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DENTAL PROFILING IN FORENSIC SCIENCE

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Summary

Forensic sciences include a wide spectrum of different disciplines, which are applied individually or collectively in order to obtain answers to questions within a legal context. A forensic dentist can reliably establish the identity of an individual by analysing the teeth and the oral cavity. The study of teeth and the surrounding tissues of the oral cavity for the purpose of establishing the identity of a victim is called dental profiling. By applying the dental profiling techniques, not only age, gender and race of an individual can be determined, but also the data about their socio-economic status, personal habits, oral and systemic health, occupation, diet, familial relationship as well as psychological characteristics. A dental profile is more detailed and reliable if more than one technique is applied. Each individual has their own dental profile which makes them unique and one of a kind. Education in the field of forensic dentistry and techniques of dental profiling is necessary since it contributes greatly to the reputation of the dental profession in other related disciplines as well as in public, and it encourages dentists to view their own achievements from a wider perspective.

***Key words*:** forensic sciences; forensic dentistry; dental profile.

INTRODUCTION

Forensic sciences represent a wide range of various disciplines, which are applied individually or collectively in order to obtain answers to questions within a context of law. Each application of specific scientific methods (independently of the scientific field to which it pertains) within a legal context could be viewed as an aspect of forensic science. Therefore, today there are numerous scientific fields which have their forensic role [1-3]. The field of natural sciences includes forensic medicine, forensic dentistry, forensic anthropology, forensic archaeology, forensic entomology, forensic pathology, forensic botany, forensic toxicology, etc.; in the field of social sciences there are, for example, forensic psychology and forensic psychia-

try [2]. With the advances of modern computer technology and the widespread use of computers, there are many cases of their abuse, which leads to the simultaneous development of forensic computer sciences specialised in network technologies, databases, mobile devices, multimedia, etc.

In obtaining answers to questions from a legal context, which concern people and their health, that is, their life or death, forensic or legal medicine plays a major role. It connects medicine and law, thus forming a specialised scientific basis for assisting in legal procedures relating to medical/health questions, both in civil and/or criminal cases. One of the tasks of legal medicine is identification of victims in individual or mass casualties. Mass casualties mostly occur suddenly and are usually caused by natural disasters (earthquake, tsunami, flood, fire, etc.), traffic accidents (air, naval, railroad, car, etc.) as well as wars and terrorist attacks. There is no unique definition of mass casualties regarding the number of victims. Some experts believe that the death of two people can be seen as a mass casualty, while others consider only accidents including ten or more victims to be mass casualties. However, identification of unknown persons requires an interdisciplinary cooperation and team work, regardless of the number of victims. A forensic identification team usually consists of a forensic medicine specialist, a dentist, an anthropologist, a radiologist and an expert in DNA analysis, and naturally, all in collaboration with police officials [4]. The task of the team is to accurately and reliably match the post-mortem remains of an individual with their real name and surname, that is, to establish their identity in the shortest possible time. In order to accomplish this task, large number of forensic methods and procedures is available.

One of the methods for establishing identity is dental identification performed by a forensic dentist [5-7]. By analysing the teeth and the oral cavity, the forensic dentist can reliably establish an individual's identity. The study of teeth and adjacent dental tissues in the oral cavity for the purpose of establishing the victim's identity is called dental profiling. Dental profiling refers to the making of a dental profile which comprises a group of more or less specific individual characteristics relating to the oral cavity and/or the teeth. Sometimes dental profiling is used not only to establish the identity of an unknown individual, but also to confirm the identity of a known person, which was done in cases of Saddam Hussein, Muammar Gaddafi and Osama bin Laden.

Although dental profiling can be considered a subgroup of oral profiling, since the term points to the teeth and the oral cavity rather than to the teeth only which is the case in dental profiling, in everyday practice the term oral profiling is less commonly used and it refers more to the techniques by which the samples of oral tissues and secretions are taken for forensic purposes. For example, saliva as a body

fluid also represents a biological trace and as such can be the object of a legal and biological testing. Saliva can be found on clothes, handkerchiefs, cigarette butts, etc. [2]. Saliva is used as a source of samples for DNA analysis. Saliva comprises exfoliated epithelial cells in which sufficient amounts of DNA necessary for forensic analysis are contained [8,9].

Dental profiling is carried out by examining the oral cavity and the teeth, by analysing the x-ray images and photographs taken during the victim's life, both the professional ones (dental) an amateur ones, as well as by using certain techniques for special purposes [7]. Techniques used during dental profiling can be invasive and non-invasive. In invasive techniques, the analysed material is partially or completely destroyed, whereas in non-invasive techniques the analysed material remains preserved. Depending on the technique used, the application of invasive techniques is usually technically more complex to perform, and also more expensive and time-consuming, however, the results are often more reliable. Non-invasive techniques are simple, quick and cheap but the results of their application are not always completely reliable. Not only age, gender and race of an individual, but also data on their socio-economic status, personal habits, oral and general health, professional activities, diet, familial relations and psychological characteristics can be obtained by dental profiling techniques. The more techniques are used, the more complete and reliable the dental profile is. When the dental profile is made, the premortem and post-mortem data are compared in order to establish the identity.

THE ASSESSMENT OF AGE, GENDER AND RACE IN THE PROCESS OF DENTAL PROFILING

Age, gender and race are three basic demographic-anthropologic features of each individual. Therefore, the assessment of age at the time of death as well as of gender and race are the most common features which are determined upon dental profiling and as such are basic components of every dental profile.

Techniques for determining the age at the time of death differ depending on whether it is a child or an adult. In children, determining the age at the time of death is based on the analysis of the development and growth of the teeth and jaws, wherein the x-ray and atlas techniques are most commonly used [10]. In x-ray techniques, the stages of development and growth of the teeth, which are visible on the x-ray image of the jaws and teeth of an individual, are analysed and compared with standard values which are characteristic for each technique; they are then evaluated and the conclusions about age are drawn. The best known x-ray techniques for estimating the age of children are techniques by Demirijan, Haavikko, Moorrees and

Cameriere [11-14]. The atlas techniques are similar to x-ray techniques in their procedures. In atlas techniques, the x-ray images of jaws and teeth are compared with images of growth and development of teeth in specific atlases. Probably the most known atlas technique are those developed by Schour and Massler, that is, Ubelaker [5]. The children's age can be estimated accurately up to a month. In adults, age at the time of death is estimated on the basis of dental surfaces wear (abrasion), cranial suture closure, dentin opacity on the apex of the root of tooth, obliteration of the pulp chamber, alveolar bone resorption, accumulation of acellular cementum, root resorption, etc. Numerous methods have been developed for this purpose including one or several mentioned parameters and/or their combinations. the best known methods are those by Gustafson, Johanson, Cameriere and Lovejoy [2,15-19]. The level of accuracy for age estimation of children is higher than the level of accuracy of adults, especially, if the techniques are applied for which nationally specific standards have been developed.

Gender determination in dental profiling is based on analysis of the tooth size, congenital and acquired morphological characteristics of the teeth and their position [20,21]. It is a known fact that men have large teeth in large jaws, and this particularly refers to second molar and the canine. Besides that, in men the difference in mesiodistal diameters between the central and lateral incisor is small. Women have small teeth in small jaws, with pronounced second molar and canine and the difference in mesiodistal diameters between central and lateral incisor is great. The differences in tooth size between men and women are genetically caused. Namely, the Y chromosome increases mitotic potential of the tooth bud, thus stimulating dentinogenesis, whereas amelogenesis is stimulated by the X chromosome. Morphological features of the tooth crown or root which create a difference between men and women may appear due to different thicknesses of the enamel, that is, dentin. However, these features are neither permanent nor always reliable, and can be population-specific. The most common morphological characteristic of the tooth which differentiates men from women is the so-called deflecting wrinkle which represents a variation of the medial ridge on the mesiolingual cusp of the first lower molar, wherein the ridge deflects towards the distolingual cusp. The existence of this wrinkle is a feature which only appears in men [20,21]. Among the acquired morphological characteristics which differentiate men from women, tooth abrasion is the most important. Due to stronger masticatory muscles and greater masticatory forces, men experience more tooth wear than women, which may lead to a lowered tooth crown height. On the other hand, women are more prone to oral ornaments and dental jewellery. Men can also be differentiated from women by the position of the teeth in the jaw. In women, teeth are placed in a dental arch which has a shape

of a semi-ellipsis or a parabola, whereas in men, the teeth are placed in a U-shaped arch [15]. The upper canines are particularly prominent in men, which contributes to the square shape of the upper jaw. The gender of a child's skeleton is determined on the basis of comparison between teeth calcification and the degree of development of the postcranial skeleton. The speed of teeth calcification is identical for boys and girls, whereas the postcranial skeleton develops more quickly in girls. If the age estimation obtained on the basis of teeth calcification corresponds with the estimation obtained on the basis of postcranial skeleton development, it is a boy. If the estimations differ, it is a girl [2].

Morphological characteristics of teeth on the basis of which it is possible to differentiate the races were determined by numerous dental anthropological studies. It is a known fact that Caucasians have a characteristically high prevalence of Carabelli cusp, reduced number of dental cusps and simplification of the fissure system. Asians have a high prevalence of shovelled incisors, the fissure system of the teeth is complex and there is no reduction of the number of dental cusps. The black races neither have a high degree of Carabelli cusp prevalence, nor the shovelled incisors; however, they have a complex fissure system and the usual number of cusps on the teeth [2,15,21].

THE EVALUATION OF THE SOCIO-ECONOMIC STATUS IN DENTAL PROFILING

The evaluation of an individual's socio-economic status for the purpose of dental profiling is carried out when there is a justified reason for it on the basis of the dental examination. Namely, the evaluation of socio-economic status cannot be made solely on the basis of healthy, intact teeth. However, if there are visible traces of dental work on the teeth and/or the jaws, such an evaluation is possible. Nowadays, poorly maintained teeth, with a great number of caries, with old and inadequate fillings (most commonly amalgam fillings), numerous extracted teeth and with prosthetic replacements fabricated from cheap materials, point to a person of a low income status. On the other hand, aesthetically pleasant, treated teeth, with high-quality fillings (newer materials, for example, composites), with dental implants, orthodontic appliances and possible dental ornaments point to a person of a high income status.

DETECTION OF PERSONAL HABITS IN DENTAL PROFILING

Many personal habits leave permanent or semi-permanent trace on the teeth, which can be very important in dental profiling and in determining the identity

of an individual. Long-term and frequent smoking habit can cause discoloration of teeth (particularly on lingual surfaces of lower teeth) and rapid accumulation of dental plaque. Excessive and incorrect use of oral hygiene products such as tooth brushes, dental floss or tooth picks can cause specific defects on hard dental tissues (particularly in cervical parts of the teeth). On the basis of these defects, it is sometimes possible to differentiate between right and left-handed people. Open bite, cross bite and protruded incisors can indicate numerous inappropriate habits in children such as excessive sucking of the pacifier, thumb sucking, etc.

ASSESSMENT OF SYSTEMIC AND ORAL HEALTH STATUS IN DENTAL PROFILING

The oral cavity mirrors the health of an individual. Numerous systemic diseases can manifest and be recognised in the oral cavity because they cause changes and leave marks on both the soft and hard tissues of the oral cavity. Systemic diseases which cause changes on teeth and bones of the oral cavity are particularly important to dental profiling because the soft oral tissues are unstable and decay quickly.

Early childhood diseases accompanied by a fever which occur while the teeth are still developing can cause hypoplasia of the enamel, which becomes visible only when permanent teeth erupt. Genetic disorders of dental tissue development such as *amelogenesis imperfecta* and *dentinogenesis imperfecta* become visible on the teeth soon after their eruption [22]. The quality of hard dental tissues affected by such diseases is poor and such teeth wear and decay more quickly. Poor and inadequate diet accompanied by malnutrition can also cause disturbances and disorders in normal metabolism of soft and hard oral tissues. This can manifest as hypoplastic defects of the enamel (both linear and spotted), and on the supportive system of teeth in the form of higher susceptibility to periodontal diseases and increased mobility of teeth (such as scurvy), which leads to them falling out too early [23]. In elderly women, osteoporosis reduces density of temporomandibular bones making them unsuitable for implant-prosthetic treatment. In individuals with eating disorders (bulimia/anorexia) who frequently vomit, there are characteristic erosive changes on the teeth. People who underwent head and neck radiation often suffer from radiation disease. In the oral cavity, it manifests itself by a decrease in salivary secretions and by an increase in dental caries. When determining the oral health status for the purpose of dental profiling all dental caries, dental trauma, abscesses, periodontal diseases, orthodontic anomalies and, naturally, all dental treatments, including those which are visible only on radiographs, should be carefully recorded. These post-mortem dental data have a great importance when it comes to comparison with

dental data which were recorded during life and can be essential for determining the identity of an individual [5].

PROFESSIONAL ACTIVITIES AND DENTAL PROFILING

In the past, apart from mastication (biting, grinding and crushing food), the teeth were used as tools for work. They were used to tan leather, fabricate ropes, nets and many other household utensils. All these activities left specific traces on hard dental tissues on the basis of which the profession of an individual could be guessed. Nowadays, teeth are less used for non-dietary purposes, but in certain professions, it is still possible to find dental defects characteristic for a certain profession. Specific defects can appear on the incisal edges of upper and lower incisors of glass-blowers, shoemakers and musicians who play wind instruments. The shape of such defects matches the shape of the object these individuals hold in their mouths daily during work, such as blowpipes, nails, mouthpieces, etc. Individuals who work in chemical industry and professional swimmers (in pools) can be exposed to long-term effects of chemical substances (such as chlorine) which erode the dental enamel, thus creating erosive defects.

RECONSTRUCTION OF DIETARY HABITS IN DENTAL PROFILING

By detailed analysis of dental status, which primarily refers to the number, size and position of carious lesions, degree of tooth wear, erosive defects and tooth discoloration, it is possible to reconstruct the dietary habits of an individual [24]. Diet rich in refined carbohydrates, which easily stick to dental surfaces and are difficult to remove from the teeth, is accompanied by high incidence of dental caries. Frequent consumption of hard food and nuts (walnuts, hazelnuts, almonds, sunflower seeds) excessively wears out occlusal dental surfaces (particularly those of posterior teeth) so that islets of exposed dentin which spread out and connect themselves proportionally with age become visible very soon. Sometimes tooth wear caused by a specific dietary pattern can be difficult to differentiate from tooth wear caused by parafunctional movements or bruxism. Frequent nibbling of seeds (such as pistachios) can create specific defects on incisal edges of incisors. Long-term and excessive consumption of acid and carbonated beverages undoubtedly leads to erosive changes on hard dental tissues [25].

DETERMINING FAMILIAL RELATIONS BY DENTAL PROFILIONG TECHNIQUES

Sometimes dental profiling techniques are used to determine familial relations among the victims' remains. This is possible by analysing the morphological characteristics of the teeth and by odontometrics [26]. Since the level of reliability of results obtained in such a way is relatively low compared with other techniques for determining familial relations (such as DNA analysis), and since it requires certain population standards and extensive statistic analysis, familial relations are determined in such a way only in exceptional situations when there are no other possibilities.

ASSESSMENT OF PSYCHOLOGICAL CHARACTERISTICS BASED ON THE DENTAL PROFILE

By making a dental profile on the basis of teeth and oral cavity examination, it is possible to roughly sketch certain psychological characteristics of an individual. Poor oral health with decayed teeth and untreated dentition can indicate a depressed person with a lack of motivation to preserve his/her own health, possibly even life. In exceptional situations, if it is a little child or an elderly person, that is, persons who were supposedly incapable of caring for their oral health, there is a possibility of dental neglect [15]. In individuals with severely worn out teeth, which is not in accordance with their age, bruxism (involuntary teeth grinding) should be suspected. The causes of bruxism are different, but stress is among the most common ones.

CONCLUSION

Each person has their own dental profile which makes them unique and inimitable. Therefore, making a dental profile has great practical value in the process of determination of identity. Possibilities of dental profiling by using new scientific and technological achievements should be developed in collaboration with experts from other forensic sciences. Education of dentists in the field of forensic dentistry and techniques of dental profiling is necessary because it contributes to the reputation of the dental profession both among other related disciplines and in public, while simultaneously encouraging dentists to view their own work from a wider perspective.

References

[1] *Ruffell A.* Forensic pedology, forensic geology, forensic geoscience, geoforensics and soil forensics. Forensic Sci Int. 2010 Oct 10;202(1-3):9-12.

[2] *Zečević D*. Sudska medicina i deontologija. Zagreb: Medicinska naklada 2004.

[3] *Ubelaker DH*. The forensic evaluation of burned skeletal remains: a synthesis. Forensic Sci Int. 2009 Jan 10;183(1-3):1-5.

[4] *Zietkiewicz E, Witt M, Daca P, Zebracka-Gala J, Goniewicz M, Jarzab B, et al.* Current genetic methodologies in the identification of disaster victims and in forensic analysis. J Appl Genet. 2012 Feb;53(1):41-60.

[5] *Brkić H*. Forenzična stomatologija. Zagreb: Školska knjiga 2000.

[6] *Gnanasundaram N.* Tooth for truth (The glory of forensic dentistry). J Forensic Dent Sci. 2010 Jul;2(2):51-2.

[7] *Pretty I, Sweet D.* A look at forensic dentistry - Part 1: The role of teeth in the determination of human identity. Brit Dent J. 2001;190(7):359-66.

[8] *Muruganandhan J, Sivakumar G*. Practical aspects of DNA-based forensic studies in dentistry. J Forensic Dent Sci. 2011 Jan;3(1):38-45.

[9] *Primorac D*. Analiza DNA u sudskoj medicini i pravosuđu. Zagreb: Medicinska naklada 2008.

[10] *Albert AM, Ricanek K, Jr., Patterson E.* A review of the literature on the aging adult skull and face: implications for forensic science research and applications. Forensic Sci Int. 2007 Oct 2;172(1):1-9.

[11] *Demirjian A, Goldstein H, Tanner JM.* A new system of dental age assessment. Hum Biol. 1973 May;45(2):211-27.

[12] *Haavikko K*. Tooth formation age estimated on a few selected teeth. A simple method for clinical use. Proc Finn Dent Soc. 1974 Feb;70(1):15-9.

[13] *Cameriere R, Ferrante L, Liversidge HM, Prieto JL, Brkic H.* Accuracy of age estimation in children using radiograph of developing teeth. Forensic Sci Int. 2008; April 7;176(2-3):173-7.

[14] *Moorrees CF, Fanning EA, Hunt EE, Jr*. Age Variation of Formation Stages for Ten Permanent Teeth. J Dent Res. 1963 Nov-Dec;42:1490-502.

[15] *Clement JG, Ranson DF.* Craniofacial identification in forensic medicine. London: Arnold 1998.

[16] *Solheim T.* Dental root translucency as an indicator of age. Scand J Dental Res. 1989 Jun;97(3):189-97.

[17] *Solheim T*. Amount of secondary dentin as an indicator of age. Scand J Dent Res. 1992 Aug;100(4):193-9.

[18] *Solheim T, Kvaal S*. Dental root surface structure as an indicator of age. J Forensic Odontostomatol. 1993 Jun;11(1):9-21.

[19] *Gustafson G.* Age determination on teeth. J Am Dent Assoc. 1950 Jul;41(1):45-54.

[20] *Alt KW, Rosing FW, Teschler-Nicola M*. Dental anthropology: fundamentals, limits, and prospects. Wien; New York: Springer 1998.

[21] *Scott GR, Turner CG.* The anthropology of modern human teeth: dental morphology and its variation in recent human populations. Cambridge: Cambridge University Press 1997.

[22] *Šutalo J.* Patologija i terapija tvrdih zubnih tkiva. Zagreb: Naklada Zadro 1994.

[23] *Newman MG, Takei HH, Carranza FA*. Carranza's clinical periodontology. 9th ed. / [edited by] Michael G. Newman, Henry H. Takei, Fermin A. Carranza. ed. Philadelphia; London: W.B. Saunders 2002.

[24] *Vodanovic M, Brkic H, Slaus M, Demo Z*. The frequency and distribution of caries in the mediaeval population of Bijelo Brdo in Croatia (10th-11th century). Arch Oral Biol. 2005 Jul;50(7):669-80.

[25] *Brkić H, Čuković Bagić I, Plančak D, Rustemović N, Tarle Z.* Dentalna erozija – etiologija, dijagnostika, terapija. Zagreb: Školska knjiga 2011.

[26] *Kolesnikov LL, Pashinyan GA, Abramov SS*. Anatomical appraisal of the skulls and teeth associated with the family of Tsar Nicolay Romanov. Anat Rec. 2001 Feb;265(1):15-32.

Sažetak

Dentalno profiliranje u forenzičkim znanostima

Izrada dentalnog profila najčešće se koristi u forenzičkim i arheološkim istraživanjima kada zbog nedostatka prijesmrtnih dentalnih podataka nismo u mogućnosti postići identitet nepoznatih ljudskih ostataka, već je potrebno na temelju statusa zubala nastojati postići dobnu, spolnu te rasnu pripadnost. Problem koji se danas javlja u visoko razvijenim zemljama svijeta je velika količina imigranata iz Afrike i Azije koji ilegalnim ulascima nastoje pridobiti državljanstvo. Oni su obično bez osobnih dokumenata pa im se ne zna ime i prezime niti starost odnosno jesu li maloljetni ili punoljetni. U takvim je slučajevima procjena dentalne dobi uz vanjska fenotipska obilježja često jedini način za određivanje nečijeg profila.

U ovom radu prikazujemo rezultate određivanja dentalne dobi pomoću europske formule prema Camerieru, a koja se bazira na širini otvorenih korijenskih kanala za vrijeme rasta i razvoja. Uzorak u ovom istraživanju činilo je 500 ortopantomograma djece u dobi od 5 do 16 godina iz nekoliko mediteranskih zemalja: Hrvatska, Slovenija, Italija i Španjolska. Rezultati su pokazali da određivanje dentalne dobi postupkom po Camerieru pokazuje blago odstupanje od kronološke dobi: 0,081 godina za djevojčice i 0,036 za dječake. Rezultati su također pokazali da na promatranom uzorku djece iz različitih mediteranskih zemalja nema razlike u postignutoj dentalnoj dobi u odnosu na kronološku dob. Dobiveni rezultati omogućavaju korištenje europske formule za dentalnu dob na uzorku djece iz Hrvatske.

Ključne riječi: forenzičke znanosti; forenzička dentalna medicina; dentalni profil.

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