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Technical Note

Complex layered dental restorations: Are they recognizable and do they survive extreme conditions?

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ABSTRACT

Recent research has shown that restorative dental materials can be recognized by microscopy and elemental analysis (scanning electron microscopy/energy dispersive X-ray spectroscopy and X-ray fluorescence; SEM/EDS and XRF) and that this is possible even in extreme conditions, such as cremation. These analytical methods and databases of dental materials properties have proven useful in DVI (disaster victim identification) of a commercial plane crash in 2009, and in a number of other victim identification cases. Dental materials appear on the market with ever expanding frequency. With their advent, newer methods of restoration have been proposed and adopted in the dental office. Methods might include placing multiple layers of dental materials, where they have different properties including adhesion, viscosity, or working time. These different dental materials include filled adhesives, flowable resins, glass ionomer cements, composite resins, liners and sealants. With possible combinations of different materials in these restorations, the forensic odontologist is now confronted with a new difficulty; how to recognize each individual material. The question might be posed if it is even possible to perform this task. Furthermore, an odontologist might be called upon to identify a victim under difficult circumstances, such as when presented with fragmented or incinerated remains. In these circumstances the ability to identify specific dental materials could assist in the identification of the deceased. Key to use of this information is whether these new materials and methods are detailed in the dental chart. Visual or radiographic inspection may not reveal the presence of a restoration, let alone the possible complex nature of that restoration. This study demonstrates another scientific method in forensic dental identification.

1. Introduction

Forensic Odontology is a "branch of dentistry that is involved with the examination and evaluation of dental evidence, which may then be presented in the interests of justice" [1]. Forensic odontologists are regularly called upon to carry out dental identification on unknown deceased individuals in coronial cases or in mass fatality incidents, also known as disaster victim identification. Identification of incinerated human remains can be a daunting and intensive task, especially where newer restorative dental materials and complex layered dental restorations that can replicate tooth structure and colour. Recent research [2–4] has shown that restorative dental materials can be recognized by microscopy and elemental analysis (scanning electron microscopy/energy dispersive X-ray spectroscopy and X-ray fluorescence; SEM/EDS and XRF), however it is not known whether individual restorative dental materials could be identified in a complex layered dental restoration in incinerated teeth. This project was designed to determine if it is possible to identify these complex layered dental restorations using SEM/EDS technologies.

2. Materials and methods

Six disks of restorative dental materials, 1 cm in diameter, were prepared and cured according to manufacturers' instructions. The restorative dental materials that were used are as listed in Table 1.

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Table 1
List of dental materials and manufacturer details used in this study.

Product name	Manufacturer
GC Fuji IX GP	GC Corporation (Tokyo, Japan)
Grandio SO	VOCO GmbH (Cuxhaven, Germany)
Grandio Heavy Flow	VOCO GmbH (Cuxhaven, Germany)
Tetric EvoFlow	Ivoclar Vivadent (Amherst, NY, USA)
Tetric EvoCeram	Ivoclar Vivadent (Amherst, NY, USA)
Ultrablend Plus	Ultradent Products Inc (South Jordan, UT, USA)

Table 2
List of combined dental materials.

Product name (one)	Product name (two)
Grandio Heavy Flow (VOCO GmbH)	Grandio SO (VOCO GmbH)
Tetric EvoFlow (Ivoclar Vivadent)	Grandio SO (VOCO GmbH)
GC Fuji IX GP (GC Corporation)	Tetric EvoCeram (Ivoclar Vivadent)
Ultrablend Plus (Ultradent Products Inc)	Tetric EvoCeram (Ivoclar Vivadent)

Manufacturer details can also be found in this table. Four separate areas on each disk were analyzed and the average of the elemental composition was taken. These data served as controls for recognition of the materials.

Extracted teeth were obtained from SUNY (State University of New York) at Buffalo School of Dental Medicine. The teeth were removed due to periodontal disease, gross decay or third molar impaction. Those with gross decay were not used in this study.

The teeth were prepared by one of the authors (A.S.), where Class II preparations were made on posterior teeth, and Class IV preparations were made on anterior teeth. Two different restorative dental materials from Table 1 were combined, and placed in extracted teeth as per manufacturer's instructions. The combination of restorative dental materials used to restore these preparations are listed in Table 2.

The restored teeth were placed in a burnout oven and heated for 900 °C for 30 min in a ceramic crucible. After removal from the burnout oven, the incinerated teeth remains were inspected visually without any magnification aid to determine if the restorative dental material could be distinguished from tooth structure. Next, the selected incinerated debris underwent SEM/EDS analysis with a Hitachi S-4000 Field Emission Scanning Electron Microscope, equipped with an IXRF 500 X-ray microanalysis system.

2.1. Electron imaging

The control and incinerated restorative dental materials were examined, and images were taken at magnifications of 100× and 1000×, using secondary electron imaging and backscattered electron imaging (BEI). Secondary electron images provides high resolution microstructural information, while BEI provides an image in which the contrast dictated by average atomic number, e.g. bright regions represents high atomic number elements.

2.2. EDS analysis

The control and incinerated restorative dental materials were examined under these conditions: 500× magnification 25 keV acceleration voltage, 43 takeoff angle, for 100 s live time. In this study, a beryllium (Be) window detector was used making detection of elements below sodium (Na) in the periodic table not possible. These analysis conditions are typical for many SEM/EDS installations. X-ray maps were also collected for selected elements in the X-ray maps, regions that have a higher concentration of an element appear as brighter areas. The maps show the distribution of elements in the samples.

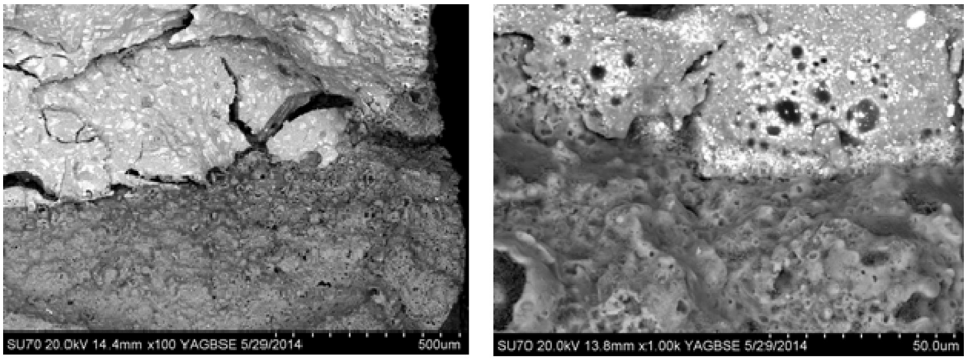
3. Results

The incinerated combined restorative dental materials could be easily distinguish from burnt tooth structure visually, however it is not possible to differentiate one material from another by this means. With SEM/EDS analysis, it was possible to further differentiate the different dental materials in restorations using a combination of secondary electron imaging, BEI, and EDS. Incinerated restorative dental materials elemental compositions also matched those of pre-incinerated controls.

Microstructural analysis (using both secondary electron imaging and BEI): it is possible to identify the different restorative materials, such as Tetric EvoCeram (Ivoclar Vivadent, Amherst, NY, USA) and GC Fuji IX GP (GC Corporation, Tokyo, Japan) (Fig. 1). The charred restorative dental materials, especially the resin composites, showed fused or melted microstructures that were consistent with the results of previous similar studies. These melted restorative dental materials however did not become totally co-mingled or fused with each another and thus were still recognizable as individual materials.

Elemental analysis (using EDS): it is possible to distinguish two different restorative materials (Figs. 2 and 3), even of the same type of dental restorative material (e.g. resin composites) (Fig. 3). Furthermore, by using the elemental analysis and mapping (Figs. 2(b–d) and 3(b–d)), it is possible to further differentiate the different restorative dental materials into the different types of restorative dental materials based on its elemental composition.

The microstructural and elemental analysis of the restorative dental materials could be also cross referenced to an existing



(a) x100 magnification **(b) x1000 magnification**

Fig. 1. Post-incineration complex dental restoration interface: Tetric EvoCeram (Ivoclar Vivadent, Amherst, NY, USA) and GC Fuji IX GP (GC Corporation, Tokyo, Japan) (Microstructural Analysis) (a) 100× magnification, (b) 1000× magnification.