9	8	7	8	10
Yes	271	87	148	87	108	89	6	100	42	93	224	86	74	86	176	91	101	93	76	90
7 - Should 3D digital replicas be considered as being the same as the original human bone and thus with the same ethical considerations regarding their display online?	310	100	170	100	122	100	6	100	45	100	259	100	85	100	195	100	108	100	84	100
Strongly agree	67	22	46	27	18	15	0	0	11	24	55	21	20	24	38	19	23	21	19	23
Somewhat agree	64	21	38	22	20	16	3	50	6	13	56	22	17	20	40	21	21	19	19	23
Neither agree nor disagree	49	16	24	14	22	18	1	17	10	22	38	15	14	16	30	15	18	17	5	6
Somewhat disagree	65	21	33	19	29	24	1	17	10	22	53	20	15	18	43	22	25	23	22	26
Strongly disagree	65	21	29	17	33	27	1	17	8	18	57	22	19	22	44	23	21	19	19	23
8 - Should 3D models of human remains be displayed online for:*	311	—	171	—	122	—	6	—	45	—	260	—	86	—	195	—	109	—	84	—
The greater public for non-educational purposes	58	19	24	14	32	26	1	17	11	24	45	17	11	13	41	21	22	20	16	19
The greater public only for educational purposes	191	61	109	64	73	60	5	83	27	60	160	62	48	56	124	64	69	63	50	60
Research in anthropology, biology, anatomy and medicine	252	81	152	89	83	68	5	83	31	69	215	83	72	84	155	79	90	83	58	69
No, 3D models of human bones should never be available online	6	2	3	2	3	2	0	0	2	4	4	2	0	0	6	3	1	1	0	0
9 - In which platforms could 3D models of human bones be available?*	287	—	156	—	114	—	6	—	41	—	240	—	80	—	181	—	104	—	79	—
News website	42	15	17	11	20	18	2	33	8	20	31	13	8	10	30	17	17	16	7	9
Social media (e.g., Facebook, Twitter)	35	12	11	7	19	17	2	33	7	17	25	10	9	11	23	13	13	13	6	8
Museum website	188	66	100	64	74	65	6	100	26	63	157	65	52	65	121	67	65	63	52	66
University and/or research centre website	272	95	147	94	110	96	6	100	39	95	227	95	77	96	171	94	99	95	74	94
3D models online repository (e.g., SketchFab, Morphosource)	197	69	114	73	71	62	5	83	25	61	167	70	50	63	131	72	80	77	53	67
Not listed	14	5	6	4	5	4	0	0	2	5	12	5	2	3	9	5	4	4	4	5
10 - Should there be some control over how the 3D models of human bones are disseminated?	290	100	159	100	115	100	6	100	39	100	246	100	81	100	183	100	106	100	81	100
No, digital 3D models should be freely available on any online platform	105	36	49	31	52	45	2	33	19	49	82	33	23	28	73	40	38	36	28	35
Yes, there should be a registration and login to access the 3D model online	185	64	110	69	63	55	4	67	20	51	164	67	58	72	110	60	68	64	53	65
11 - Which 3D models of skeletal remains can be available online for the greater public?*	280	—	153	—	111	—	6	—	41	—	234	—	79	—	176	—	103	—	79	—
Human skeletal remains of individual(s) that have passed away more than 100 years ago	226	81	122	80	90	81	6	100	29	71	192	82	53	67	152	86	91	88	55	70
Unknown human skeletal remains of individual(s) that have passed away less than 100 years ago	181	65	99	65	74	67	3	50	26	63	153	65	46	58	122	69	66	64	48	61
Identified human skeletal remains of individual(s) that have passed away less than 100 years ago without disclosing identity	193	69	112	73	73	66	5	83	28	68	163	70	48	61	132	75	73	71	56	71
Identified human skeletal remains of individual(s) that have passed away less than 100 years ago with disclosed identity	59	21	25	16	30	27	1	17	12	29	47	20	17	22	40	23	23	22	19	24
12 - Should available online digital 3D models of human bones possibly be downloaded for personal use by the greater public?	291	100	159	100	116	100	6	100	42	100	244	100	81	100	184	100	105	100	81	100
Strongly agree	53	18	18	11	33	28	1	17	8	19	43	18	13	16	35	19	18	17	18	22
Somewhat agree	56	19	28	18	27	23	0	0	13	31	41	17	16	20	34	18	21	20	21	26
Neither agree nor disagree	30	10	19	12	11	9	0	0	5	12	25	10	5	6	24	13	11	10	8	10
Somewhat disagree	64	22	40	25	19	16	1	17	8	19	56	23	20	25	36	20	21	20	12	15
Strongly disagree. The digital 3D models of human remains should only be used for research.	88	30	54	34	26	22	4	67	8	19	79	32	27	33	55	30	34	32	22	27
13 - Should a description/context of 3D models of human bones be always associated with the models?	291	100	159	100	116	100	6	100	42	100	244	100	81	100	184	100	105	100	81	100
Strongly agree	190	65	113	71	67	58	4	67	27	64	160	66	42	52	128	70	77	73	50	62
Somewhat agree	54	19	25	16	25	22	1	17	9	21	44	18	20	25	31	17	16	15	10	12
Neither agree nor disagree	39	13	19	12	19	16	1	17	5	12	33	14	16	20	23	13	10	10	18	22
Somewhat disagree	4	1	1	1	2	2	0	0	1	2	3	1	1	1	2	1	1	1	1	1
Strongly disagree	4	1	1	1	3	3	0	0	0	0	4	2	2	2	0	0	1	1	2	2

Figure 3. Descriptive statistics on the opinion of Portugal residents over the creation, use, and sharing of three-dimensional models online per gender, education, religion, and occupation. Figure legend: */—: 100% was not attributed since participants could choose more than one option; N = frequency; % = percentage; SD = standard deviation.

Table 5. Chi-square test results concerning the opinion of Portugal residents over the creation, use, and sharing of three-dimensional models online.

Group	Question	χ^2	df	*p*
Gender	Would you not be ok with your skeleton and those of family members being 3D digitized after death?	13.845	2	**<0.001**
	Should 3D digital replicas be considered as being the same as the original human bone and thus with the same ethical considerations regarding their display online?	10.842	4	**0.028**
	Should there be some control over how the 3D models of human bones are disseminated?	5.946	1	**0.015**
	Should available online digital 3D models of human bones possibly be downloaded for personal use by the greater public?	17.543	4	**0.002**
	Should a description/context of 3D models of human bones be always associated with the models?	6.525	4	0.163
Education	Should 3D digital replicas be considered as being the same as the original human bone and thus with the same ethical considerations regarding their display online?	3.236	4	0.519
	Should there be some control over how the 3D models of human bones are disseminated?	3.482	1	0.062
	Should available online digital 3D models of human bones possibly be downloaded for personal use by the greater public?	6.271	4	0.180
	Should a description/context of 3D models of human bones be always associated with the models?	1.331	4	0.856
Occupation	Should 3D digital replicas be considered as being the same as the original human bone and thus with the same ethical considerations regarding their display online?	5.202	4	0.267
	Should there be some control over how the 3D models of human bones are disseminated?	0.033	1	0.856
	Should available online digital 3D models of human bones possibly be downloaded for personal use by the greater public?	2.444	4	0.655
	Should a description/context of 3D models of human bones be always associated with the models?	6.760	4	0.149
Religion	Should 3D digital replicas be considered as being the same as the original human bone and thus with the same ethical considerations regarding their display online?	1.075	4	0.898
	Should there be some control over how the 3D models of human bones are disseminated?	3.206	1	0.073
	Should available online digital 3D models of human bones possibly be downloaded for personal use by the greater public?	3.664	4	0.453
	Should a description/context of 3D models of human bones be always associated with the models?	11.113	4	**0.025**

Legend: bold *p*-values are indicative of statistical significance; df = degrees of freedom.

Table 6. Descriptive statistics of participants' age per question answered (questions 6 to 13).

Question and Options	Age (Years)					
	N	Mean	SD	Median	Min	Max
6—Would you be ok with your skeleton and those of family members being 3D digitized after death?	——	——		——	——	——
No	36	43	14.61	42	20	75
Yes	257	39	12.83	38	18	70
7—Should 3D digital replicas be considered as being the same as the original human bone and thus with the same ethical considerations regarding their display online?	——	——		——	——	——
Strongly agree	64	36	12.83	35	20	69
Somewhat agree	58	37	12.75	37	18	70
Neither agree nor disagree	46	46	12.98	43	19	75
Somewhat disagree	63	39	13.43	40	20	70
Strongly disagree	62	41	13.03	38	20	69
8—Should 3D models of human remains be displayed online for: *	——	——		——	——	——
The greater public for non-educational purposes	54	36	11.72	36	18	69
The greater public only for educational purposes	180	38	13.30	37	18	75
Research in anthropology, biology, anatomy and medicine	236	39	13.04	38	18	70
No, 3D models of human bones should never be available online	6	44	15.53	42	20	64
9—In which platforms could 3D models of human bones be available? *	——	——		——	——	——
News website	36	41	13.03	39	19	69
Social media (e.g., Facebook, Twitter)	30	41	13.48	41	18	69
Museum website	178	40	13.20	40	19	75
University and/or research centre website	258	39	12.87	38	18	75
3D model online repository (e.g., SketchFab, Morphosource)	184	37	11.96	36	18	75
Not listed	12	40	11.82	39	24	65
10—Should there be some control over how the 3D models of human bones are disseminated?	——	——		——	——	——
No, digital 3D models should be freely available on any online platform	99	39	13.45	39	18	75
Yes, there should be a registration and login to access the 3D model online	175	39	12.37	37	20	70
11—Which 3D models of skeletal remains can be available online for the greater public? *	——	——		——	——	——
Human skeletal remains of individual(s) that have passed away more than 100 years ago	212	38	12.63	36	18	75
Unknown human skeletal remains of individual(s) that have passed away less than 100 years ago	176	38	13.03	36	18	75
Identified human skeletal remains of individual(s) that have passed away less than 100 years ago without disclosing identity	186	38	12.79	36	18	75
Identified human skeletal remains of individual(s) that have passed away less than 100 years ago with disclosed identity	58	36	10.91	36	18	63
12—Should available online digital 3D models of human bones possibly be downloaded for personal use by the greater public?	——	——		——	——	——
Strongly agree	51	40	11.58	40	19	65
Somewhat agree	52	37	14.26	35	18	70
Neither agree nor disagree	30	40	12.05	41	21	75
Somewhat disagree	60	40	12.80	39	21	70
Strongly disagree. The digital 3D models of human remains should only be used for research.	83	38	12.55	37	20	69
13—Should a description/context of 3D models of human bones be always associated with the models?	——	——		——	——	——
Strongly agree	180	38	12.41	37	18	70
Somewhat agree	50	42	14.20	41	21	75
Neither agree nor disagree	38	41	11.78	40	21	65
Somewhat disagree	4	46	13.59	48	31	58
Strongly disagree	4	38	3.70	38	33	41

Legend: */——: 100% was not attributed since participants could choose more than one option; N = frequency; % = percentage; SD = standard deviation; Min = minimum age; Max = maximum age.

3.4. Social Media Comments

The Facebook comments on the survey were diverse. In total, 13 comments were expressed: 6 individuals pointed out that 3D digitalization of human bones is not controversial and stressed the relevance of 3D models to scientific knowledge; 3 commenters voiced their opposition on the matter; 3 other Facebook users were unaware of the existence of 3D digitalization of human bones and questioned the purpose of this practice; 1 social media user shared a link to the National Geographic webpage about the human body.

4. Discussion

This paper's primary aim was to explore Portuguese residents' opinions on issues related to the digitalization of human bones, dissemination of bones 3D models, their use and access, and ultimately to develop guidelines on how to handle human bone digitalization adequate to the Portuguese population and in line with international guidelines that are already being developed [21,24,28]. The survey had two major areas of data collection: (1) it addressed participants' engagement with visualization and creation of 3D digital replicas of human bones; and (2) it addressed participants' opinion on the creation, use, and dissemination of 3D models of human skeletal remains. The results highlight some exciting trends discussed within a broader context on the use and access to human remains and associated ethical issues.

Despite the subject's dissemination on social media (i.e., Facebook, Twitter, and LinkedIn) and in a news article showcasing the current study and appealing for participation [27], the number of participants was only 312: this is hardly representative of the Portuguese population. The sample is also skewed towards participants holding an academic degree. Hence, interpretation of the results will be cautious. On the low number of respondents, and based on comments provided by those participating, some felt uncomfortable providing an option on the topic since they regarded themselves as "non-experts,": this may have deterred others from participating. Furthermore, the lack of interest in science among the general population, may have further contributed to the low levels of participation. Although there has been, since 1989, an increase in science promotion and engagement in Portugal [29]: it is clearly not enough. This assumption is sustained by a report commissioned in 2010 by the Portuguese governmental program, *Ciência Viva,* to the Eurobarometer, Bauer, and Howard [29], which showed a lower interest in science in Portugal compared with other European Union countries [29]. The poor prominence of science in major Portuguese media outlets [30,31] may be another contributing factor. Finally, the need to access the survey using the internet may have further limited the amount of participation: digital literacy continues to be a problem in Portugal, hence the lack of a social media account, lack of a Gmail account, and/or know-how to "navigate" the internet has undoubtedly limited delivery and access to the survey. Nevertheless, the interpretation of the data collections offers a view of 3D replicas of human remains in Portuguese territory.

4.1. PART 1: Visualization of Three-Dimensional Models of Skeletal Remains

4.1.1. Viewing 3D Models

The visualization of 3D models of human bones has been moderately widespread in Portugal, as 43% (n = 133) of participants viewed at least one bone digitalization, with most of the visualizers being specialists—not surprising, as specialists are more likely to come across human bone digitalization within their professional sphere. Men (54%) likewise visualized more 3D models than women (35%); a finding which is puzzling given how 63% of the women participants were in specialized occupations compared to 34% of men.

Most models visualized were created outside of Portugal. One of the reasons is that the digitalization of human remains in Portugal is not a major trend, even in biological anthropology, which has a significant academic profile in Portugal and internationally [18]. Furthermore, access to real human remains has always been favored due to the amount of human osteological collections available [18,26], and research involving 3D technology

is recent [32–35]. However, this may have changed due to the COVID-19 pandemic, as physical access to human osteological collections was restricted, and digital resources were favored [36]. The impact of COVID-19 associated lockdowns on Portuguese research practices is to be considered in future research.

The primary source of visualization of 3D digital models were websites associated with academia and academic outputs and online repositories (e.g., SketchFab and Morphosource), followed by museum websites and social media platforms. Many participants expressed seeing bone digitalization on social media (n = 43) and museum websites (n = 45). Although social media offers the opportunity for scientists to engage in virtual communities worldwide, the unselective sharing of imagery of human bodies and human remains on social media can be problematic since, most times, it does not offer context information or donors' consent—we may either assume it exists or not [37]. Also, the specific circumstances behind posting 3D models are unknown, as they are often non-disclosed. With growing concern on the access and use of human remains worldwide, the provenance of the replicas and associated remains is something to consider. Similarly, the low number of visualizations of 3D models from museums may derive from the reluctance of these institutions to showcase human skeletons [38], which may be aligned with the conceptual change in the exhibition spaces. Exhibitions began to favor a more intimate and emotional experience for patrons visiting human remains in order to humanize them, replacing the scientific objectification of the remains [39].

4.1.2. Creating and Sharing 3D Models

Ownership, availability, and contextualization of 3D data are linked with one's ability to create and share 3D models. Unfortunately, many participants (89%: question 3, Figure 2) have never created a 3D model, even those classified as specialists. The lack of engagement in 3D creation is undoubtedly related to the sample profile. However, one cannot discard the impact that Portuguese digital illiteracy may have at this point and the overall deficit of the Portuguese population involvement in science and scientific progress, as reported by Eurobarometer [29].

Linked to the creation of 3D replicas, discussions on ownership and copyright of 3D data are a growing concern since they relate to the reproduction and commercialization of human derivative replicas, and because, in most cases, consent to such actions was not given by the individuals to which the remains had belonged. Alberti et al. [40] (p. 4) posed the question of "can we speak for people dead 10,000 years?", aiming to address who/whom the remains belong to. This is a very complex issue. It involves various groups and institutions, such as the individuals themselves (and their express will), legal next of kin, religious sects, and governments. However, one human should never own another human, nor even one's remains.

Issues on ownership may have other contours linked with authorship. For example, to whom should the copyright of 3D models belong, the researcher or the institution [41]; also, most collection managers distinguish 3D from written and photographic/video data, thus behaving differently and drawing different considerations [42]. Smith and Hirst [42], in a study addressing a survey on the opinions of curators versus researchers on 3D digital data, reported that only 40% (n = 50) of collection managers had a formal arrangement in place regarding 3D models. They also concluded that without institutional agreements, researchers perceived 3D data as theirs [42]. However, communities' wishes and requirements should be recognized and considered on 3D digitalization's copyright for research and teaching uses [21,43]. Intellectual property laws in the UK and US concede copyright rights to individuals if a 3D model somewhat differs from the original [42]—which poses a problem since the aim with 3D models is to have them as similar as possible to the original bone. However, the resulting model usually has some distortion from the original bone. For example, surface scanners have difficulty in replicating deep and small structures and pathological changes. Missing areas are artificially filled through user decisions aligned with non-disclosed logarithm packages associated with a software [44–46]. Furthermore,

the legislation is unclear on how many changes a 3D model must feature to be qualified as intellectual property [41,42].

In recent years, in line with the politics of Open Science, calls for 3D data open access for research and teaching are growing in the scientific community [47]. This has become a mandatory requirement for projects funded by European Commission and European Governmental Grants (Requirements available at: https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020--2024/our-digital-future/open-science/open-access_en, accessed on 1 May 2022). Therefore, when planning to 3D digitalize a human bone, researchers must consider not only the purpose of the research, but likewise making their research data findable, accessible, interoperable, and reusable (FAIR) [48,49]. Furthermore, this open access to data requires extended care when an individual's identity is known, notably when handling private medical data, including image scans in a forensic setting [50] and other contexts.

Another concern is the unregulated and unrestricted public availability of 3D models. These models will exist perpetually, reaching users without scholarly supervision, and will be disseminated on e-platforms without ethical scrutiny [28,51]. Moreover, although the sharing of 3D models should occur with written authorization by custodians (i.e., institutions and/or descendant communities), all those involved in the digitalization process should be acknowledged, including students, technicians, and funding bodies [21,52]—though this is often not the case. Finally, although data sharing is envisaged to avoid gatekeeping, and promote broader access to data and information [28,47,53], a lack of standardization on digitalization procedures might induce observation error and bias when using multiple databases [42,54–56].

4.1.3. Temporal Distance and Empathy

The most visualized 3D digital replicas were of individuals who passed away over 100 years ago (61%), followed by those with unknown identity (21%) (Figure 2, question 5). This may be because it is easier to access and use remains from archaeological contexts since these are non-identified remains, with lesser or without (or limited) connections to living communities. In such cases, no consent is thought necessary and/or is impossible to obtain, and chronological distancing and historical curiosity favor their publication. This contrasts with remains that belonged to people recently deceased, which may exert more empathy with the living population due to chronological proximity [57]. Regardless of the reason, issues related to chronology should not be used to justify the display of ancient human remains, as opposed to those of the recently deceased, since the same ethical issues apply—one needs to respect not only communities and cultural beliefs but the individual itself regardless of his/hers chronological age [58,59].

It is, therefore, accurate to state that for Portugal residents, the temporal distance between the living and the dead is relevant in bone digitalization. However, other studies have shown that "time" is essential for other communities. For example, Kilmister's [57] study at the Petrie Museum showed that patrons favored the display of ancient human remains while reacting more emotionally to the display of individuals deceased for less than 100 years, considering the distress it might provoke in descendants [57]. Also, in 2001, Rumsey noticed a higher aversion to displaying medically preserved body elements and infants in the UK [60]. These different reactions illustrate contrasting public empathies regarding the display of dry bones vs. soft tissue, maybe because a body may have more human identifiable features than merely dried bone [61]. Additionally, the display of infants may evoke protective feelings in the audience [61].

In either case, curiosity to observe the human body and/or skeleton on display is a driving motive to visit/access an exhibition. It is also important to consider that a person's opinion on this matter may even change with time: either due to personal experiences, as a result of exposure to studies on ethical issues related to human remains, or as expressed by Freeman [62], due to interactions within social groups.

4.2. PART 2: Opinion of Portugal Residents over the Creation, Use, and Sharing of Three-Dimensional Models Online

4.2.1. The Status of the Three-Dimensional Replicas Compared to Human Bones: An Object or a Bone?

The surveyed sample was divided regarding this topic (Figure 3, question 7): 43% of participants view 3D replicas as human bones, while 42% regarded them as mere objects. Women (49%) were more likely to view 3D models as being equal to bone when compared to men (31%). Participants without an opinion on the matter were significantly older on average (46 years) than those who considered it either a bone or an object. Although the motives behind the visualization of 3D models cannot be discerned, we can conclude that women would be more cautious in visualizing bones' 3D models due to their opinion.

Most important was the observation that across all categories (e.g., gender, education, religion, and occupation), most participants (>87%) would be willing to allow the digitalization of one's skeleton and that of a family member (question 6, Figure 3). These responses do not relate to the fact that a 3D bone model was considered akin to real bone or not since the responses given in that respect were diverse (see responses to question 7, Figure 3): e.g., whether a participant viewed a 3D replica as real bone or not, the majority would allow for one's skeleton or a family member skeleton digitalization.

The necessity to place human remains in their appropriate social and cultural contexts was acknowledged. This opposes the Western illuminist philosophy, which contributed to the objectification of the body based on a dualistic split of the body and mind widely adopted in scientific and medical spheres, ignoring the body as the vessel for religious and social identities and experiences within a community [63]. The concept of seeing a replica as "real bone" may be odd, but it needs to be included in the discussion of building and disseminating 3D models. Aligned with this preoccupation, Márquez-Grant, and Errickson [64] questioned if 3D models were replicas, reconstructions, or reproductions. Regardless of the many possibilities, they concluded that 3D models should be treated with the same respect and dignity as the body, as they are digital records of a person's remains. 3D models are unique because, unlike a photograph, they embody the shape and form of real bones, can be rotated like real bones, and, if the degree of digitalization and printing is detailed enough, may be perfect and equivalent to the original bones. However, it will never be part of a living individual, at least with regard to replicas of human remains, since many 3D replicas may also be used in biomedical sciences.

4.2.2. Three-Dimensional Replicas: Display and Dissemination

Linked with the willingness to have one's skeleton digitized and displayed, are the benefits that its access and use may have to science. The results support this statement as most participants saw research and education as the most appropriate settings for displaying 3D models of human bones, contrary to social media or news outlets (question 8, Figure 3). Accessing 3D replicas of human remains may provide an educational opportunity to interact with a digital version of the dead body. The use and access of remains in educational and research contexts had the highest agreement.

The mass production of digital bones, primarily through 3D printing, may risk depersonalizing the remains, re-enforcing their view as objects and disposable goods [24]. Hence, this ready accessibility to replicas and their easy manipulation may dehumanize the dead, and the unrestricted usage of digital models to satisfy curiosities, entertainment, or even trade is alarming and highly unethical. Exhibiting human remains, either online or physically, with dignity and respect is a relative notion, as it can entail many responses from various actors and communities [40].

4.2.3. Contextualization of 3D Data

Data contextualization is critical in archaeology and bioanthropology. By contextualizing the remains, the necessary background information is given: its chronology (which may impact a person's opinion on the access to remains—see Section 4.1.3), its relationship with

living communities, its social and cultural contexts, and associated health, behavior and social inequalities issues (to name a few examples). The responses show that context is vital, regardless of gender, education, religion, or occupation. Most of the participants (>84%) agree that some sort of description should be included with the exhibition and/or availability of 3D models online (question 12, Figure 3). They also advocated (n = 64%) that online access should require registration and login access (question 10, Figure 3), aligning with the aggregation of 3D models dissemination to education and research. Although many know that online sharing platforms require an account setup, models may be uploaded without context. For example, MorphoSource, an online archive for digital data access to 3D models, requires users to set up an account to upload and/or access models, descriptions, and metadata from scholars, researchers, and museums [65]. However, the level of information uploaded into MorphoSource varies depending on how much information users share. In addition, several levels of access restriction exist, including if users do not own 3D models' copyright, which grants custodian institutions the power of decision over 3D data access requests [65]. Regardless of access limitations, it is important to note that 3D models of human remains can only be uploaded into MorphoSource if associated with permission records [51].

Many researchers and institutions view data contextualization as a best practice [28,38,52]. Decker and Ford [50] have reinforced that, when handling sensitive data, security via password-locked devices in secured areas ought to be established in the initial states of a project. This should be incorporated into any well-thought data management plan and to thought regarding logistic issues involving repository costs, short- and long-term data maintenance, and data access—who decides and who can have fair and equitable access to 3D data [21,66]. Ideally, researchers should seek training in data security, regulations, laws, and ethics [50]. The implementation of limited access and/or data access exclusion/blocking by those not complying with guides and regulations should be further considered [21]. Additionally, data repositories should be selected with care as private for-profit company servers may not share the same ethical considerations as scholars, museums, universities, and custodians [21].

4.3. Ethical Consideration of the Creation, Study, and Dissemination of Three-Dimensional Replicas of Human Bones

Ethical discussions concerning the 3D digitalization of human bones are recent e.g., [18,21,24,25,27–29,42,43,51,52,66,67]. Previous codes and guidelines on the matter have not included public reflections, focusing on scholars and scholarly work. This study represents an initial step in understanding public perceptions in Portugal and a way to promote a more inclusive discussion on the matter. It is necessary to remember that, although the remains are highly employed in science, they are first contextualized within and belonging to communities. Furthermore, there may be multiple opinions even within a country, as many countries are composed of a larger mosaic of communities (e.g., religion, ethnic affiliations).

There has been a worldwide effort to promote more respectful and dignified treatment of human remains and associated material (e.g., images, data), but they need to expand the care towards human remains, as well as their digitalized and printed versions outside of the UK and US. For example, BABAO [29] recommended avoiding sensationalist reporting and presenting justifications for the display of a 3D model alongside an ethical statement on data sharing. Meanwhile Schug et al. [21] proposed adding an educational disclaimer to the public about the ethics of printing 3D models available online, as well as a CC BY-NC (non-commercial) license. Also, researchers must consider the origin of the osteological remains being digitalized, especially if their provenance was rooted in racial and colonial ideologies [21]. Therefore, the contextual documentation of the remains and 3D models is essential for researchers to decide whether to access and use 3D models of unethically retrieved human remains. The same applies to the access and use of real bones incorporated into osteological collections. Even in cases where individuals are willing to have their

skeletons digitized after death (see question 6) the issue of consent needs to be considered. A person may consent to have his/her remains digitalized, but not disseminated, or modified. Hence, any informed consent should specify the manner in which the digitalized remains may be used, including allowed distribution, remix, adaptations, or being built upon. The alternative is to limit the use to a sole purpose.

Osteological human remains lacking context are problematic, as their identity and origin are unknown, making it difficult to access their provenance, and thus also difficult to consult with descendants [21]. Furthermore, it is also impossible to ascertain the circumstances in which those remains were exhumed/accessed/obtained. This need for context is further reinforced when faced with the commodification of human remains online—not only real bones [68–70] but their digital replicas.

Commercialization of 3D Models

Commercialization of human remains is an ongoing practice, which has expanded considerably via social media [68–73]. Would commercializing 3D models of human bones help curb the sale of human remains? Moreover, is it ethically acceptable? Sketchfab (https://sketchfab.com/, accessed on 9 June 2022) is one of the best-known 3D modeling platforms to share, publish, buy and sell 3D content. It was not initially built for academia and research but art, architecture, and gaming purposes [53]. The commercialization of 3D models via Sketchfab is widely available to anyone. The platform provides assessment (consultation and selling) of a comprehensive profile of 3D models of bones: some belong to identified individuals (e.g., individual's age at death and sex is stated), while others not; some models have contextualized information, most have not. The reference to the acknowledgment and/or permission of commercialization of the replicas is also scarce, not to say absent. Other models have been uploaded by higher education institutions and museums, mainly for educational purposes, as models are not downloadable and contain annotations explaining bone landmarks and other features. Most importantly, the general lack of contextual information found in Sketchfab can be problematic for research and education practices since it may bias data interpretation and adequate assessment of the remains and because it raises ethical concerns as it is impossible to assess the circumstances of their acquisition.

Schug et al. [21] (p. 226) considered that "human remains are part of a public trust, never to be used for advertising or commercial purposes. If there is a monetized project to disseminate remains, the endeavor must be nonprofit, and the money should be used to facilitate the teaching, research, and outreach mission of the institution and its relevant members, students, faculty, and staff." However, this continues to be "selling." On the other hand, 3D models freely available online for research or educational purposes can potentially be mishandled by users, as models can be downloaded and sold in other repositories without institutional consent [51]. It can also give rise to other ethical issues related to ownership (if applicable) and curation of the 3D replicas, their commercialization without consent from all those associated with the replica, and original remains that gave origin to the replica. This debate is only in its infancy, and to the best of our knowledge, no law in Portugal addresses the commercialization of 3D models/prints of human bones, nor is it being discussed in legal domains.

5. Conclusions

Visualizing 3D models of human skeletons is becoming widespread in Portugal, although most survey respondents were not involved in their production and/or distribution. The digitalization of human skeletons may be associated with a higher focus on research not associated with 3D technology, especially in biological anthropology. Most of the models visualized were from individuals who had been deceased for over 100 years and came from educational and research associated platforms. Portugal residents positively responded positively to the creation, use, and dissemination of 3D digital models of human bones, if associated with some requirements. Most participants held the view that access to online

models should be walled behind registration for research and teaching. Contextualization of 3D models was also perceived to be paramount by the participants. The digitalization of individuals deceased for less than 100 years was not viewed as problematic as long their identity, if known, was not revealed. Opinions were split on the 3D model status, either as an object or a bone. However, significantly more women than males, most in specialized occupations, perceived models as having a similar status as a bone. However, one cannot assume that this is the reason why women had a lower visualization rate of 3D models when compared to men: this causal inference was not addressed in the questionnaire. When planning research that involves the creation of 3D replicas of human bones, researchers and institutions should envision ethical concerns, especially on the online accessibility of those models, as those derive from deceased humans and thus deserve respect. The results reflect public opinion, which may be a great support for researchers and scholars implementing ethical practices dealing with 3D models of human bones; however, it can be argued that this may be better applicable to the Portuguese scientific community. Therefore, this study should be expanded worldwide, engaging other countries in this discussion, since disseminating 3D models is a worldwide practice. Future directions may involve understanding which contexts relate to 3D models of human bones that have been shared and/or commercialized on online platforms and undertaking the survey again after a 10-year gap in order to register potential opinion changes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/heritage5030085/s1: Survey's questions.

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Informed Consent Statement: An ethical review was not considered necessary, since the participation was voluntary, and anonymity was warrantied to all participants. Also, the questionnaire informed all participants on the data use, and context of the research, which was developed under the scope of a funded project subjected to peers evaluation—Shaping voids and building bridges: towards an ethic and legal framework and societal approach to Portuguese human identified skeletal collections (HISC) (REF-FCT IF/00127/2014). Any ethical issues were addressed within the proposal description, and deemed addressed by jury panel. Facebook group administrators had at all times the power to eliminate our survey post if they deemed it inappropriate for their followers. Once a survey post was deleted by a Facebook group administrator, we stopped posting the survey on that group.

Data Availability Statement: The dataset of responses used in this manuscript will be made available in the Zenodo Open Data Repository with reference Alves-Cardoso, Francisca, & Campanacho, Vanessa. (2022). Database publication-To Replicate, or Not to Replicate? The Creation, Use, and Dissemination of 3D Models of Human Remains: A Case Study from Portugal [Data set]. Zenodo. https://doi.org/10.5281/zenodo.6802255.

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Alves-Cardoso, Francisca

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