CASE REPORT

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Tenerife Revisited: The Critical Role of Dentistry*

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ABSTRACT: The authors record the contribution of dentistry to the identification of victims of one of the most significant disasters in the history of aviation—the March 1977 collision of two Boeing 747 jumbo jets in the Canary Islands, which resulted in 583 fatalities. Dental identification was the primary method of victim identification because a high percentage of the bodies were severely burned. Virtually all aspects of the U.S. identification efforts have been reported with the exception of the valuable role of dentistry. The dental team's organization, methodology, and significant contributions to forensic dentistry and a variety of remarkable problems that the team encountered are documented.

KEYWORDS: forensic science, forensic odontology, mass disasters, dental identification, Tenerife

The largest number of deaths in any air crash to date occurred in the collision of a Pan American 747 with a KLM 747 at Santa Cruz de Tenerife airport in the Canary Islands on 27 March 1977 (1,2). Five hundred seventy-seven passengers initially perished; the final count reached 583 (2). Dental comparison was the principal means of identification because a majority of the victims were severely incinerated (3,4).

Both aircraft were diverted to the Tenerife airport from the airport at Las Palmas on Gran Canaria Island, where a terrorist bomb had exploded earlier that day. The Pan American 747 was chartered by a group of middle-aged people, mostly from California. At the time of the crash, the airport runway was being used for a taxiway and a runway. Fog had drastically reduced visibility. The KLM plane tried to take off, but too late saw the taxiing Pan American (Pan Am) plane and tried to clear it. They collided, the KLM plane flew a few hundred yards, and then crashed. On impact passengers were exchanged between aircraft. Adhering to Tenerife law that required burial within 48 h of death, local authorities rapidly removed the bodies from the planes and crash sites, promptly eviscerated them and treated them with a preservative, and placed them in wooden caskets (1). Identification of the dead was complicated because a high percentage of the bodies were severely burned or partially incinerated. In addition, all detached body parts, fragments, and eviscerations were kept by the local authorities. As a result, once the remaining remains reached the United States, dental identification became the primary method of victim identification.

Shortly thereafter, an account of the Dutch identification efforts in the Tenerife disaster was published (5), and several subsequent articles documented many aspects of the accident investigation and efforts of the identification team in the United States (6–13). These reports examined the identification-center administrative organization and function (6,7), the role of medical radiology (8,9), and the use of personal effects (10), and included an overall summary of the means used to identify the victims (3), the morticians' involvement (11), the reliability of the survivors as witnesses (12), and medicolegal issues (13). However, missing from these comprehensive accounts is the participation of dentistry from the dentists' perspective.

Therefore, this paper chronicles the valuable role that dentistry played in the investigation and identification process of one of the most significant disasters in aviation history and records its historical significance.

Materials and Methods

A team from the Armed Forces Institute of Pathology (AFIP) was responsible for investigating the 326 victims after their return to the mortuary at Dover Air Force Base, DE. The AFIP Department of Oral Pathology was charged with providing forensic dentistry support for this endeavor. At the time, the Department of Oral Pathology complemented the AFIP Department of Forensic Sciences with aerospace pathology, toxicology, and forensic pathology divisions (14). The chairman of the Department of Oral Pathology was chief of the Forensic Dentistry Section for the disaster mission. The assembled dental team, all members of the U.S. Air Force, consisted of 13 dental officers (five general dentists, three AFIP oral pathologists, three oral surgeons, an endodontist, and a prosthodontist), and 17 dental technicians, four of whom had dental radiology expertise. Additional dental officers were recruited as needed from air force bases in the region. In preparation for this article, the authors reviewed, categorized, and tabulated data from the official AFIP dental findings and literature (3,6,15) on the disaster, relied on their own firsthand experience as members of the AFIP dental identification team, and considered only the organization, information procedures, victim processing, and problems that were uniquely associated with the dental team.

Results

Wolcott and Hanson (3) have provided a detailed, in-depth account of the means used to identify the 326 Pan Am victims. Of

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the remains returned to the United States, 212 were identified as Pan Am passengers and four as KLM; 110 remained unidentified (3). Four victims found in the Pan Am wreckage were among the remains returned to Holland and identified by Dutch authorities.

Identified Remains

The dental team had available for comparison antemortem dental records and antemortem dental radiographs for 199 of the 212 victims. Four victims had antemortem dental charts only, and three had dental radiographs only. Abbreviated antemortem dental information was available for the remaining six. A total of 187 (88%) of the 212 victims were identified by dental means. Dental comparison was the only means of positive identification in 156 (74%) victims. Dental plus fingerprint (19 victims), medical radiographs (8 victims), personal effects (3 victims), and medical findings (1 victim) accounted for 31 positive identifications or 14%. Dental findings were supportive in seven victims (3%), mostly involving the matching of dentures to the remains. Six of the edentulous were identified by means other than dental. Medical radiographs were the next most successful method of identification (25 victims) followed by fingerprints (24 victims) (3).

Unidentified Remains

Of the 110 remains not identified, 84 were without dental/jaw structures. Four were edentulous. A total of 22 had at least some detectable dental evidence; of these, ten had relatively good postmortem dental features. However, adequate antemortem dental information was not available for these ten. At least some antemortem dental information was available on 105 of the unidentified victims. Evidence gleaned from this antemortem dental information indicated that 17 of these unidentified victims with missing dental/jaw structures were edentulous. Commingling of the remains from the two aircraft precluded identification by any type of exclusion process (3).

Discussion

Written accounts and opinions abounded in the aftermath of the Tenerife catastrophe (16–22). While these reports were not always entirely favorable towards the investigative and identification teams (16), the dental personnel took solace in the fact that they had carried out their duties in a highly professional, precise, and uncompromising manner. The following briefly describes the dental methods they used and the problems they encountered in the various components of the investigation.

Preplanning Aspects

The Tenerife disaster was the first massive test of the ability of the world community to cope with a modern air disaster involving two passenger-filled jumbo jet aircraft (13), which were still relatively new in 1977. Needless to say, there was a great deal of immediate planning necessary to accommodate the operation since this was the first truly large-scale mass disaster that had confronted the Department of Oral Pathology at the AFIP. Fortunately, the military system allows for quick response to requests for material and personnel in a crisis. Many of the U.S. Air Force dentists selected for the team, including the authors, had previous dental identification experience, albeit on a much smaller scale. In addition, U.S. Air Force personnel had recently gained mass-disaster identification experience helping to identify 139 victims killed in a flash flood (23). Furthermore, several articles reporting on the role of dentistry in mass disasters provided excellent guidelines for the organization of and techniques for a dental identification team (24–32), and the department had been sponsoring the then 15-year-old AFIP Annual Forensic Dentistry Course from which its dentists had consequently learned. They had also benefited from their ongoing participation in international forensic dentistry conferences (28). All of the aforementioned were instrumental in the team determining the organization, staffing, and protocol of the forensic dental section and its attendant subsections—postmortem dental examination and radiology, antemortem record reconstruction, and records comparison section.

Postmortem Examination and Radiology Subsection

Most of the victims were badly burned, and therefore their jaws were resected so that the oral cavity could be thoroughly examined and radiographed. The oral surgeons' expertise expedited this initial phase of the dental processing. The surgical-resection method (33,34) that they used allowed the mandible to remain attached to the victim, which was the right ethical decision in this particular disaster because it kept the body intact and eliminated the possibility of inadvertently commingling body parts.

Because of the large number of unidentified remains, a validating system was needed. It was decided that repeating each of the various examination procedures at the time of the initial examination would help provide more accurate documentation. In order to do this in the postmortem examination section, teams composed of three dentists conducted the examinations using a multiple verification technique, which greatly reduced errors in charting. One dentist examined, one charted, the third verified that the first reported accurately and then verified that the other charted correctly. They then switched roles and on the same remains again employed the multiple verification technique to reduce further the chance for error. This method of redundancy allowed for verification of findings, consultation on questionable findings, and, with the alternation of team members in the roles of examiner and recorder, fatigue reduction (32).

The dental team knew that many victims were edentulous but could not use dental means to identify most because local authorities had removed all removable prosthetic appliances from the victims. These appliances were given numbers that were different from the assigned body numbers and were subsequently stored all together and separate from the bodies (15). It is almost needless to mention the frustration that the dental-identification team experienced.

Victims with no dental or jaw anatomy totaled 84, but the use of whole-body radiographs was valuable in screening for dental evidence that had been displaced to other parts of the body (6).

Other problems affecting postmortem data collection were lack of recovery of dental structures, fragmentation of jaws and dental structures, and incineration of teeth in the intense fire. Possibly contributing to the lack of recovery of dental evidence was the fact that the local authorities would not give the U.S. dental-identification team access to the crash site and remains that were recovered in Tenerife. Also, as stated previously, the local authorities kept all detached body parts, fragments of remains, and eviscerations.

Whenever possible, the U.S. dental-identification team took a full-mouth series of periapical radiographs on the victims. It was believed that periapical radiographs would increase the chances for identification because they would show the entire tooth, its surrounding bony trabecular pattern, and bone loss from periodontal

disease. Wet gauze placed intraorally held the film in place on intact jaws. The dental radiology technicians adapted quickly to the problem of taking radiographs on remains. Their efficiency and high-quality radiographs were directly responsible for the success of the dental identification.

Antemortem Reconstruction Section

The almost impossible task of comparing dental records from dental offices with postmortem dental records required that the team transcribe all antemortem dental evidence to a single antemortem dental-record form in order to create a composite antemortem picture. This composite thus made comparison of the reconstructed antemortem dental record to the postmortem findings recorded on the postmortem dental record much easier. Antemortem record retrieval by the airlines was admirable and facilitated the team's use of multiple verification. One dentist transcribed the antemortem dental-record information to a standardized form, which was then verified by a second dentist. This was necessary, in part, due to the volume of dental records received, many of which were less than ideal quality. Another problem was that many dental records were not current. The team made many phone calls to dental offices attempting to clarify dental records in question. In several instances, dentists sent only duplicate copies of dental charts and radiographs. Duplicate radiographs without patient identification and/or anatomic-side (right vs. left) designations were additional problems with which the team had to contend. There were also presumptuous and crass intrusions that the team ignored. On more than one occasion, a dentist sent the victim's unpaid balance to the antemortem team requesting that they ensure its receipt by next of kin. One dentist even requested that a business card of the dentist's own family member, an attorney, be forwarded to the victim's next of kin.

Postmortem Record and Comparison Section

The Postmortem Record and Comparison Section received postmortem dental records and completed antemortem composite dental records from the respective sections. Members of this section were responsible for comparing all postmortem examination and radiographic findings with the completed composite antemortem dental records and radiographs.

The records-comparison team became more active late in the course of the three-week identification process as the work of the postmortem and antemortem teams progressed to completion. The comparison of antemortem records to postmortem records was performed manually with the latter distributed on tables. The postmortem records were sorted by gender and removable-prosthetic-appliance categories in an effort to enhance comparison efforts. A dentist would then carry an antemortem record up and down the table aisles trying to match it to the corresponding postmortem record. This manual comparison of one composite antemortem dental record to over three hundred postmortem dental records took an estimated 2.5 h for each record, a tedious, overwhelming chore that would later spur the development and application of computer technology to forensic dentistry. In fact, members of the dental team and computer programmers first began devising coding methodology for antemortem and postmortem dental data during the Tenerife identification process.

After the initial manual comparison, the chief of the forensic dentistry section or his designee would review all possible matches. Multiple verification was used in this section, too. An official identification summary form was used to summarize the identification data and to document the decision-making process. This form was signed by the chief or designee along with a minimum of one and often two dentists who were in agreement with the final interpretation. The degrees of certainty were essentially (1) positive (certainty), (2) consistent with (findings support an identification but not to a degree allowing certainty), and (3) unidentified (insufficient evidence). Some interesting problems arose in the Comparison Section. For example, a passenger using another's name hindered our attempts at dental identification because the dental records for the passenger listed on the airline manifest did not match the believed-to-be remains. In addition, Pan Am indicated that no children were on board, which was contrary to postmortem evidence that indicated that the remains of a child were commingled with the remains of adults. Another realization also came to light. A positive dental identification negated identification by another modality, which stressed the importance of using all available means of identification to increase the validity of the identification.

Conclusions

Forensic dentistry made at least four major contributions to victim identification in the Tenerife disaster and to forensic science in general. First, it validated the value of postmortem dental radiographs in several ways: (*a*) the comparison of antemortem and postmortem radiographs was responsible for a high percentage of identifications, (*b*) postmortem dental radiographs gave the identification team one of its first clues to the occurrence of commingling, and (*c*) comparison of antemortem and postmortem dental radiographs disproved a positive identification by another forensic discipline. A second major contribution of forensic dentistry was that ideas and information assimilated during this disaster were instrumental in the development of a forensic dentistry computer system that was subsequently used in the Jonestown, Guyana, tragedy and other disasters (20,35). The Computer-Assisted Postmortem Identification System (CAPMI) (36), developed at the Army Institute of Dental Research in 1984, and, more recently, the WinID program (37) in the 1990s represent continued development of computer technology in forensic dentistry. The third contribution was that forensic dentists recognized that continuing education courses in forensic dentistry are an invaluable readiness tool. The experience of forensic dentists in Tenerife led the military to develop portable "hands-on" disaster and radiographic laboratories that use remains for training dentists in mass casualty identification. The fourth, and by no means the least, contribution was that the dental organization, function, and techniques developed in this disaster became the template for the standardization of the protocol that military dental identification teams currently use—not only in mass disasters, but also in smaller accidents and single-victim identification.

Many of the significant contributions that the dental team made probably seem insignificant by today's standards for mass-casualty protocol. However, the success of many of the dental identification methods during the 1977 Tenerife disaster provided incontestable justification for their continuance in the burgeoning forensic mission of the federal system that soon followed. One fact that forensic professionals realized without doubt was that the results of the Tenerife catastrophe unequivocally justified the rightful place of forensic dentistry in mass-disaster identification.

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