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Editorial note:

In the course of medico-legal death investigation and disaster victim identification, forensic pathologists always work in close collaboration with colleagues in other forensic disciplines, including forensic odontologists. In this article, Dr. Carl Leung, a local forensic odontologist, has provided an account on the principle of forensic odontology and its application in fieldwork. We welcome any feedback or suggestions. Please direct them to Dr. Bobby Shum (e-mail: bsfshum@graduate.hku.hk) of Education Committee, the Hong Kong College of Pathologists. Opinions expressed are those of the authors or named individuals, and are not necessarily those of the Hong Kong College of Pathologists.

Forensic Odontology

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Introduction

Forensic odontology, or forensic dentistry, was defined by Keiser-Neilson in 1970[1] as "that branch of forensic medicine which in the interest of justice deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of the dental findings." There are three major areas of activity embracing current forensic odontology, namely:

1. The examination and evaluation of injuries to teeth, jaws, and oral tissues resulting from various causes
2. The examination of marks with a view to subsequent elimination or possible identification of a suspect as the perpetrator
3. The examination of dental remains (whether fragmentary or complete, and including all types of dental restorations) from unknown persons or bodies with a view to the possible identification of the latter [2]

The natural teeth are the most durable organs in the bodies of vertebrates, and humankind's understanding of their own past and evolution relies heavily upon remnant dental evidence found as fossils.[3] Teeth can persist long after other skeletal structures have succumbed to organic decay or destruction by some other agencies, such as fire.[4]

Identification by dental means is not a new technique. It has been said that Nero's mistress, Sabina, in 66 A.D., satisfied herself that the head presented to her on a platter was Nero's wife as she was able to recognize a black anterior tooth.

Another historic case is the dental identification of the remains of Adolf Hitler. Thirteen bodies were

found in the garden of the Chancellery on May 4, 1945: six children, five adults and two dogs. For two of the burned adults, visual identification was impossible. The Soviets later found the dental charts, the dental X-ray and the dental technician who performed the dental work for Hitler and Eva Braun. After comparison, the human remains were then positively identified by dental means.

Comparative Dental Identification

After the comparison of antemortem record and postmortem findings, a range of conclusions can be reached when reporting a dental identification. The American Board of Forensic Odontology recommends that these be limited to the following four conclusions: [6]

Positive identification: The antemortem and postmortem data match in sufficient details, with no unexplainable discrepancies, to establish that they are from the same individual.

Possible identification: the antemortem and postmortem data have consistent features but, because of the quality of either the postmortem remains or the antemortem evidence, it is not possible to establish identity positively.

Insufficient evidence: The available information is insufficient to form the basis for a conclusion.

Exclusion: the antemortem and postmortem data are clearly inconsistent.

It is important to note that there is no minimum number of concordant points that are required for a positive identification which is different from the analysis of fingerprint. In some cases, a single tooth can be used for identification if it contains sufficient identifying or unique features. Equally, a full mouth series of radiographs may not reveal sufficient detail to render a positive identification.[6] The certainty of identification conclusion lies with the forensic odontologist, who must be prepared to justify his conclusions in court.

Postmortem Dental Profiling

When antemortem dental records are unavailable and other methods of identifications are not possible, the forensic odontologist can assist in limiting the population pool to which the deceased is likely to belong and thus increase the likelihood of locating antemortem dental records.[5] This process is known as postmortem profiling. The information from this process will enable a more focused search for identity. A postmortem dental profile can provide information on the age, ancestry background, sex and socio-economic status of the deceased. In rare circumstances, it is also possible to provide additional information regarding occupation, dietary habits, habitual behaviour and occasionally on dental or systemic disease.

Forensic anthropologists most often provide details of osteological studies, but forensic dentists can assist in the process.[12-17] The determination of sex and ancestry can be assessed from skull shape and form. Generally, from skull appearance, forensic dentists can determine race within the three major groups: Caucasoid, Mongoloids and Negroid. Additional characteristics, such as cusps of carabelli, shovel-shaped incisors and multi-cusped premolars, can also assist in determination of ancestry.[18] Sex determination is usually based on cranial appearance, as no sex differences are apparent in the morphology of teeth. Microscopic examination of teeth can confirm sex by the presence or absence of Y-chromatin and DNA analysis can also reveal sex.[19-21]

The presence of erosion can suggest alcohol or substance abuse, an eating disorder or even hiatus hernia while stain can indicate smoking, tetracycline use or betel nut chewing.[22-31] Unusual wear patterns may result from pipe stems, cigarette holders, hairpins, carpet tacks or previous orthodontic treatment.[32] The quality, quantity and presence or absence of dental treatment may give an indication of socio-economic status or likely country of residence.[33]

Facial Reconstruction and Facial Superimposition

If the postmortem profile does not elicit the tentative identity of the deceased, it may be necessary to reconstruct the individual's appearance during life. This is the responsibility

of forensic artists who utilize the dental profile to help with facial reconstruction.[34-36] The use of antemortem photographs to permit facial superimposition of skeletal and teeth fractures have been used in cases of identification. This technique requires the availability of suitable antemortem photographs showing the teeth. Often, angulations and magnification impose difficulties in positioning the images.[37-39]

Age Assessment

The evaluation of dental tissue has long been regarded as a good tool for the assessment of age, and therefore, age assessment techniques involving these tissues have been widely used by forensic dentists and anthropologists. The rationale for scientific evaluation of dental tissues for age estimation can be divided into three criteria: tooth formation and growth changes, postformation changes, and biochemical changes.

Tooth formation and growth changes involve the progressive morphological development of the crown, root and apex of any given tooth and/or its timed emergence and eruption sequence.[40] An advantage of tooth formation and growth techniques is that they are noninvasive with age assessment easily accomplished through visual and radiographic examination. Additionally, tooth development techniques are classically "thought to be the most accurate and reliable way of correlating growth and development" to age. Through the development of tooth maturation stages, researchers have developed dental age estimation techniques.[41,42] There are multiple staging systems that have been proposed and it is imperative that the forensic scientist always be mindful to utilize the appropriate staging system that is associated with a given study's data set. Because tooth development is a maturation process, techniques that utilize this rationale are reserved for cases involving fetuses, infants, children, and adolescents. Naturally, as an adolescent individual approaches adulthood, they also approach the end of dental and skeletal development. Therefore, anthropological considerations that utilize bones of the hand and wrist, clavicle, ribs, and cervical vertebrae become more important in the age assessment process.

Once dental and skeletal growth has ceased, forensic dental investigators must use a technique that involves either biochemical tooth changes or dental postformation changes to assess age. There are two biochemical dental age estimation techniques: amino acid racemization method[43] and carbon-14 dating. They are both laboratory techniques that involve the sacrifice of tooth structure and are expensive and time consuming.

Postformation tooth changes are adult dental considerations and can be subdivided into gross anatomical and histological changes. The gross anatomical changes include but are not limited to attrition, periodontal condition, apical root resorption, pulpal size to tooth size ratios, root smoothness, and dentine coloration. The histological changes include secondary dentine apposition, cementum apposition, and root dentine transparency.[44]

Unfortunately, there are other factors at play in the scientific dental assessment of age other than the aforementioned criteria. They include the gender and ancestry of the individual in question. The classic anthropologic ancestries are European, Asian and Africa. However, many of the newer published dental age estimation studies are population specific versus being of ancestral specificity. Population specific studies help to eliminate questions of ancestral admix and the potential influence of a myriad of environmental considerations. Some of these environmental factors include climate, nutritional health, disease, lack of disease, habits, addictions, occupation, place of residence, and dental and skeletal abnormalities.

DNA in Forensic Odontology

The resilient nature of the dental hard tissues to environmental assaults ensure that teeth represent an excellent source of DNA material.[45] When conventional dental identification methods fail, this biological material can provide the necessary link to prove identity. With the advent of the polymerase chain reaction, a technique that allows amplification of DNA at pre-selected specific sites, this source of evidence is becoming increasing popular with investigators. Comparison of DNA from the teeth of an unidentified individual can be

made to a known antemortem sample like stored blood, hairbrush, clothing, cervical smear and etc. or to a parent or sibling.[5] A recent study has found out that mitochondrial DNA can be sourced from dentine powder obtained via cryogenic grinding, and also via dentine in the case of root-filled tooth.[46-48] In fact, Interpol DVI has suggested to use the teeth as a source of DNA in the investigation because of the abundance of DNA materials in the tooth.

Bitemark

In mortal combat situations, such as the violence associated with life and death struggles between assailants and victims, the teeth are often used as a weapon. Indeed, using the teeth to inflict serious injury on an attacker may be the only available defensive method of a victim. Alternatively, it is well known that assailants in sexual attacks, including sexual homicide, rape and child sexual abuse, often bite their victims as an expression of dominance, rage and animalistic behavior.[49]

A bitemark is a pattern created by teeth contacting a surface, most commonly food but also other objects and human skin. A bitemark on human skin is a patterned injury, and the examination and analysis of those injuries often become the responsibility of forensic dentists.[50]

The amount and degree of detail recorded in the bitten surface may vary from case to case. And even if it is assumed that the dentition is individual enough to warrant use in forensic context, it is not known if this individuality is recorded specifically enough in the injury. In situations where sufficient detail is available, it may be possible to identify the biter to the exclusion of all others. Perhaps more significantly, it is possible to exclude suspects that did not leave the bitemark.

Recognition, evidence collection, and analysis of a bitemark is challenging and complex. The comparisons of the teeth of putative biters, the reports of the results of these comparison, and the subsequent expert testimony regarding those comparisons are the most controversial areas of forensic odontology.

The analysis process involves the evaluation of the evidence quality and the features in that evidence. It is these analyses that enable forensic dentists to offer information to officials and others charged with the protection of society about the nature of those injuries. A separate and distinct activity is the subsequent comparison of bitemarks with the dentition of the suspected biters. All suspected bitemarks should be analyzed. Only those that reach a threshold of evidentiary value should be compared to suspected biters.

The most common analyses are those of suspected bitemarks on human skin. However, tooth markings have also been analyzed on numerous inanimate objects including various foods, chewing gums, Styrofoam cups, cigarette butts, wooden pencils, a steering wheel, and more.[51,52]

Human Bites as Forensic Biological Evidence

During the process of biting and also during kissing and sucking, saliva is deposited on the skin's surface. It has been shown that this trace evidence is present in sufficient quantity and quality to enable PCR-based typing of the DNA that is present in saliva from white blood cells and possibly from sloughed epithelial cells.[53,54] Significantly, since high intensity alternative light sources and lasers are now widely used by the police to locate stains from bodily fluids at the crime scene, saliva stains deposited on the skin – even in the absence of marks from teeth – can be found and recovered. After analyzing the salivary DNA and establishing the depositor's DNA profile, this result can be compared with the DNA profile of any suspects obtained from buccal swabs containing saliva or whole blood taken using a lancet.[55]

Child Abuse

Child abuse is a non-accidental trauma or abuse inflicted on a child by a caretaker that is beyond the acceptable norm of child care. [56] The head and facial areas are frequently injured in such cases. These areas are exposed and accessible and the face and mouth are considered representative of the whole being. Human bitemarks are often seen in child abuse cases, frequently accompanied by other injuries. Those found in infants tend to be on

different locations from those in older children or adolescents, and reflect punitive measures.[57,58] The marks may be ovoid or semicircular. Bites from adults will often only mark clearly from one arch, while a child who has been bitten will frequently mark with both arches. Bites may be aggressive or sexual, the latter occasionally displaying suck marks. However, it is important not to overlook the fact that the child may have bitten itself or had the arm or hand forced into the mouth to silence it.[59]

Other Dental Evidence

Civil claims on personal injury due to traffic accidents, occupational accidents and other accidents which may involve insurance purpose will also need a forensic expert opinion and assessment. Recently, court will usually demand both parties to appoint two experts or even one expert to make a joint report so as to save the cost and time for both parties and the court. Although general dentists can also play the role as experts when dental evidence is required, it is more sensible to appoint a forensic dentist since he or she are trained to write legal reports and understand the words of lawyers and court.[58, 60]

Dental evidence such as identification of tooth fragments and elucidation of their origins may play a critical role in court proceedings, as illustrated by several similar cases in which the author was involved. Foreign bodies found in food is not uncommon. It can be anything, including insects, blades, or even a tooth fragment. Food suppliers may be prosecuted by the Food and Environmental Hygiene Department following complaints of discovery of foreign bodies in the food supplied. The author was appointed on several occasions as expert witness by the defence to examine tooth fragments in chocolate, fruit tarts, pineapple buns or even hamburgers. After careful examinations on the complainants, it was found out that the tooth fragments were indeed from the broken teeth of the complainants, who were having very poor oral hygiene. They did not even notice that the tooth fragments were from their own mouths and that they have retained roots in their oral cavities. The defendants of these cases were eventually acquitted.

Reference

1. Keiser-Neilsen, S., *Person Identification by Means of Teeth*. 1980, Bristol: John Wright & Sons.
2. Keiser-Nielsen, S., *Forensic odontology.* Int Dent J, 1968. 18(3): p. 668-83.
3. Tobias, P., *The Skulls, ebocast and teeth of Homo habilis*. 1990, New York: Cambridge University Press.
4. Holden, J.L., J.G. Clement, and P.P. Phakey, *Age and temperature related changes to the ultrastructure and composition of human bone mineral.* J Bone Miner Res, 1995. 10(9): p. 1400-9.
5. Sweet, D. and J.A. DiZinno, *Personal identification through dental evidence--tooth fragments to DNA.* J Calif Dent Assoc, 1996. 24(5): p. 35-42.
6. *Body identification guidelines. American Board of Forensic Odontology, Inc.* J Am Dent Assoc, 1994. 125(9): p. 1244-6, 1248, 1250 passim.
7. INTERPOL. *Disaster Victim Identification*. 2015; http://www.interpol.org/.
8. Bajaj, A., *Disaster victim identification: Tsunami.* Br Dent J, 2005. 198(8): p. 504-5.
9. Berketa, J.W., H. James, and A.W. Lake, *Forensic odontology involvement in disaster victim identification.* Forensic Sci Med Pathol, 2012. 8(2): p. 148-56.
10. Levine, S., *Forensic odontology--identification by dental means.* Aust Dent J, 1977. 22(6): p. 481-7.
11. Taylor, J., *Development of the Australian Society of Forensic Odontology disaster victim identification forensic odontology guide.* J Forensic Odontostomatol, 2009. 27(2): p. 56-63.
12. Steyn, M. and M.Y. Iscan, *Sexual dimorphism in the crania and mandibles of South African whites.* Forensic Sci Int, 1998. 98(1-2): p. 9-16.
13. Burris, B.G. and E.F. Harris, *Identification of race and sex from palate dimensions.* J Forensic Sci, 1998. 43(5): p. 959-63.
14. Hsu, J.W., et al., *The effect of shovel trait on Carabelli's trait in Taiwan Chinese and Aboriginal populations.* J Forensic Sci, 1997. 42(5): p. 802-6.
15. Solheim, T., *A new method for dental age*

estimation in adults. Forensic Sci Int, 1993. 59(2): p. 137-47.
16. Shapiro, H.L., *Forensic anthropology.* Ann N Y Acad Sci, 1978. 318: p. 3-9.
17. Noble, H.W., *The estimation of age from the dentition.* J Forensic Sci Soc, 1974. 14(3): p. 215-21.
18. Whittaker, D.K. and L.W. Rawle, *The effect of conditions of putrefaction on species determination in human and animal teeth.* Forensic Sci Int, 1987. 35(2-3): p. 209-12.
19. Sweet, D., D. Hildebrand, and D. Phillips, *Identification of a skeleton using DNA from teeth and a PAP smear.* J Forensic Sci, 1999. 44(3): p. 630-3.
20. Adachi, H., *[Studies on sex determination using human dental pulp. I. The observation of Y-chromatin for the paraffin section using quinacrine mustard staining]*. Nihon Hoigaku Zasshi, 1988. 42(1): p. 38-41.
21. Adachi, H., *[Studies on sex determination using human dental pulp. II. Sex determination of teeth left in a room]*. Nihon Hoigaku Zasshi, 1989. 43(1): p. 27-39.
22. Harley, K., *Tooth wear in the child and the youth.* Br Dent J, 1999. 186(10): p. 492-6.
23. Murray, M.O. and N.H. Wilson, *Ecstasy related tooth wear.* Br Dent J, 1998. 185(6): p. 264.
24. Bartlett, D., *Regurgitated acid as an explanation for tooth wear.* Br Dent J, 1998. 185(5): p. 210.
25. Nunn, J., L. Shaw, and A. Smith, *Tooth wear--dental erosion.* Br Dent J, 1996. 180(9): p. 349-52.
26. Robb, N.D. and B.G. Smith, *Prevalence of pathological tooth wear in patients with chronic alcoholism.* Br Dent J, 1990. 169(11): p. 367-9.
27. Milosevic, A. and P.D. Slade, *The orodental status of anorexics and bulimics.* Br Dent J, 1989. 167(2): p. 66-70.
28. Smith, B.G. and J.K. Knight, *A comparison of patterns of tooth wear with aetiological factors.* Br Dent J, 1984. 157(1): p. 16-9.
29. Lochary, M.E., P.B. Lockhart, and W.T. Williams, Jr., *Doxycycline and staining of permanent teeth.* Pediatr Infect Dis J, 1998. 17(5): p. 429-31.
30. Livingston, H.M. and T.M. Dellinger, *Intrinsic staining of teeth secondary to tetracycline.* Ann Pharmacother, 1998. 32(5): p. 607.
31. Cuff, M.J., et al., *The presence of nicotine on root surfaces of periodontally diseased teeth in smokers.* J Periodontol, 1989. 60(10): p. 564-9.
32. Gupta, B.N., *Occupational diseases of teeth.* J Soc Occup Med, 1990. 40(4): p. 149-52.
33. Maupome, G. and M.I. MacEntee, *Prosthodontic profiles relating to economic status, social network, and social support in an elderly population living independently in Canada.* J Prosthet Dent, 1998. 80(5): p. 598-604.
34. Austin-Smith, D. and W.R. Maples, *The reliability of skull/photograph superimposition in individual identification.* J Forensic Sci, 1994. 39(2): p. 446-55.
35. Turner, W., et al., *Computer-aided forensics: facial reconstruction.* Stud Health Technol Inform, 2006. 119: p. 550-5.
36. Vanezi, P., et al., *Facial reconstruction using 3-D computer graphics.* Forensic Sci Int, 2000. 108(2): p. 81-95.
37. Dorion, R.B., *Photographic superimposition.* J Forensic Sci, 1983. 28(3): p. 724-34.
38. Brocklebank, L.M. and C.J. Holmgren, *Development of equipment for the standardization of skull photographs in personal identifications by photographic superimposition.* J Forensic Sci, 1989. 34(5): p. 1214-21.
39. Maat, G.J., *The positioning and magnification of faces and skulls for photographic superimposition.* Forensic Sci Int, 1989. 41(3): p. 225-35.
40. Anderson, D.L., G.W. Thompson, and F. Popovich, *Age of attainment of mineralization stages of the permanent dentition.* J Forensic Sci, 1976. 21(1): p. 191-200.
41. Gustafson, G., *Age determination on teeth.* J Am Dent Assoc, 1950. 41(1): p. 45-54.
42. Gustafson, G. and G. Koch, *Age estimation up to 16 years of age based on dental development.* Odontol Revy, 1974. 25(3): p. 297-306.
43. Arany, S. and S. Ohtani, *Age estimation by racemization method in teeth: application of aspartic acid, glutamate, and alanine.* J Forensic Sci, 2010. 55(3): p. 701-5.
44. Drusini, A., I. Calliari, and A. Volpe, *Root*

dentine transparency: age determination of human teeth using computerized densitometric analysis. Am J Phys Anthropol, 1991. 85(1): p. 25-30.
45. Schwartz, T.R., et al., *Characterization of deoxyribonucleic acid (DNA) obtained from teeth subjected to various environmental conditions.* J Forensic Sci, 1991. 36(4): p. 979-90.
46. Sweet, D. and D. Hildebrand, *Recovery of DNA from human teeth by cryogenic grinding.* J Forensic Sci, 1998. 43(6): p. 1199-202.
47. Sweet, D.J. and C.H. Sweet, *DNA analysis of dental pulp to link incinerated remains of homicide victim to crime scene.* J Forensic Sci, 1995. 40(2): p. 310-4.
48. Hutchison, C.A., 3rd, et al., *Maternal inheritance of mammalian mitochondrial DNA.* Nature, 1974. 251(5475): p. 536-8.
49. Barsley, R., et al., *Bitemark analysis.* J Am Dent Assoc, 2012. 143(5): p. 444, 446; author reply 446, 448.
50. Bowers, C.M., *Bitemark analysis.* J Am Dent Assoc, 2011. 142(12): p. 1334-5.
51. Bernitz, H. and B.A. Kloppers, *Comparison microscope identification of a cheese bitemark: a case report.* J Forensic Odontostomatol, 2002. 20(1): p. 13-6.
52. Nambiar, P., et al., *Identification from a bitemark in a wad of chewing gum.* J Forensic Odontostomatol, 2001. 19(1): p. 5-8.
53. Sweet, D. and G.G. Shutler, *Analysis of salivary DNA evidence from a bite mark on a body submerged in water.* J Forensic Sci, 1999. 44(5): p. 1069-72.
54. Sweet, D., et al., *PCR-based DNA typing of saliva stains recovered from human skin.* J Forensic Sci, 1997. 42(3): p. 447-51.
55. Sweet, D. and D. Hildebrand, *Saliva from cheese bite yields DNA profile of burglar: a case report.* Int J Legal Med, 1999. 112(3): p. 201-3.
56. Ambrose, J.B., *Orofacial signs of child abuse and neglect: a dental perspective.* Pediatrician, 1989. 16(3-4): p. 188-92.
57. Beckstead, J.W., R.D. Rawson, and W.S. Giles, *Review of bite mark evidence.* J Am Dent Assoc, 1979. 99(1): p. 69-74.
58. Verma, A.K., et al., *Role of dental expert in forensic odontology.* Natl J Maxillofac Surg, 2014. 5(1): p. 2-5.
59. Wagner, G.N., *Bitemark identification in child abuse cases.* Pediatr Dent, 1986. 8(1 Spec No): p. 96-100.
60. Pashinian, G.A., et al., *[Forensic medical expert evaluation in connection with civil actions of patients complaining of improper dental care]*. Sud Med Ekspert, 2000. 43(6): p. 8-13.