TECHNICAL REPORT

Three-dimensional visualization of composite fillings for dental identification using CT images

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Objectives: This study aimed to discriminate between enamel and composite resins by differences in Hounsfield units shown on 16 section multidetector CT (MDCT) images taken of unidentified bodies.

Methods: First, we determined the Hounsfield units of composite resins in 15 extracted human teeth. We then filled a single cavity prepared in each of the teeth with one of five different types of composite resins, and scanned the teeth using our routine post-mortem CT protocol for the head and neck. Obtained data were transferred to a radiological workstation and reconstructed. Furthermore, post-mortem CT images of the head of three unidentified bodies were reconstructed in the same manner.

Results: Four types of composite resins containing radio-opaque fillers showed a constant value of 4000 HU, and one radiolucent composite resin showed values in the range of 660–800 HU in the extracted teeth. Pixels at 4000 HU indicated that the composite resins were selected and visualized as three-dimensional colour images. Composite resins could be visualized on reconstructed images of the three unidentified bodies, and the sites visualized matched those noted on the forensic dental charts.

Conclusions: Discriminating enamel and composite resins containing radio-opaque materials was difficult because of their similar Hounsfield unit values. However, we did succeed in visualizing the composite resins despite limitations of the CT scale. CT reconstructed images can contribute to dental identification, particularly in cases where it is difficult to detect composite resins on external investigation, and these images can be prepared during routine dental identification work.

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Introduction

Teeth have four or five surfaces each and can undergo a variety of dental treatments. Therefore, post-mortem dental information is one of the most reliable methods for personal identification. However, incorrect post-mortem dental charting due to overlooked dental treatments will result in misidentification. Composite resins are one example of treatments that can be overlooked. These resins are often used clinically as aesthetic filling materials, and recently tooth-coloured materials have been used to further improve aesthetic

outcome.¹ Generally, small or shallow cavities are filled with composite resins, and they can be overlooked in dental charting in cases of rigor mortis, since the mouth cannot be opened sufficiently to note all restorations with tooth-coloured materials.

To avoid such oversights, many studies have used ultraviolet irradiation or radiophotography to identify and discriminate composite resins. However, scintillation does not occur in some composite resins, which means that they cannot be detected by ultraviolet irradiation. Moreover, radiophotographs provide only two-dimensional information, making it difficult to identify filled areas in three dimensions. Post-mortem CT imaging is a useful tool for forensic diagnosis in general, and it is now being introduced into the field of forensic odontology.^{2–4}

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If composite resins could be visualized accurately on reconstructed CT images in cases where it is difficult to detect them by external investigations alone, this would aid more accurate dental identification.

To this end, in this study, we examined whether composite resins in extracted human teeth could be visualized using a radiological workstation that is used in our routine work. We then applied the method to practical personal identification in the cases of three unidentified bodies.

Materials and methods

We aimed to identify the presence of composite resins in 15 extracted human teeth (2 incisors, 2 premolars and 11 molars) on the basis of their Hounsfield unit values on CT scans. A single cavity was prepared in each of the teeth according to Black's classification of caries lesions: a Class III cavity in each of the incisors, a Class V cavity in the premolars, and a Class I cavity in the molars.⁵ Each cavity (approximately 2 × 3 mm) was filled with one of five different types of composite resins: Clearfil Majesty™ LV (Kuraray Medical, Tokyo, Japan), Clearfil AP-X™ (Kuraray Medical), MI FIL (GC, Tokyo, Japan), Filtek Supreme Ultra™ (3M ESPE, Tokyo, Japan) or SOLARE (GC). With the exception of SOLARE, the composite resins used in this study contained radio-opaque fillers. To mimic the jaw bone and soft tissue which can attenuate X-rays at 150–200 HU, all of the teeth were embedded in anhydrite (Elite Rock®; Zhermack Technical, Badia Polesine, Italy).^{6,7}

All examinations were performed with a 16 section multidetector CT scanner (Eclos; Hitachi Medical, Tokyo, Japan) and according to our routine post-mortem CT protocol for the head and neck. The protocol consisted of the following parameters: tube voltage, 120 kV; tube current, 200 mAs; rotation time, 1 s; collimation, 0.6 mm; micro-focus; reconstruction thickness, 0.6 mm; reconstruction interval, 0.3 mm; reconstruction kernel, 41 (bone). Data obtained in all examinations were transferred to a CT workstation (Synapse Vincent; Fujifilm Medical, Tokyo, Japan).

For the purpose of enhancing the border between the enamel and the composite resins, the images were displayed without pixel interpolation. As composite resins containing radio-opaque filler have more radio-opacity than enamel, the cut-off value was set to 4000 HU (the maximum Hounsfield unit value of our workstation) in order to select pixels indicating the composite resins. The volume data obtained were superimposed on the original CT image and the location of the composite resin fillings was displayed on the same three-dimensional (3D) images. Furthermore, CT images of the head of three unidentified bodies were reconstructed in the same manner.

Results

The four types of composite resins containing radio-opaque material that were filled in 12 extracted teeth

had a constant value of 4000 HU because the maximum Hounsfield unit value of our workstation was 4000 HU. The one radiolucent composite resin that was filled in three extracted teeth showed values in the range 660–800 HU. Enamel showed values in the range 3350–3850 HU, and dentin in the range 1790–1900 HU. While it was easy to make a clear distinction between the radiolucent composite resin and enamel because of their dissimilar Hounsfield unit values, it was difficult to determine the boundary between the composite resins containing radio-opaque fillers and enamel in the images because of their close Hounsfield unit values. We decided therefore to display in colour pixels at 4000 HU, which would represent the composite resins on multiplanar reconstruction (MPR) images for the cut-off value. Displaying the images without pixel interpolation made it as easy as possible to select the coloured pixels. Selected pixels on the MPR images were reconstructed as volume-rendered (VR) images, and the composite resins could be visualized on the 3D images (Figure 1). Composite resins could also be visualized on the reconstructed CT images of the three unidentified bodies and the sites of the resins matched those noted on the forensic dental charts.

Case 1

A highly decomposed body with exposed bones found on the seashore in supine position. Composite resin fillings at the cervix of the left first and second mandibular premolars could be seen macroscopically (Figure 2a). These composite resins were visualized on the 3D CT images (Figure 2b). In the mandible, both the left and the right central incisors and the left canine were missing, and the left first and second molars had metal inlays. The right second premolar to second molar had a metal frame bridge fitted. Using our method, the composite resins fillings in the cervix of the teeth that could be seen macroscopically were confirmed. Although streak artefacts resulting from

Figure 1 (a) Extracted tooth that was filled with composite resins at the approximal surface. (b) Areas of more than 4000 HU were coloured on multiplanar reconstruction images (MPR). (c) Selected pixels on the MPR images were reconstructed as a volume-rendered image

Figure 2 Composite resin fillings at the cervix of Teeth 34 and 35. (a) Left lateral aspect; (b) volume-rendered image. Composite resin filling in the cervix was not affected by streak artefacts

metal dental materials decreased the 3D image quality, reconstruction of the composite resin fillings in the cervix was not affected by these artefacts.

at this site on the 3D CT images (Figure 3b), and the reconstructed CT images were helpful for describing the area of composite resins in the dental chart.

Case 2

A drowned body found on the seashore in supine position. Composite resin fillings could be seen macroscopically in some of the maxillary and mandibular teeth. The right lateral maxillary incisor had a temporary composite resin filling that appeared to have been used for aesthetic purposes for root canal treatment (Figure 3a). Although in general the border between an aesthetic dental filling material and the labial surface of a maxillary anterior tooth is difficult to recognize, the composite resins were clearly visualized

Case 3

A drowned body found on the seashore in prone position. A metal crown could be seen on the left second mandibular premolar. Macroscopically, there seemed to be attritions on each tooth and some excavations into the dentine filled with composite resins; however, since the surfaces of the excavations were smooth and glossy, it was difficult to ascertain whether there were in fact composite resin fillings present or not. The CT images clearly identified them as composite resin fillings. Streak artefacts resulting from

Figure 3 Tooth 12 had a temporary composite resin filling that was considered to be for aesthetic purposes. (a) Frontal aspect; (b) volume-rendered image of palatal surface. In Tooth 12, the border of the composite resin filling with the tooth was difficult to identify. Reconstructed three-dimensional CT images were useful for describing the area of the composite resins on the dental chart

a

b

c

d

Figure 4 Composite resin fillings can be seen in some maxillary and mandibular teeth; there is a metal crown on Tooth 35. (a) Occlusal aspect of the maxilla; (b) occlusal aspect of the mandible; (c) volume-rendered image of the maxilla; (d) volume-rendered image of the mandible. We could visualize the composite resin fillings in the maxillomandibular area. Streak artefacts resulting from the metal crown did not affect the visualization of composite resins

the metal crown did not affect the visualization of the resins (Figure 4).

Discussion

Most composite resins contain radio-opaque fillers in order that the condition of the filling can be determined or secondary caries can be detected in the future.⁸ Jackowski *et al*⁹ reported that hybrid composites were radio-opaque in the range ~11 200 to ~14 000 HU, that dentine covered the range 1717–2130 HU, and that enamel reached a mean of 4350 HU. In this study, we examined the Hounsfield unit values of one radiolucent

and four radio-opaque composite resins. The radiolucent composite resin (660–800 HU) was easy to distinguish from enamel because of their dissimilar Hounsfield unit values. By contrast, the composite resins containing radio-opaque fillers showed a constant value of 4000 HU on the reconstructed CT images, which was the limit of our radiological workstation, and thus enamel and these composite resins showed close Hounsfield unit values. The radiological workstation used in our study has a standard maximum window of 4000 HU. Jackowski *et al*⁹ reported that the teeth were scanned on a dual-source CT scanner (Definition; Siemens Medical, Erlangen, Germany) using ultra-high-resolution settings (z-Sharp™ technology).

Raw data acquisition 120 kv, 182 mAs, 12×0.3 -mm collimation, rotation time 1 s, pitch 0.9 and a 50 mm field of view image reconstruction in a 512 matrix resulted in a voxel size of $0.1 \times 0.1 \times 0.24$ mm (U70 reconstruction kernel and extended CT scale). On our standard workstation, it is difficult to distinguish all dental materials on a standard CT scale within 4000 HU, as metal materials show the same values as composite resins. However, by selecting pixels that indicate composite resins on the MPR images, we could display only the composite resins on the VR images. By displaying images without pixel interpolation, it was possible to select each pixel. Although the quality of the images was degraded, we could gain sufficient information from these images for dental identification. Enamel also showed some pixels at 4000 HU, but the pixels were scattered and few in number and thus did not affect discrimination. Existence of metal dental materials such as crowns or bridges will become streak artefacts which affect Hounsfield unit values and result in incorrect Hounsfield unit values.¹⁰ With our method, it was not always easy to obtain precise dental information from the Hounsfield unit values in order to identify the type of dental material because we could not

obtain more detailed information about the tooth-coloured materials because of the CT scale limit.^{11,12} However, we did succeed in visualizing the composite resins despite this limitation to 4000 HU. Given that not all composite resins will show up at 4000 HU on reconstructed images, the method we describe should not be used as the sole procedure for identifying whether composite resin fillings are present or not; however, it should function well as an adjunct method for dental identification.

In conclusion, the 3D CT reconstructed images created have value as an adjunctive method for dental identification when combined with external investigations, and these images can be prepared during routine dental identification work. In sudden and unexpected disasters, these reconstructed images could be compared with ante-mortem radiological data and contribute to large-scale personal identification efforts.

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