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Research on 3D Measurements used for Archaeological Materials in Japan

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Abstract— This study reviews our research in Japan on examining the 3D measurement method and the accuracy of 3D models. Recently, 3D measurements and the data have been used in various archaeological situations (e.g., recording at excavations, preservation, repairs, education, and research analysis). In particular, SfM/MVS photogrammetry has received increasing attention because it is versatile and inexpensive. However, there are some issues. First, a systematical way to construct 3D model by SfM/MVS photogrammetry has not been established yet, even though various conditions can be set. Considering the sustainability and convenience of 3D data in the future, it is preferable to investigate the degree of effect on 3D model in different conditions and settings (e.g., the number of photos, the kind of camera, the photographing setting of cameras). Second, while archaeologists have classified relics by detail types, there still is a lack of verification between methods. Third, the analysis results of 3D data and previous studies should be compared. We measured and compared one style of jar (Ongagawa style) and human skeletal remains by SfM/MVS and used laser measurement to resolve the first and second issues. We first compared the same materials measured under different cameras conditions and settings. Having applied the SfM/MVS methods of this study, there was only a small difference in the quality of models created by the different methods. Second, we compared the SfM/MVS models with laser models. The result was that the differences between models are little, which shows that SfM/MVS models, under certain conditions, are not inferior to laser measurement models.

Keywords— the method of 3D measurement; potteries; human skeletal remains; Japan

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I. Introduction

Recently, three-dimensional (3D) measurements and data have been used in various archaeological situations. In particular, Structure-from-Motion/Multi-View-Stereo (SfM/MVS) photogrammetry has received increasing attention. SfM/MVS, which requires a camera, software, and PC to create a 3D model, is inexpensive than the other 3D measurement. In addition, it is highly versatile for materials. By changing the camera lens and settings, archaeological materials of various colors, materials, and sizes can be modeled in 3D with color. Therefore, SfM/MVS and 3D models have been used to record excavations, preserve and repair archaeological remains, educate museums and schools, and research. However, there are some issues with ensuring the accuracy of 3D models created using SfM/MVS.

This study reviews our research in Japan on examining 3D measurement methods and the accuracy of 3D models. First, I will describe the background of 3D measurements in Japanese archaeology. Subsequently, I will present our research as one of research to resolve these issues. The measurement materials comprised a jar (Ongagawa style) and human skeletal remains. This is because of the similarity in basic shape, color tone, and other characteristics, alongside the large number of materials.

In our research, we first constructed 3D models from the same materials under different camera conditions and settings, and then compared the models. This was performed to investigate whether the degree of difference in the camera-setting conditions affects the constructed 3D model. Second, we created 3D models of the same materials using SfM/MVS and laser scanning and compared the SfM/MVS models with the laser models. This was performed to examine how the SfM/MVS set to obtain models of similar or better quality compared to laser scanning.

As described in the next section, while 3D measurements have various validities, the quality of the model is an issue requiring examination. This research promotes sustainable data accumulation.

II. Background of 3D measurements and data in Japanese archaeology

A. *Utilizing 3D measurement*

In Japan, there are approximately 9,000 excavations each year, most of which are conducted for development and construction [1]. Each prefecture, city and town has archaeological specialists as official staff who excavate and record the archaeological findings. Basically, two-dimensional records, such as surveyed drawings and photographs, are taken, published, and shared as official reports in a certain year. A vast amount of archaeological 2D records have already been accumulated in Japan. In this situation, 3D measurements and data have received increasing attention in recent years.

At some excavation sites, several surveyed drawings and photographs must be taken. If time and manpower are limited, recordings using 3D measurements may save time and effort. Additionally, 3D data can be used to share more realistic situations and visual information among staff and/or citizens.

By constructing 3D models and providing data to museums and other institutions, accessibility to materials can also be ensured. Many people can view, enjoy, and observe them on a website or via devices, especially if the material is difficult to transport to a museum, if it is a delicate material to display for a long time, and/or if it is difficult to see the reverse side of the material when placed in a fixed position [2] [3].

In the emergency cases, 3D data can be useful. A lot of disasters occur in Japan, and some areas are affected annually. Archaeological materials are no exception. By obtaining 3D data before disasters occur, the damaged parts of archaeological materials can be identified from the data, to be restored. For example, in Kumamoto Prefecture, the stone wall of Kumamoto Castle partially collapsed because of a massive earthquake in 2016. However, the 3D model was constructed from photographs taken before the earthquake, the original positions of the collapsed stones were determined by analyzing the 3D data, and the stones were restored or reconstructed [4]. In addition, we can quickly prepare to preserve and restore materials after disasters if the damaged or destroyed conditions of the materials can be shared. The 3D data of damaged or destroyed archaeological materials are also important for education on disaster prevention [5].

As an activity of civic participation, Hida City has acquired 3D data of local archaeological artifacts with citizens to cultivate interest in archaeological artifacts of the city and cultivate awareness of cultural properties' protection [6].

In research, by creating 3D data, we can choose other analyses to compare materials. It is possible to analyze whether the molds of different clay artifacts such as roofing tiles, are the same. Differences in shape, that are similar in typology can also be analyzed quantitatively, for example, in pottery [7].

Thus, 3D measurements and data have recently been used extensively for various applications in Japanese archaeology. SfM/MVS has been used in many cases. Archaeological materials vary in size, shape, and color. Therefore, one of the important points is that the measurer can change the settings to suit the respective object.

B. Problrems regarding the quality of 3D data

This study has several limitations. First, a systematic method for constructing a 3D model using SfM/MVS has not yet been established because of the possible variable settings. In most cases, each person measures the material by SfM/MVS using their own method. Although it is necessary to establish a way according to the characteristics of the materials, it is also necessary to examine the degree of influence on the 3D model by changing the settings.

Second, there are other 3D measurements, although SfM/MVS is often used. However, there is still a lack of verification of these methods. Therefore, it is necessary to investigate the difference in the quality of 3D models using different methods.

Third, the analysis results of the 3D data and previous studies should be compared. Originally, the main recording method was 2D, and numerous 2D records have been acquired and published in Japanese archaeology. If the quality of the 3D model is suspected, as described above, it is important to examine whether the 3D data reach the quality standard required for archaeological studies, by comparing the results of previous studies, rather than being overconfident that the latest technology will suffice.

These issues are related to the aspects of records and research. It is enough to place texture on the 3D model if the aim of the 3D measurement and the data are to enjoy being observed. However, if we focus on research and analysis using a 3D model, not ensuring its enough quality may become a problem in the future. In addition, this type of equipment is not necessarily sustainable. It is unclear how long it will be available for, because of rapid technological innovation. Several studies have indicated these quality issues [8].

III. RESEARCH ABOUT QUALITY OF 3D DATA

A. Setting of SfM/MVS

SfM/MVS is a method for constructing 3D models by analyzing photographs. Mainly, there are two ways to take photographs. One is the person go around artifacts and takes photographs, and the other is the artifact on the turntable is rotated. Some studies on SfM/MVS have attempted to automate the second method because of the creation of a uniform mesh of 3D models [7] [9][10].

For example, Reference [7] used the photo studio set, the FOLDIO 3 by ORANGEMOKIE (https://orangemonkie.com/) . The set has lights, a portable photo studio, and a turntable that connects a camera to a mobile phone (Fig. 1). Once the dedicated application is downloaded and set up, the camera can capture pictures by turning the turntable automatically. The total number of photographs captured was approximately 120-200. The cameras were set that photography angles were from 5 to 6, the ISO ranges from 100 to 200, the F number ranges from 13 to 18, and the shutter speed ranges from 1/100 to 1/40. Size information was obtained using the Metashape marker (https://www.agisoft.com/) on a turntable. The 3D model constructed ‘high’ from ‘Align Photos’ to ‘Build Mesh’ with Agisoft Metashape 1.6.5, except checking to obtain data on field surveys *(Fig.2)*.

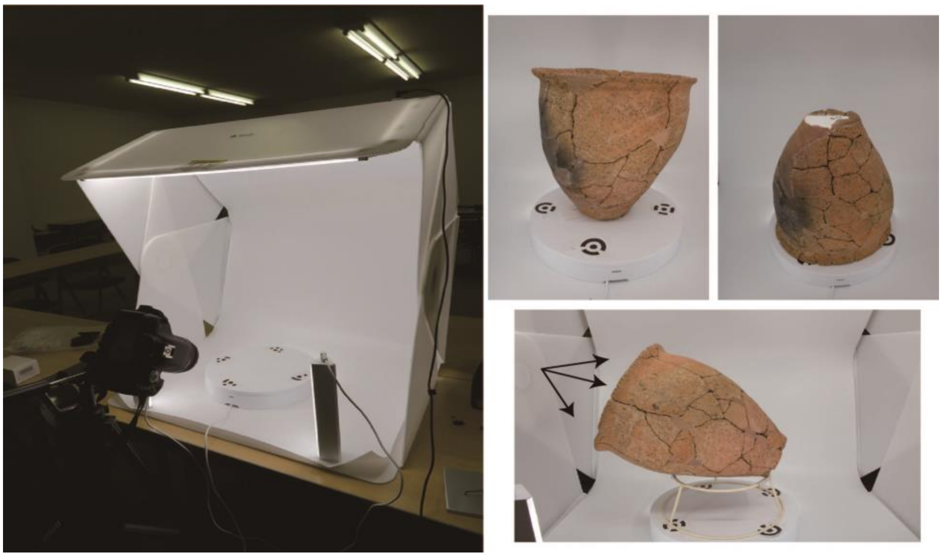

Fig.1. The Setting of the photo studio and photography angles*[10]*. In addition to the equipment mentioned in the text, a tripod and a gray card are used. The jar of Ongagawa style in Tamura sute is stored by Kochi Prefecture Board of Education.

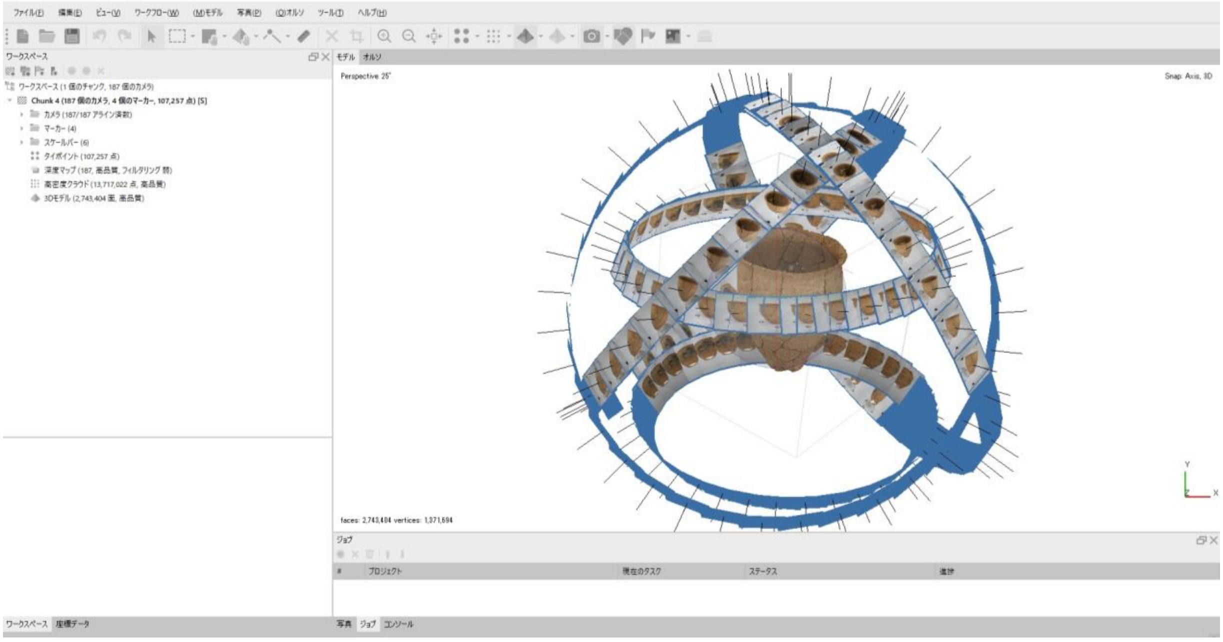

Fig.2. Align Photos on Metashape. The jar of Ongagawa style in Tamura sute is stored by Kochi Prefecture Board of Education.

This research constructed 3D models from the same materials using a camera and compared different settings. As a result, the differences in the above settings between the models were negligible.

B. Comparing the SfM/MVS and Laser models

Reference [7] and [10]compared the SfM/MVS models with laser models [7][10]. The SfM/MVS settings and materials were the same as those described above.

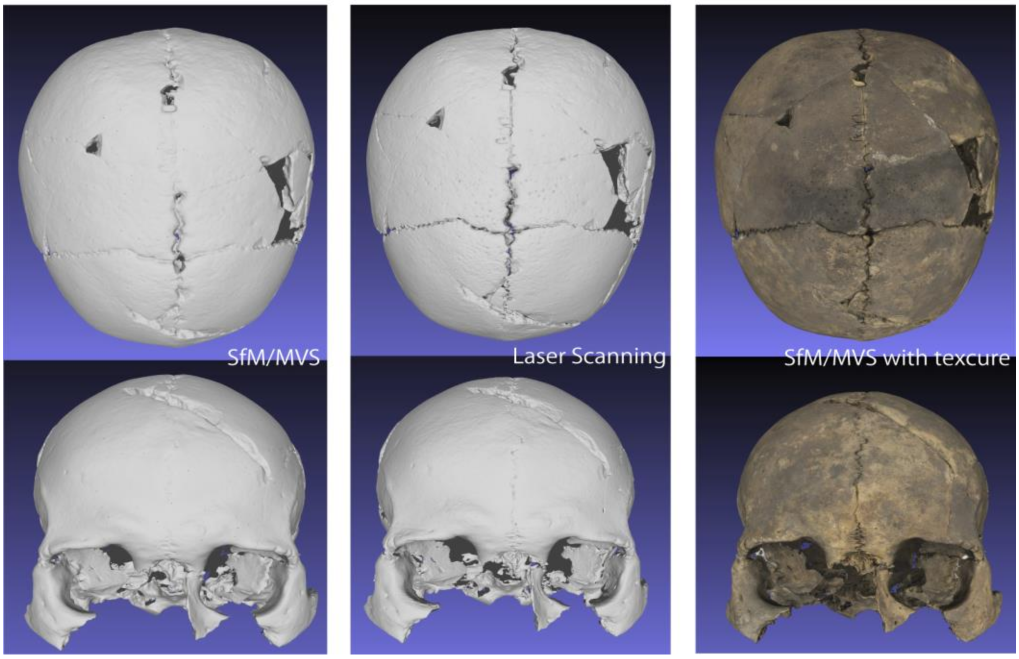

Fig.3. Models of SfM/MVS and Laser scaning *[10]. There is not much differences in appearance between methods. The human skull of odake shell midden is stored by Toyama Prefectural Center for Archaeological Operations.*

Fig.4. Compared results of the jar with GOM Inspect. This figure show that smaller differences is green color and bigger differrences is red color. This material has bigger differences on its tip and crack. The jar of Ongagawa style in Tamura sute is stored by Kochi Prefecture Board of Education.

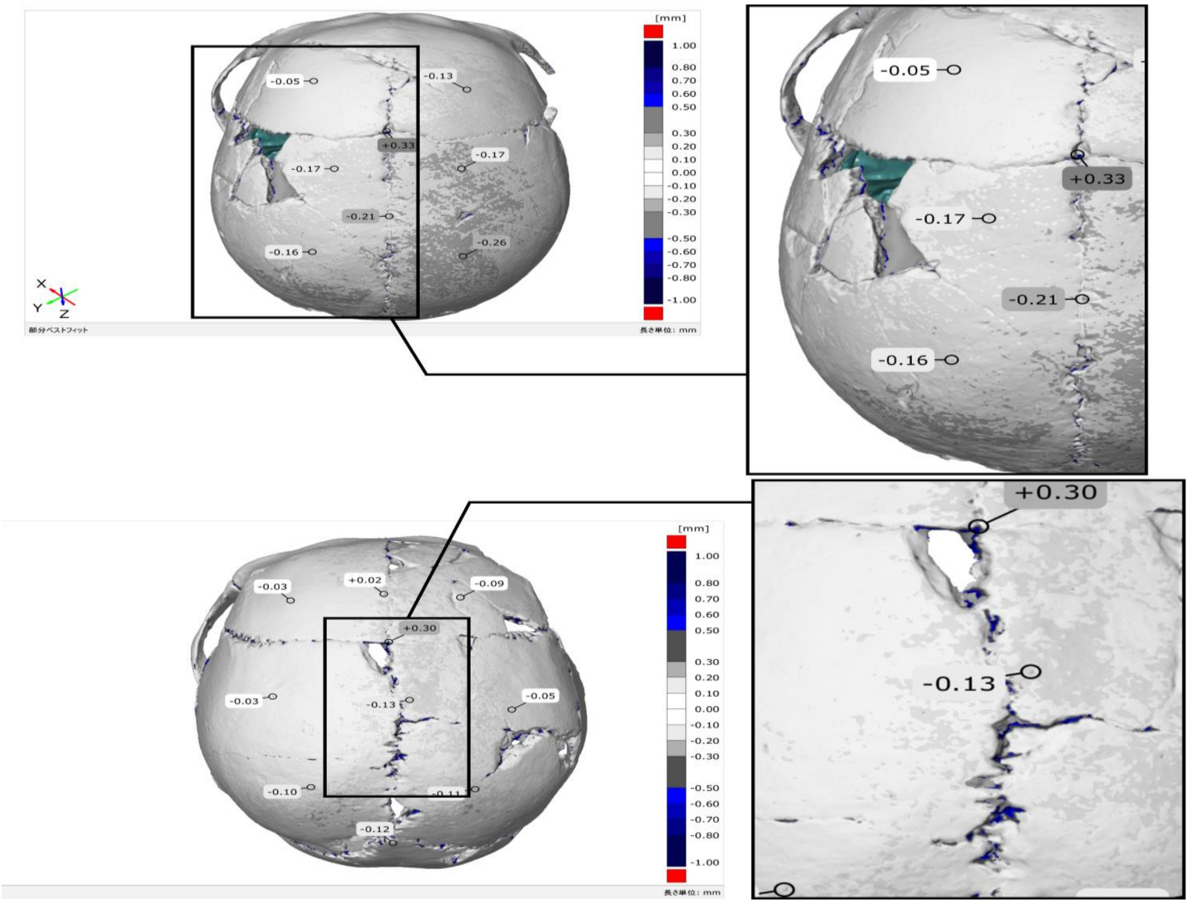

Fig.5. Compared results of human skull with GOM Inspect and the part of bigger differences *[10]*.

Laser scanner used was with the Creafrom HandySCAN BLACK™ | Elite. It is originally used for design and measurement productions. The model accuracy of the scanner is 0.025 mm (https://www.creaform3d.com/). Although the equipmentis high cost and overperformance on archaeology, the model is constructed quickly. Reference [7] and [10] adopted 0.2mm accuracy of the scanner due to obtain data of more materials on field surveys.

They compared each model with GOM Inspect (https://www.gom-inspect.com/). The software was originally designed to inspect industrial products.

The results showed that the differences between models as a whole shape were negligible, which showed that SfM/MVS models, under certain conditions, were not inferior to laser measurement models *(Fig. 3 and 6)*. However, differences were large in some parts, for example, cracks and parts inside eye sockets *(Fig. 4 and 5)*. If we need information of these parts from SfM/MVS models, it is better to modify the total number of photographs or camera setting.

IV. Conclusion

The results of these studies will be useful for validating the settings and equipment used in Japanese archaeology. In addition, these studies have shown that under certain conditions, it is possible to create models using SfM/MVS that are comparable to laser measurements.

The choice of equipment, setting, method, etc., depends on the shape of the archaeological material. However, in the case of archaeology, especially in Japan, there is a large accumulation of archeological material type classifications. Therefore, it may be preferable to establish a 3D measurement method based on these style classifications. Future research can promote the accumulation of sustainable and stable data.

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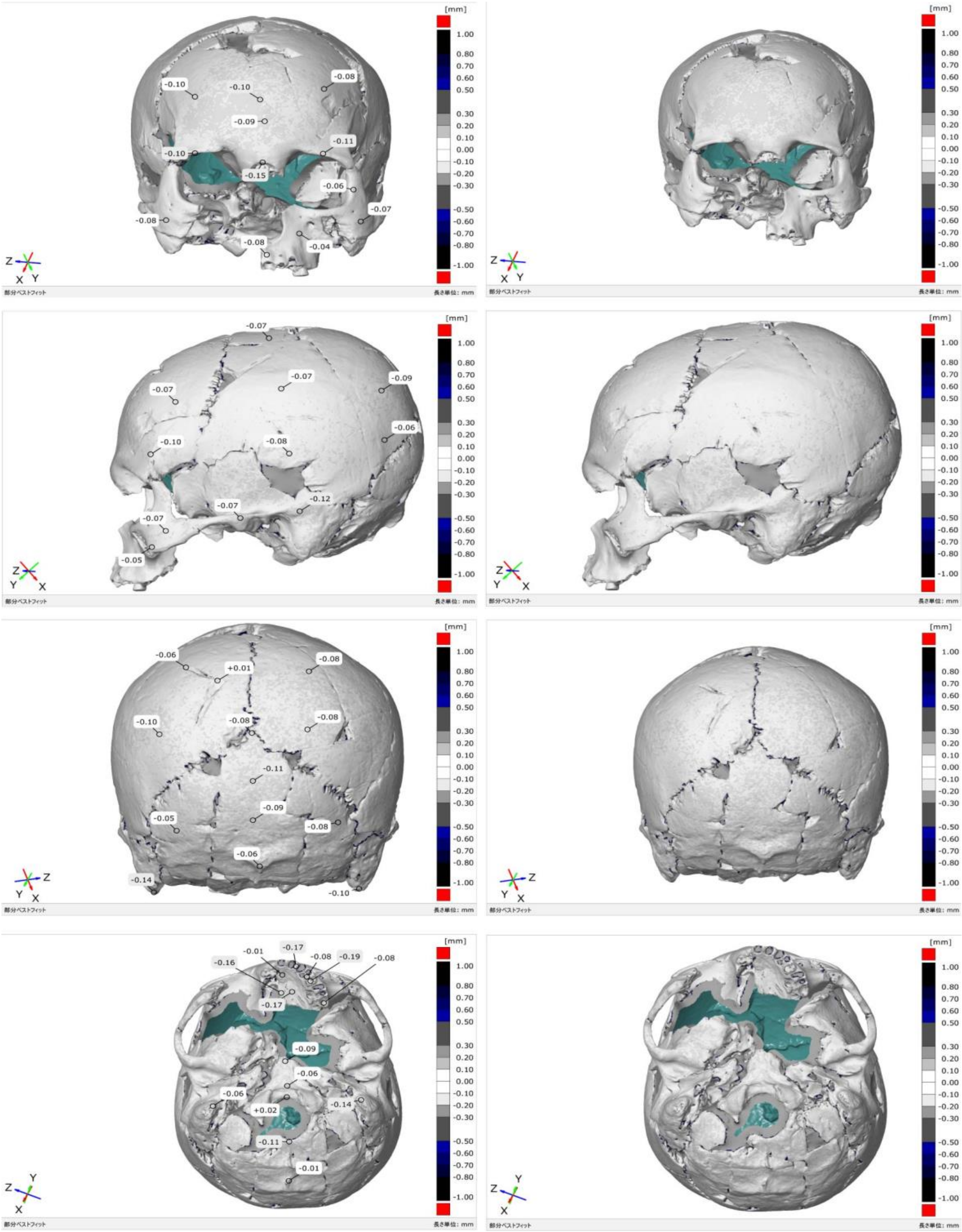

Fig.6. Compared results of the human skull with GOM Inspect *[10]*. This figure show that smaller differences is light color and bigger differrences is dark color. This material has bigger differences on cracks. The human skull of odake shell midden is stored by Toyama Prefectural Center for Archaeological Operations.

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