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A common origin for dental porcelain derived from an accused's hand and the deceased victim of an assault

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Summary. A small, solid fragment removed from a wound on a hand of a murder suspect was submitted to electron microprobe analysis and found to have the properties of dental porcelain. A sample of porcelain removed from the dental bridge of the deceased had an essentially similar elemental profile. This investigation assisted the Court by providing valuable objective evidence of a physical contact between the accused and the victim.

Key words: Dental Porcelain – Forensic Odontology – Objective evidence – Electron probe microanalysis

Zusammenfassung. Ein kleines, festes Teilchen aus der Handwunde eines Tatverdächtigen wies bei Elektronenstrahl-Mikroanalyse die Eigenschaften von Dentalporzellan auf. Eine Vergleichsprobe von der Zahnbrücke des getöteten Opfers entsprach in ihrer Elementenzusammensetzung weitgehend der gesicherten Partikel. Aufgrund der Untersuchungsergebnisse sah das Gericht einen physischen Kontakt zwischen Opfer und Tatverdächtigem als erwiesen an.

Schlüsselwörter: Dentalporzellan – Forensische Stomatologie – Objetiver Beweis – Elektronenstrahl-Mikroanalyse

Introduction

A principal matter that may have to be resolved in the investigation of a murder is to demonstrate that the accused person and the victim were at the same location and that physical contact had occurred between them. The transference of material, from the locus to both parties, or between the assailant and the victim, in accordance with Locard's principle are objective means through which such a contact can be established to the satisfaction of a Court of Law.

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Case report

The body of a 37-year-old male was found in the street of a small town on a snowy December night. The man, who was smelling heavily of alcohol, was lying in a pool of blood and suffering from severe facial injuries. An ambulance and an emergency medical team were called to the site but prolonged emergency resuscitation on site proved of no avail. At autopsy extensive facial injuries were found and these were indicative of repeated punching, stamping and kicking of the deceased resulting in extensive fracturing of the facial skeleton and massive inhalation of blood into the ariways. There was also evidence of kicking to the chest and of a mesenteric rupture resulting in a haemoperitoneum. The blood alcohol level was 228 mg/100 ml.

Witnesses were found by police who testified to seeing the deceased being kicked and punched on that night. Several hours later a man was apprehended and charged with homicide. He denied having been involved in a fight with the deceased or having had

Fig. 1. Left hand of the accused. Arrow indicates the wound from which a radio-opaque fragment was removed

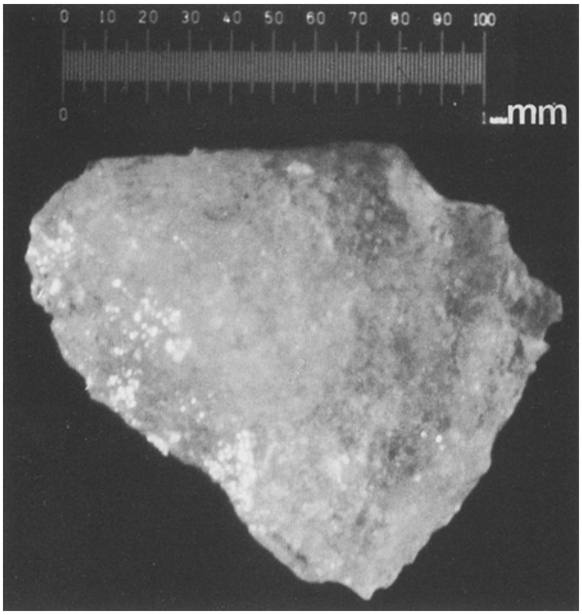

Fig. 2. Radio-opaque fragment retrieved from the accused's hand

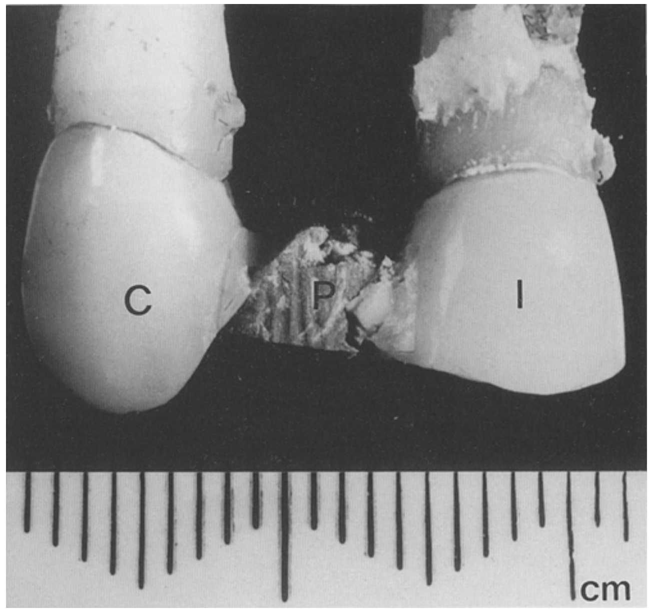

Fig. 4. Anterior view of extracted dental bridge. *I* = fractured maxillary central incisor. *P* = place of attachment for the lost pontic. *C* = apparently intact canine crown

Fig. 3. Fractured dental bridge in the mouth of the victim

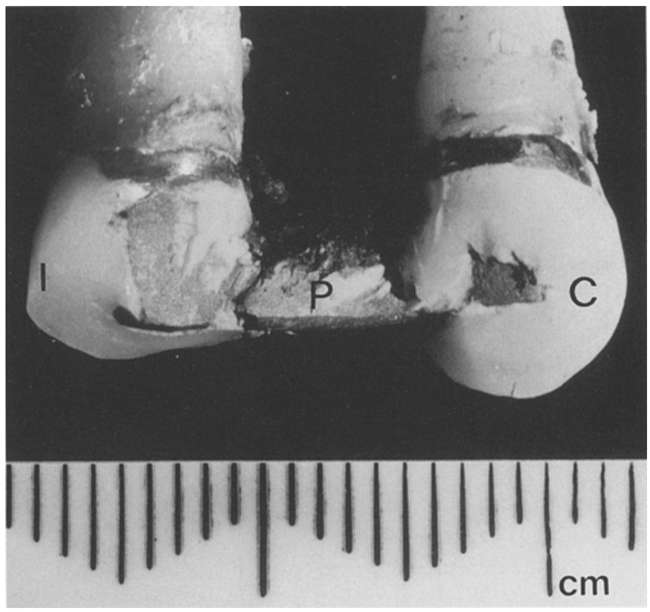

Fig. 5. Palatal view of the extracted dental bridge demonstrating an irregular and fragmentary loss of material

any other contact with him on that night. By the time that he was arrested the clothing and shoes worn at the time of the incident had been destroyed by him. Eye witness accounts and positive identification of the assailant were poor and to enable the case to have some substance, some proof was required of a physical contact between the suspect and the deceased. During the medical examination of the person in custody, carried out with his consent and full co-operation, a painful recent laceration was seen on the dorsal aspect of the third finger of his left hand very close to the metacarpophalangeal joint (knuckle) (Fig. 1). A soft tissue radiograph of the area revealed a small radio-opaque fragment within the wound (Fig. 2) and this was removed by the examining doctor and given immediately to the police. It had been observed at autopsy (Fig. 3) that the deceased had a broken dental bridge which was replacing his maxillary right lateral incisor. It was therefore suspected that the white and hard foreign body extracted from the suspect's hand might have come from the bridge and a forensic odontologist was asked to attend.

A dental examination found that the deceased's maxillary right central incisor was the mesial abutment of a fixed bridge carrying a pontic replacing the maxillary right lateral incisor. The distal abutment was provided by the maxillary right canine. Both abutment teeth were covered by fractured porcelain bonded crowns. The bridge was photographed in situ by police photographers under the direction of the odontologist and then in their presence removed atraumatically using only root elevators to minimize the risk of further damaging the bridge. A front view of the bridge (Fig. 4) demonstrates the fractured incisal edge of the crowned maxillary central incisor (I), the place of attachment for the lost pontic (P) and the apparently intact canine crown (C). The rear view of the bridge (Fig. 5) shows that the canine crown was in fact fractured. The loss of material was irregular and fragmentary. The

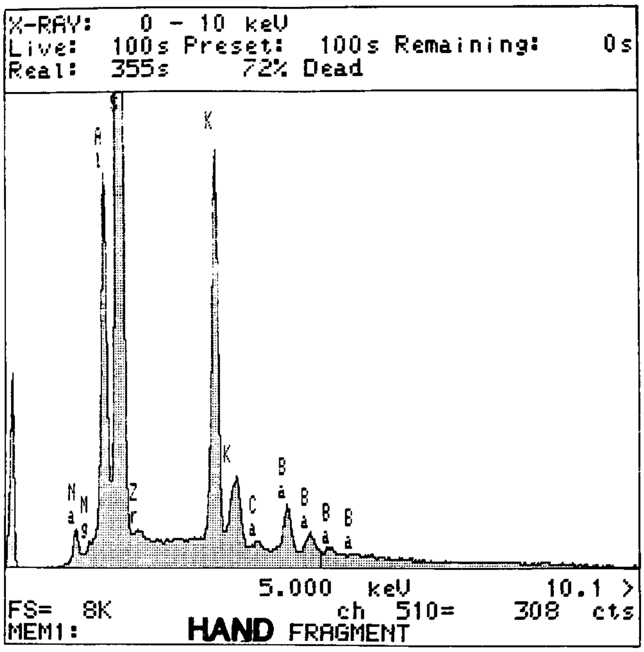

Fig. 6. X-Ray spectra from the hand fragment. Demonstrates high concentration of silicon (S), aluminium (AI), potassium (K), barium (Ba), sodium (Na) and minor quantitites of calcium (Ca), zirconium (Zr) and magnesium (Mg)

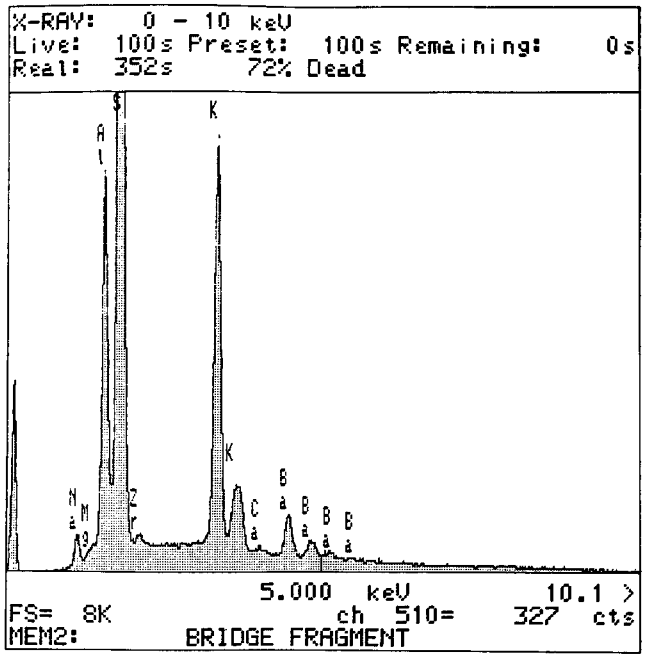

Fig. 7. X-Ray spectra from the bridge fragment. Demonstrates almost an identical qualitative and quantitative spectrum to that derived from the hand fragment

tiny fragment of hard, white, jagged-edged material, recovered from the hand of the accused measured a little over 1 mm^3. Its heterogeneous and crystalline appearance, on naked eye inspection, was consistent with dental porcelain but its minute size prohibited fitting it accurately into any part of the broken bridge. It was therefore decided to make an optical and chemical analysis of both the fragment and the dental bridge to determine whether or not any relationship might exist between them. In the presence of the examining chemist a small random fragment of porcelain was removed from the bridge, and this and the fragment removed from the accused's hand were examined.

Microscopical examination. Polished surfaces of the fragments were examined under a reflected light microscope. Both specimens were seen to be heterogeneous with small discrete inclusions of high reflectivity being distinguished readily, and ranging in size between 3 and 30 u. The inclusions were of two types: Type 1 were well-formed and varied in size from 3 to 10 u and were frequently square or rectangular in cross-section. The second species of inclusion (Type 2) were diffuse, possessed an intermediate reflectivity, were poorly defined and were generally larger than Type 1, varying from 10 to 30 u in diameter. In general appearance therefore, the two samples displayed a number of optical similarities. However, a rectangular area approximately 1.5×0.2 mm, situated on one edge of the dental bridge fragment, possessed slightly different optical properties. This zone contained a significantly greater concentration of high reflective particles. It was not possible to say whether this feature represented a facing surface applied to the porcelain during manufacture, or was representative of an inner zone of the preparation. No corresponding zone was detected on the fragment from the hand.

Because the two specimens were prepared as solid mounts, examination in transmitted light revealed little in the way of diagnostic features.

Electron Probe Microanalysis (EPMA). The microanalytical work presented was performed on a Cambridge Instruments Microscan 5 electron probe microanalyser. The instrument was operated at a gun potential of 20 KV and a probe current of 10 nanoamps, as measured by a Faraday Cup. The X-ray spectra presented in Figs. 6 and 7 were collected on a Link Analytical AN10000 energy dispersive analysis system.

Elemental distribution. Electron probe microanalysis is most frequently carried out using an electron beam focussed to as small a diameter as possible - normally in the region of 1 u. Only in this mode can the high spacial resolving capabilities of the instrument be utilised. However, in this study, because of the heterogeneous nature of the materials observed during the light microscopical examination, the major chemical study was carried out using an electron beam defocussed to a diameter of approximately 200 u. X-rays were therefore generated from a relatively large area of the sample, and the spectra so obtained were consequently more representative of its bulk composition than would have been the case had the instrument been operated in focussed mode.

Discussion

The principles of EPMA are well-established, and are described in a number of standard texts (Reed 1975; Goldstein et al. 1981). The high spacial resolution attainable in the technique makes it invaluable to the metallurgist, geologist and other material scientists when chemical information is required from micrometre-sized grains, inclusions, crystals or other particles in such a size range. The ability to examine small quantities of material also makes the technique of value to the forensic scientist, when only limited quantities of material may be available for examination. Furthermore, the technique is essentially non-destructive, and this factor makes it additionally attractive in forensic work where it may be required to produce the examined material at subsequent court hearings.

The X-ray spectra obtained from the 2 fragments are presented in Figs. 6 and 7. They bear marked similarities, showing high concentrations of silicon (S), aluminium (Al), potassium (K), barium (Ba) and sodium (Na). Minor quantities of calcium (Ca), zirconium (Zr) and magnesium (Mg) were also detectable. The major components are characteristic of minerals frequently used in the manufacture of dental porcelain e.g. alkali feldspar $(Na,K)AlSi_3O_8$, more specifically Orthoclase $(KAlSi_3O_8)$ and quartz (SiO_2) (McLean, 1979). Barium and the minor elements are typical of the materials added to the bulk minerals to create a dental porcelain of the required opacity, (McLean 1979) although barium is frequently a naturally occurring element in alkali feldspar (Deer et al. 1962). Not only are the 2 fragments similar in a qualitative sense, they are very similar in quantitative terms, as the amounts of all the elements present are very similar in both materials.

Examination of both hand and bridge fragments with a focussed electron beam permitted chemical information to be obtained from the small high reflectivity areas noted during optical examination. Whilst the small size of many of the high reflectivity inclusions prevented a clean spectrum, free of interference from the surrounding matrix, from being collected, a few of the larger well-formed (Type 1) inclusions were found to be composed almost solely of silicon and zirconium and closely resembled the X-ray spectrum typical of the mineral zircon $(ZrSiO_4)$. One or two of the high reflectivity diffuse areas in each fragment were found to contain high concentrations of yttrium. The presence of this element in both fragments is of substantial significance due to its rarity in nature. Yttrium is never found in even minor quantities in the feldspars and quartz used in dental preparations, and therefore must represent a component added during manufacture. The presence of rare elements such as yttrium and zirconium serve as extremely useful aids to comparison. The chemical inhomogeneities described might possibly be attributed to incomplete mixing of the procelain during its manufacture.

The opaque rectangular area within the bridge specimen was examined in both focussed and defocussed beam mode. In the former mode the high reflectivity particles were found to be of a similar composition to those in the bulk of the sample. Defocussed beam analysis showed that, whilst the composition of this rectangular area was similar to the adjacent material, it was not identical (Fig. 7). Whereas the major components silicon, aluminium, potassium and sodium were present in similar quantitites to the bulk, zirconium, although still a minor constituent, was present in larger quantities. The barium content in this zone was close to zero or absent totally. However, the presence of titanium, in major quantities, was noted. No analogous zone of titanium-rich porcelain was found in the section of hand fragment examined.

Small quantities of a metallic substance were found adhering to the outer edge of the titanium-rich zone of the bridge fragment. These metallic areas were only a few microns in size but were clearly identifiable as metallic palladium. It is suggested that this metal was a remnant of either a portion of the mould around which the ceramic material was built, or part of the wire work used to hold the porcelain bridge in place.

The chemical similarity between the X-ray spectra collected from the 2 samples examined was so striking, that no greater degree of sophistication of the evidence was considered necessary for the subsequent court hearing. The chemical constituents of the fragment of material removed from the accused's hand wound were consistent with that of dental ceramic and the elemental profiles of the two fragments on electron probe microanalysis were very similar. This does not necessarily imply that the two fragments were "identical" and the testimony given in Court at the time of trial (u.b. adversial system) indicated this dubeity: it is conceded that dental porcelain derived from other restorations and examined in the same manner might have produced similar elemental profiles. This specific matter is under our current investigation. Counsel appearing for the accused were unable to account for the porcelain in the accused's hand as having been introduced under any circumstances other than those suggested by the Prosecution and they did not contest the term "common origin"; their argument was directed at contesting the severity of force required for the particular blow to the mouth and they argued that a punch sufficiently hard to fragment a porcelain dental bridge need not necessarily be of very severe force and hard enough to be contributory towards death and indeed might have been inflicted in self defence. The Prosecution did not disagree with this and simply reiterated the hypothesis that on the basis of a "common origin" of the fragments of porcelain objective evidence of direct physical contact between the accused and the deceased at the time of his death was present. The experience in this trial adds support to the findings of Perper and Menges (1990) who demonstrated that skin wounds may conceal evidence and that meticulous clinical examination of both victim and accused is justified. Nichols et al. (1990) have even demonstrated the value of cytological examination of skin wound edges in a case in which they were able to extract from wound rinses microscopic fragments of crockery and thereby determine that the wound was caused by a sharp fragment of ceramic rather than by a knife. It is therefore possible that if a relatively large piece of dental ceramic was not identified in a wound caused by human teeth, as in our case, trace amounts could still be present and should be searched for using cytological methods.

Conclusions

The chemistry of the fragment of material removed from the accused's hand was consistent with that of dental ceramic.

Despite the differences in chemistry observed in one small area of the bridge fragment, the overall similarities between that fragment and the hand fragment were striking. It is therefore highly likely that the latter was not only a piece of dental porcelain, but that it originally formed part of the dental bridgework removed from the deceased.

It was reported to the Court that "it is highly likely that the fragment removed from the left hand of the accused is a piece of dental porcelain and that it, and the porcelain forming the dental bridgework removed from the deceased, probably had a common origin".

At the trial this evidence was not contested. A special plea of self defence was not successful and the accused was found quilty of culpable homicide (manslaughter) but not murder.

References

Deer WA, Howie RA, Zussman J (1962) Rock Forming Minerals, vol. 4, Framework Silicates. Longmans, London

Goldstein JI, Newbury DE, Echlin P, Joy DC, Fiori C, Lifshin E (1981) Scanning Electron Microscopy and X-ray Microanalysis. Plenum Press, London

McLean JW (1979) The Science and Art of Dental Ceramics. Quintessence Publishing, Chicago

Nichols CA, Guerry PD, Sens MA (1990) Recovery and evaluation of trace material from wound edges in traumatic injury site. Am J Forensic Med Pathol 11:71–73

Perper JA, Menges DJ (1990) The skin as a repository and masker of evidence. Am J Forensic Med Pathol 11:56–62

Reed SJB (1975) The Electron Microprobe. Cambridge University Press, Cambridge