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A Preliminary Report: Proximal Facet Analysis and the Recovery of Trace Restorative Materials from Unrestored Teeth

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ABSTRACT: A small sample of unrestored teeth with wear facets on the proximal surfaces was examined using a scanning electron microscope and energy-dispersive X-ray fluorescence spectrometry (EDS) analysis. Initial results indicate the potential of this technique for detection of residual restorative materials in these facet areas, and its resulting capability to determine the existence and composition of unrecovered adjacent restorations. The potential value of this technique in the identification of incomplete dental remains is discussed.

KEYWORDS: odontology, human identification, dentition, proximal facet, scanning electron microscope, energy-dispersive spectrometry (EDS)

The primary mission of the U.S. Army Central Identification Laboratory in Hawaii (USA-CILHI) is the recovery and identification of the remains of U.S. service personnel lost in Southeast Asia, in Korea, and in the Second World War. Most identifications are established through the comparison of postmortem dental evidence with available antemortem records and radiographs. Because of the 15 to 45 intervening years since the deaths of the personnel involved, typical USA-CILHI remains are skeletonized and often incomplete. Their condition may be further characterized by extensive fragmentation and commingling. These complications typify those cases in which the remains are of crew members of high-performance aircraft carrying explosive ordnance. Some of the remains are reported to have been buried in common graves, which further promotes skeletal exchange among crew members. And finally, remains that are received through sources other than the laboratory's own recovery efforts may have little or no provenience to assist in the identification of the dental and skeletal evidence.

Thus, the condition of the remains determines the difficulty of the reconstructive process. In this discussion the term "reconstruction" will refer to the initial effort to determine the number of individuals represented and to establish the dental condition of those individuals at the time of death. This reconstruction phase is largely a fact-finding task, in which all available information is gleaned from the dental remains. Unfortunately, the condition of the evidence dictates the amount of information attainable. An example of this problem is a case in which intact alveolar bone is recovered with distinct sockets, but some of the teeth have been lost postmortem and are not present

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for evaluation (Fig. 1). Although the appearance and shape of these remaining sockets can be used to determine some features of the lost dentition, no clues as to the actual restorative condition of a missing tooth can be ascertained. For this reason, USA-CILHI odontology personnel have routinely examined the proximal wear facets adjacent to postmortem missing teeth in an effort to discover any unique features that could contribute to the reconstruction process. This examination is usually conducted with a Nikon stereoscopic microscope, Model SMZ-10 at magnifications of $\times 10$ to $\times 40$.

Proximal Wear Facets

Proximal wear facets appear to exhibit an endless assortment of configurations. However, most have an outer, circumferential border that encompasses what will be referred to as the primary facet. Inside this primary facet may be found a variety of secondary facets or secondary characteristics (Fig. 2). It is assumed that proximal facets are formed through the constant attrition that occurs between adjacent teeth and that the unique characteristics exhibited by the facets are the result of the force of contact and the extent and direction of the movement. These, in turn, could be affected by the following: (1) the opposing cusp height, slope angle, and relationship; (2) the periodontal health and socket configuration, which affects the limits of movement; (3) the shape and size of the tooth surface in contact; and (4) therapeutic intervention, including orthodontic treatment, extraction with subsequent drifting, and operative procedures.

Elemental Contamination of Facets

Therapeutic intervention, and its potential effect on facet formation, alerted the author to the possibility of elemental contamination of a facet by restorative material, and its potential significance in dental identification. Considering the possible mechanics of proximal facet formation, the conclusion was made that the outer edge of the primary and secondary facets would be the most likely place to recover restorative residue. These areas provide rough features, where restorative material may be retained, whereas the smoother areas are more likely to polish the opposing surface and not retain debris. Microscopic examination did reveal accumulations of nonspecific debris around these interproximal areas and raised the issue of the debris composition. Specifically, the question was raised as to whether, if a restoration had existed on the proximal surface of the postmortem missing tooth, some residue of that restoration could be recovered from the debris at the site of the adjacent wear facet. If such material was present, it was believed that it would be detectable by a scanning electron microscope (SEM) and

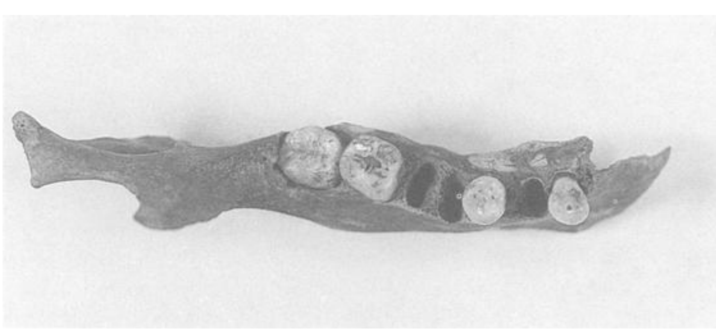

FIG. 1—*Segment of a right mandible with minimal restorative evidence and loss of teeth postmortem.*

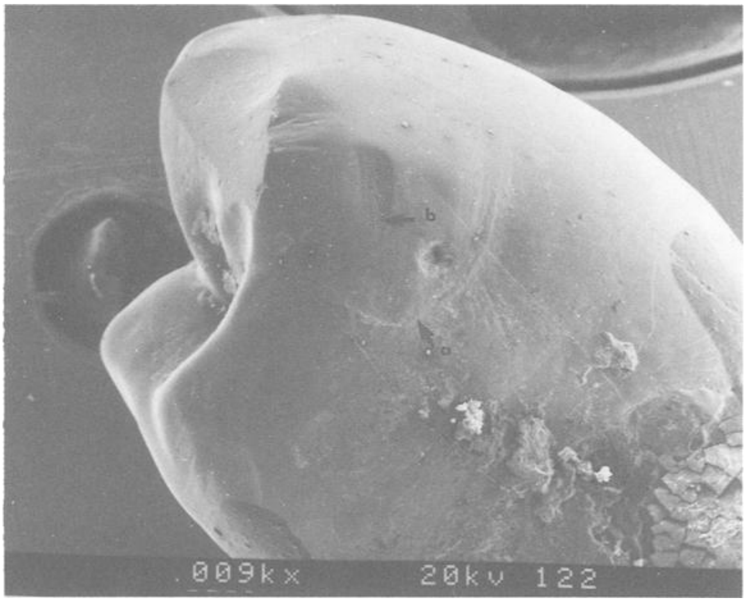

FIG. 2—*Proximal surface of a mandibular premolar showing* (a) *a primary facet and* (b) *secondary characteristics at* ×9.

energy-dispersive X-ray fluorescence spectrometry (EDS). This equipment allows visual examination of the tooth surface at high magnification and provides a means of elemental microanalysis of any debris found in the field. The EDS microanalysis has a resolution of approximately 1 μm and detection limits on the order of 1000 ppm. Thus, the purpose of this study was to determine the applicability of SEM-EDS analysis to proximal wear facets.

Materials and Methods

A sample of six teeth was selected from four sets of remains being analyzed at USA-CILHI. All six teeth were loose in their appropriate alveolar sockets, and no damaging efforts were required to remove them for the purposes of this study. The teeth shared the following characteristics: (1) they were derived from individuals who had been positively identified, based on both dental and anthropological comparison; (2) they were unrestored, as verified by stereoscopic microscope examination at magnifications up to ×40, radiographic evaluation, and review of the antemortem dental records; (3) they were known to have been adjacent to a restored proximal surface prior to death, as verified by the antemortem dental radiographs and records; and (4) they possessed proximal wear facets on the side of the adjacent restoration, which establishes that contact had occurred antemortem.

Three of the teeth were cleaned by brushing with a mild hand soap and warm tap water, and the remaining three were left as received. Three of the teeth had been adjacent to antemortem amalgam restorations and three were verified as having been in contact with cast gold restorations prior to death. All six teeth were inventoried and transported to the Analytical Electron Microscope Facility of the Hawaii Institute of Geophysics, which was located at the University of Hawaii at Manoa, Hawaii. The samples were mounted on standard aluminum electron microscope specimen stubs with butyl acetate cement and were coated with a conductive layer of carbon, using a Denton DV-502 carbon evaporator and pure carbon electrodes. The instruments used for the examination and analysis were a International Scientific Instruments Model SS-40 scanning electron microscope and a Princeton Gamma Tech 4+ EDS microanalysis system.

Particulate debris were isolated in and around the proximal facets of all six teeth and were analyzed for elemental composition using EDS. Only that material which appeared separate and distinct from the actual tooth surface was considered for analysis. Initial scanning of the facet for likely restorative residue was conducted in the magnification range of ×10 to ×100, and the actual analysis was performed at ×700 to ×1000 (Figs. 3 and 4). In addition, analysis of the tooth's enamel surface was made as a baseline for comparison (Fig. 5). The progressive examination of each tooth started on the outer edge of the primary facet and spiraled toward the center. The selection of particles for analysis was random and no attempt was made to include all particles present. The spectra were plotted on a horizontal scale of 0 to 20 keV, with a vertical full scale setting of 2000 to 15 000 counts and a live count time interval of 60 to 100 s. A positive result was considered to be any spectrum that contained significant peaks of specific elements found in restorative materials which were not observed in the baseline spectra. The primary elements of interest were silver, gold, and mercury [*1*]. The quantitative relationships among the elements found in a single spectrum were not evaluated in this preliminary study. However, since the detection limit for EDS analysis is on the order of 1000 ppm, any peak present on the 20 keV scale would have to represent a presence of no less than 0.1% by mass of that element. It should be noted that estimations for background levels of silver, mercury, and gold in normal tooth enamel are considerably less than 1000 ppm [*2*].

Results

Five of the teeth revealed residues that were consistent in elemental composition with the material contained in the adjacent antemortem restoration (Table 1). Specimen No.

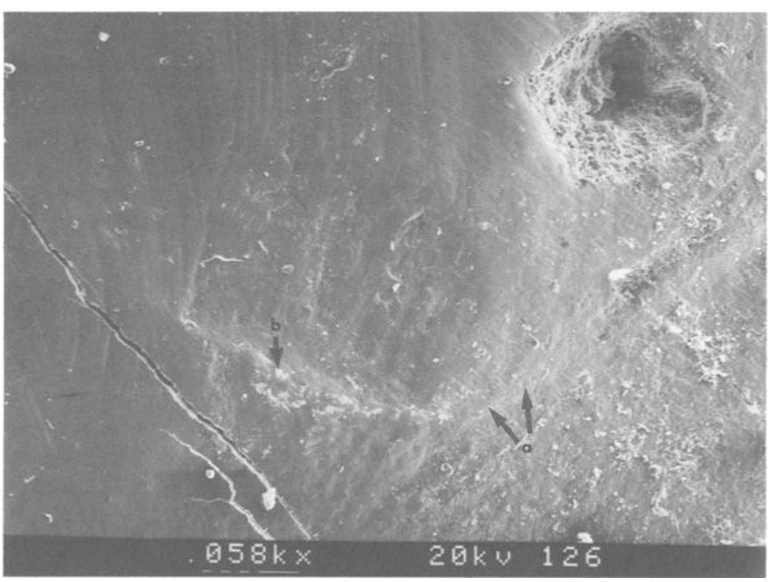

FIG. 3—*Proximal surface of a mandibular premolar showing* (a) *a primary facet and* (b) *debris at ×58.*

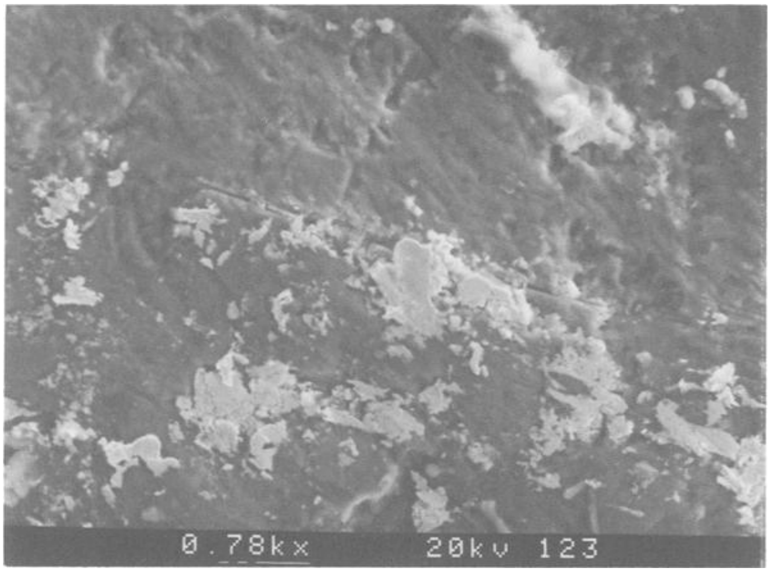

FIG. 4—*Proximal surface of a mandibular premolar showing interproximal debris at ×780.*

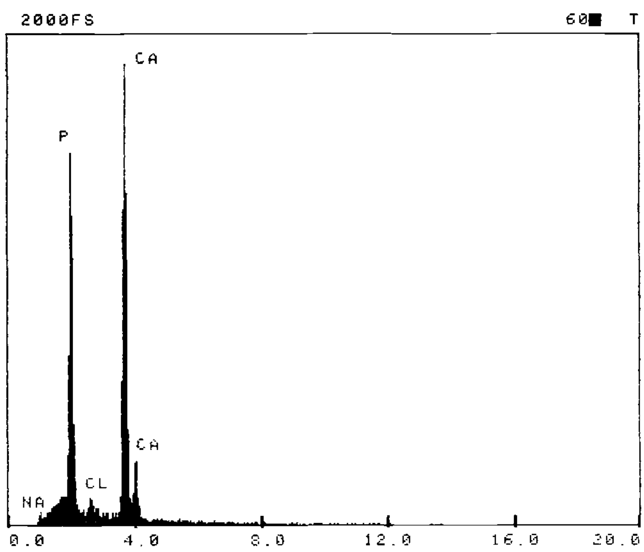

FIG. 5—*Baseline spectra in normal tooth enamel.*

3 revealed traces of mercury, but no other elements associated with amalgam were detected. Specimens No. 1, 2, 4, and 5 possessed significant levels of gold or silver in their interproximal debris, whereas Specimen No. 6 demonstrated the presence of both (Figs. 6 and 7). The debris was distributed equally on the outer edges of both primary and secondary wear facets. No restorative residues could be detected in the smooth concavities of the facets, nor were positive results obtained when carious defects in the

TABLE 1—*Comparison of the type of antemortem restoration with elemental analysis of particulate material from a proximal facet of an adjacent tooth.*

Specimen No.	Antemortem Adjacent Restoration Material	Significant Peaks
1 (cleaned)	cast gold	Au
2 (cleaned)	amalgam	Ag
3 (cleaned)	amalgam	Hg
4	amalgam	Ag, Hg, Sn
5	cast gold	Au
6	cast gold	Au, Ag

enamel were analyzed. However, the aggregation of calculus immediately cervical to the primary facet of Specimen No. 4 yielded a dramatic mercury peak, in addition to that seen in the interproximal particles.

A baseline spectrum was produced from the facial and lingual surfaces of each tooth and consistently demonstrated high levels of calcium and phosphorus, with no quantifiable peaks of gold, silver, or mercury (Fig. 3).

Discussion

Five of the six teeth analyzed provided definite traces of the restorative material documented as having existed on the adjacent tooth surface prior to death. Because the restorations themselves were not available for analysis, a notation of "amalgam" or "gold crown" in the antemortem dental record was assumed to indicate the presence of an elemental composition similar to that cited in *Restorative Dental Materials* [*1*].

Specimen No. 3 failed to contain any silver or gold but had modest levels of mercury in the interproximal debris. At this stage of research, it cannot be established whether

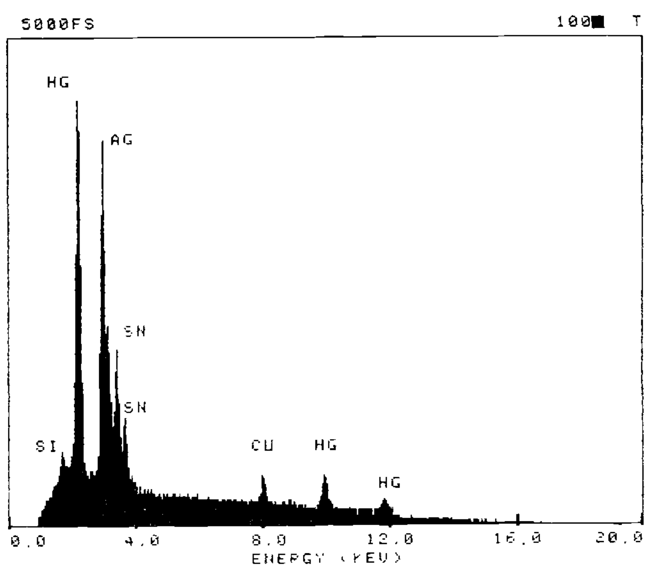

FIG. 6—*Spectra indicating the presence of amalgam residue.*

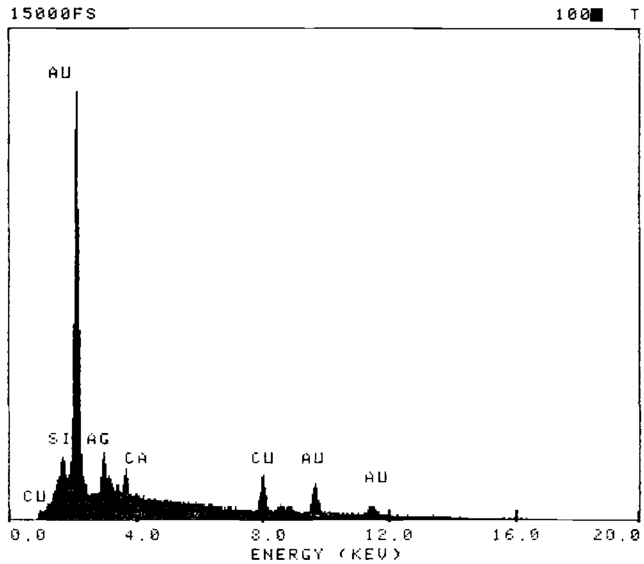

FIG. 7—*Spectra indicating the presence of gold residue.*

mercury absorption by the interproximal calculus is derived from adjacent restorations only or, through salivary contamination, from more distant amalgams. Very little information was found concerning trace element analysis of calculus, and the literature reviewed contained no reference to mercury content [2]. However, a study by Nixon et al. [3] demonstrated that the absorption of mercury by enamel from adjacent restorations is much greater than that found for enamel surfaces not in direct contact with amalgams. At present, no studies have demonstrated the length of time required to absorb significant quantities of mercury.

Specimen No. 6 revealed a significant quantity of gold and a much smaller peak for silver (Fig. 7). Although a gold peak is consistent with the presence of an adjacent cast restoration, the detection of silver was unexpected. Possibly, an alloy restoration preceded the placement of the gold crown. Unfortunately, the available antemortem records are insufficient to verify or disprove this hypothesis.

The particular value of this technique may be greatest during the early reconstructive phase of incomplete dental evidence and the subsequent comparison of the postmortem data with antemortem records. The routine use of the computer-assisted postmortem identification (CAPMI) [4] system emphasizes the dramatic influence an additional significant feature can have on the sorting process of a large antemortem dental database. The U.S. Army Central Identification Laboratory routinely uses the CAPMI to screen the over 2400 dental records of U.S. personnel unaccounted for in Southeast Asia [5]. The resulting possible identifications report (PIR), contains the dental matches and mismatches between the postmortem dental evidence and the database. The PIR may vary in length, from several hundred to less than ten potential matches, depending greatly on the quantity of postmortem evidence to be entered into the program. Trial sortings using the CAPMI and the Southeast Asian dental database repeatedly produced reductions in the number of possible identifications when one interproximal restoration was added to the postmortem screening criteria. As would be expected, more postmortem information narrows the number of identities to be considered.

The results of this preliminary study indicate that it is possible to detect restorative material residue on the proximal surfaces of unrestored teeth. The author concludes that such a find could signify the antemortem existence of a restoration on the adjacent tooth surface. This knowledge could be valuable in those identification cases in which the teeth with critical restorations were not recovered with the primary remains, but teeth proximal to those with restorations were. The samples used in this study involve only specimens adjacent to teeth lost postmortem. Therefore, no conclusion can be made as to the time required for a restoration to leave such a residue, nor to whether these deposits were left before or after death. The value of this technique in recent death cases is not known. Saliva flow, oral hygiene measures, and active mastication could reduce or eliminate the amount of interproximal debris available for analysis. In these cases, the possibility of detecting mercury absorption in interproximal calculus or enamel may hold greater promise. Regardless, SEM-EDS does provide the field of odontology with a reliable method for exploring the microscopic traces of restorative evidence, wherever they may be found.

Acknowledgments

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