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JOURNAL of FORENSIC ODONTO-STOMATOLOGY
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SECTION BITE MARKS

Analysis of Bite Marks in Foodstuffs by Computed Tomography (Cone Beam CT) - 3D Reconstruction

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The authors declare that they have no conflict of interest.

ABSTRACT

The use of three-dimensional (3D) analysis of forensic evidence is highlighted in comparison with traditional methods. This three-dimensional analysis is based on the registration of the surface from a bitten object.

The authors propose to use Cone Beam Computed Tomography (CBCT), which is used in dental practice, in order to study the surface and interior of bitten objects and dental casts of suspects. In this study, CBCT is applied to the analysis of bite marks in foodstuffs, which may be found in a forensic case scenario.

6 different types of foodstuffs were used: chocolate, cheese, apple, chewing gum, pizza and tart (flaky pastry and custard). The food was bitten into and dental casts of the possible suspects were made. The dental casts and bitten objects were registered using an x-ray source and the CBCT equipment iCAT® (Pennsylvania, EUA). The software InVivo5® (Anatomage Inc, EUA) was used to visualize and analyze the tomographic slices and 3D reconstructions of the objects. For each material an estimate of its density was assessed by two methods: HU values and specific gravity.

All the used materials were successfully reconstructed as good quality 3D images. The relative densities of the materials in study were compared. Amongst the foodstuffs, the chocolate had the highest density (median value 100.5 HU and 1,36 g/cm^3), while the pizza showed to have the lowest (median value -775 HU and 0,39 g/cm^3), on both scales. Through tomographic slices and three-dimensional reconstructions it was possible to perform the metric analysis of the bite marks in all the foodstuffs, except for the pizza. These measurements could also be obtained from the dental casts. The depth of the bite mark was also successfully determined in all the foodstuffs except for the pizza.

Cone Beam Computed Tomography has the potential to become an important tool for forensic sciences, namely for the registration and analysis of bite marks in foodstuffs that may be found in a crime scene.

***KEYWORDS*:** Cone Beam CT, bite mark, foodstuff, three-dimensional analysis

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INTRODUCTION

Both the bite mark and the dentition that inflicts it are three-dimensional phenomena [1]. The bi-dimensional registration of 3D structures implies distortion and loss of information [2]. However, the majority of the scientific community continues to describe and quantify the bite patterns in two dimensions [1]. The recent development of three-dimensional methods for bite mark analysis has become a highlighted procedure when compared to the traditional methods [3-5].

In 2003, Thali *et al.* [6] presented a new 3D method for bite mark analysis on skin, based on forensic 3D/CAD supported photogrammetry and the use of a 3D surface scanner. According to Evans *et al.*, despite the fact that this method has been validated in court, it is still very expensive and the error range is up to 1mm [7].

In 2007, Martin-de las Heras *et al* [3], studied bite marks in pig skin with a 3D contact scanner (Picza®) and a software for bite mark analysis (Dentalprint®). The scanner used has limitations due to the reduced number of registration axes, lack of mobility and slow capture time [7]. This method uses bite impressions [7].

Also in the year 2007, Blackwell *et al.* [1] presented a method of bite mark analysis by means of a laser scanner (ModelMaker H40®). In this study there were simulated bite marks in wax. This technique uses the impression of the bite marks [7] and the use of powder sprays to give the surfaces a matt finish and achieve maximum laser signal [1]. The time of capture is from 15 to 30 minutes [1].

By 2011, Evans *et al.* [7] simulated a bite mark with Photoshop®, and applied it on a prosthetic arm. This pseudo bite mark and the dental casts of the biter were registered by stereophotogrammetry (MAVIS Nikon®) and laser scanner (Vivid® 910). The MAVIS system was able to effectively produce the 3D image of the pseudo bite mark and the Vivid 910® adequately recorded the dental casts. According to the authors, to collect all the required data for three-dimensional analysis the MAVIS camera and the laser scanner must be used in conjunction [7,8]. Furthermore, the MAVIS system has an error range of +/- 1mm [7].

Naether *et al*. [2], in 2012, used 3D optical surface scanning technology (GOM ATOS 3D) for the documentation of bite marks in foodstuffs and to register the dental casts of the biters. For a successful scan, sprays had to be used to decrease the reflection factor of the surface of the objects [2].

Computed Tomography (CT) uses a source of ionizing radiation, an object and an image detector. The final image in a grayscale, results from the radiation absorbed by each component of the object [10]. The CT technique allows an accurate 3D reconstruction [11].

Cone Beam Computed Tomography, specially developed for the imaging of the structures pertinent to dentistry, uses relatively small equipment, with lower costs and lower radiation doses (15 times lower) than a conventional CT [11-14]. The images are obtained in series of DICOM files (*Digital Imaging and Communication in Medicine*), that can be analyzed through several different software suites [12].

From the tomographic images it is possible to obtain panoramic and cephalometric images, as well as 3D reconstructions. Nowadays, the latter are essentially applied in the fields of implantology, orthodontics and temporomandibular joint disorders [12,14].

The aim of this paper was to study the surface and interior of the bitten objects by Cone Beam Computed Tomography, which is used in dental practice. In this study, CBCT is applied to the analysis of bite marks in foodstuffs, which may be found in a forensic case scenario.

MATERIAL AND METHODS

Six different types of foodstuffs were used: chocolate (Nestle® Chocolat Brut,

Switzerland), cheese (Babybel®, France), apple (royal gala 70/80, cat. II, Portugal), chewing gum (Trident Senses®, Strawberry, France), pizza (Pizza Hut®, Margherita) and a custard tart. The flaky pastry of the tart contains flour, salt and butter and the custard is composed of milk, sugar and eggs. The food was bitten into and dental casts of the hypothetical suspects were made.

The dental casts were made using alginate impression material (Orthoprint®, Zhermack, Italy) and type III stone (Dental hydrocal®, Kerr, Germany) prepared according to manufacturer's specifications and in conjunction with accepted dental laboratory techniques.

Both the dental casts and bitten objects were registered using an x-ray source and the CBCT equipment iCAT® (*Imaging Sciences International, Pennsylvania, EUA*). All the images were captured with a field of view (FOV) of 16cm diameter and 6 cm height, a voxel size of 0,2mm and an exposure time of 14.7 seconds.

The software InVivo5® (*Anatomage Inc, EUA*) was used to visualize and analyze the images. An estimation of the density of the foodstuffs and dental casts was accessed by determining HU values in 6 different points for each material. To validate this data a comparative analysis was made with the specific gravity of the objects. The objects were analyzed both through the tomographic slices and the 3D reconstructions. The DICOM images were analyzed by two observers in different time periods.

RESULTS

The study obtained series of DICOM images corresponding to the axial, sagittal and coronal slices, from all the sampling (fig.1). Of all the materials in study, the dental cast had the highest density both in a grayscale evaluation (qualitative) and specific gravity (g/cm^3). Amongst the foodstuffs, the chocolate had the highest density (median value 100.5 HU and 1,36 g/cm^3), while the pizza was shown to have the lowest (median value -775 HU and 0,39 g/cm^3), in both scales. Our results supported that, and within our grayscale, chocolate is hyperdense [52HU;136 HU] and pizza is hypodense [-981 HU; -44HU]. Furthermore, for the dental casts results between -147HU and 2029HU were reported.

All the foodstuffs and dental casts were analyzed in the tomographic slices and the 3D reconstructions. In all the foodstuffs marks caused by both of the dental arches were present. Therefore, using metric and anatomic parameters it was possible to distinguish between the upper and lower dental arches.

The mesio-distal diameters of teeth and intercanine distances were successfully measured in the dental casts and in all the foodstuffs, except the pizza (figs.2 and 3). These anatomic references for bite mark analysis of anterior teeth were identified in the DICOM images from the foodstuffs. Our results demonstrate that teeth can transfer their unique features to the bitten substrate. The interobserver differences were not significant in this study. Indentifying features in the bite marks like the shape of the arch, diastema or teeth misalignment could be recognized (fig. 4).

The cheese, chocolate, chewing gum and apple were demonstrated to have the best properties for the registration of the bite marks, while the pizza was the worst (fig.6).

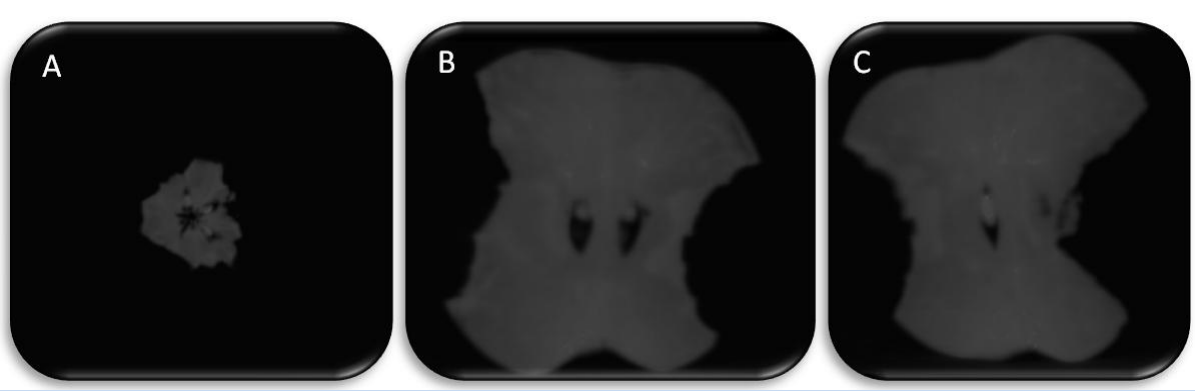

Fig. 1: Visualization of the apple . In **A**: an axial slice, in **B**: a sagittal slice and in **C:** a coronal slice.

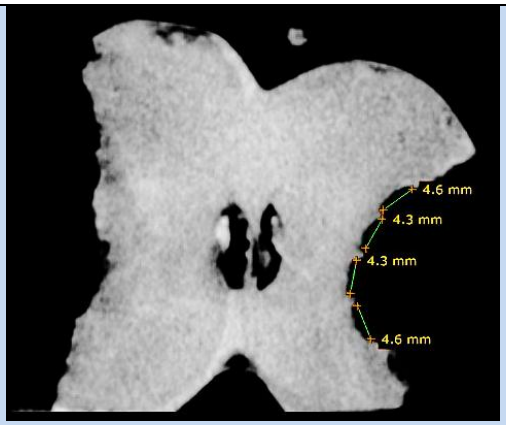

Fig. 2: Tomographic slice of the apple. Measurement of the mesio-distal diameters of the lower incisors.

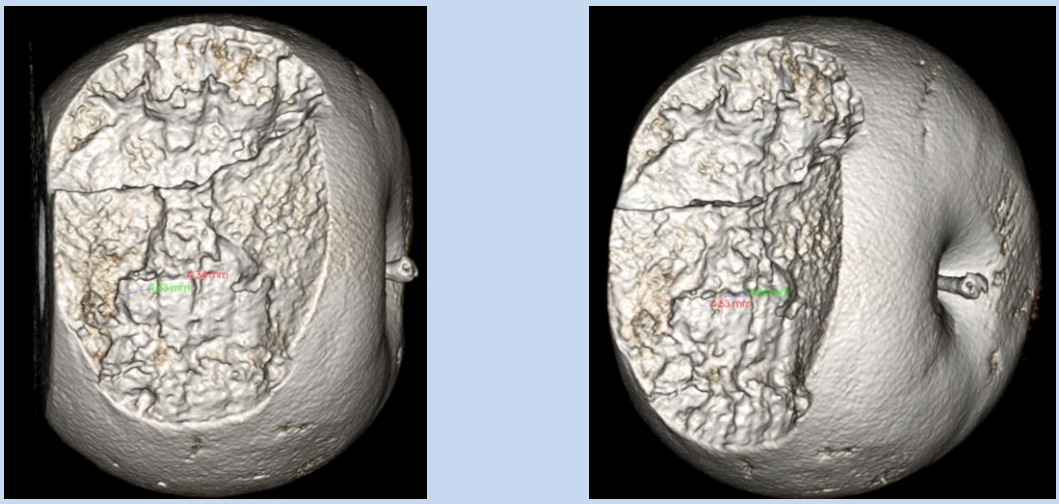

Fig. 3: 3D reconstruction of the apple. Measurement of the diameters of the left lower incisors. Left and right images correspond to different spatial orientations of 3D reconstruction with the same dimensions.

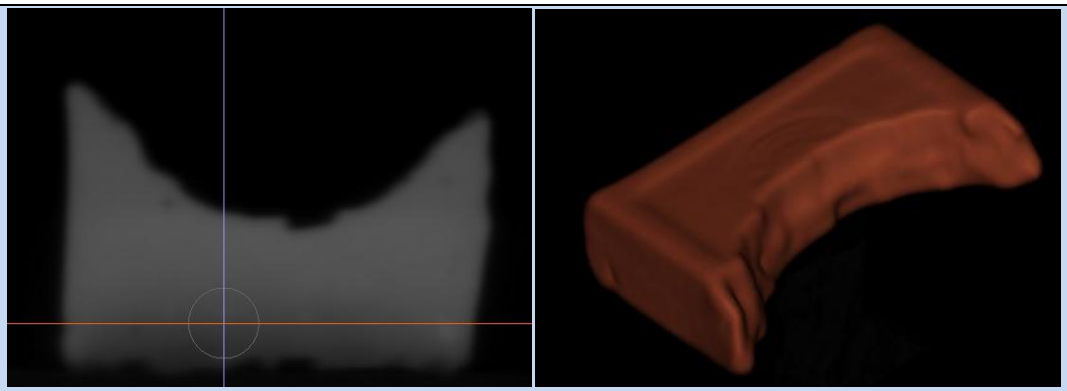

Fig. 4: Images of the chocolate. Both in the tomographic slice (left) and in the 3D reconstruction (rigth) the buccal displacement of the right lower incisor is visible

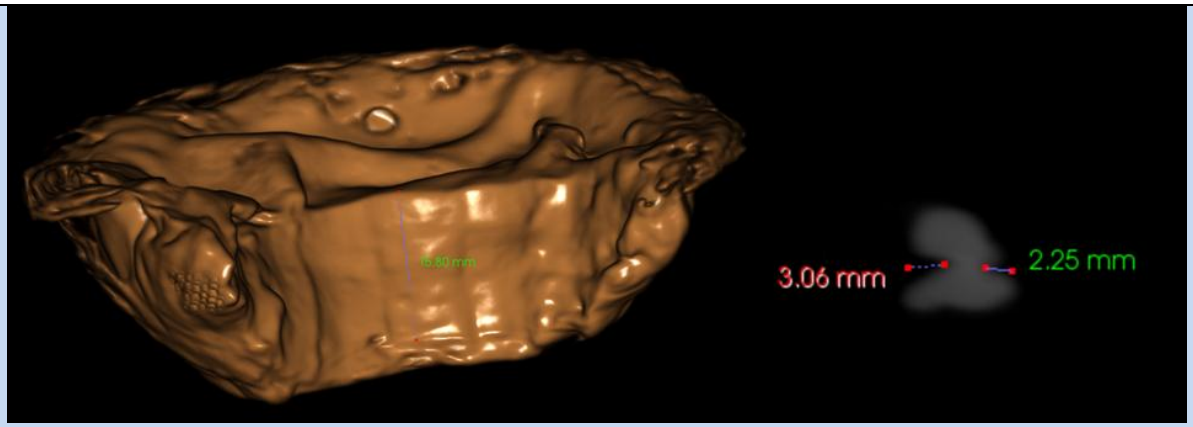

Fig. 5: Measurement of a bite mark's depth in the 3D reconstruction of the tart (left) and in a tomographic slice of the chewing gum (right).

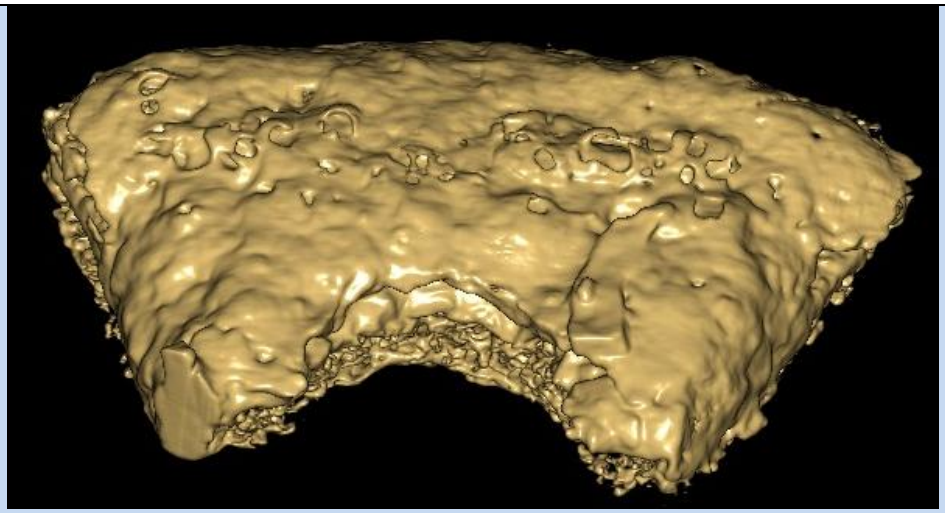

Fig. 6: 3D reconstruction of the pizza.

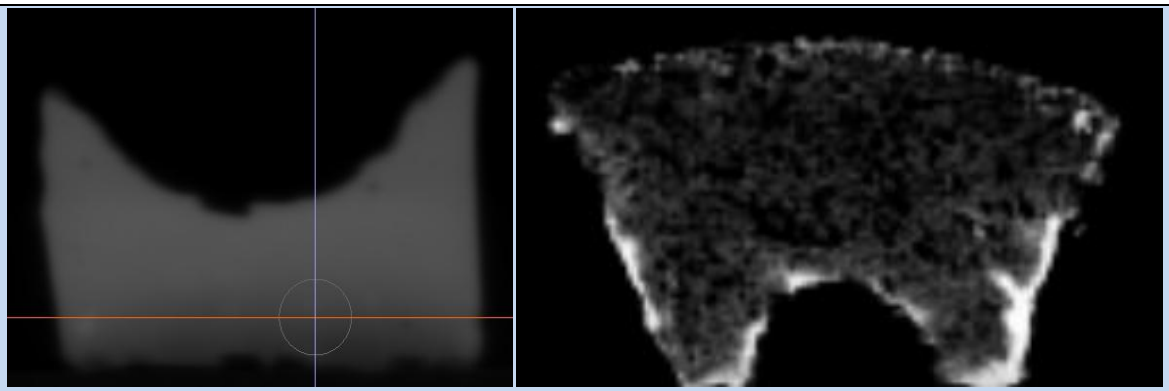

Fig. 7: Tomographic slices of the pizza (left) and chocolate (rigth) displaying the pizza's heterogeneous and porous constitution and the chocolate's homogeneous nature.

DISCUSSION AND CONCLUSIONS

The grey levels displayed by CBCT equipments are not representative of "true" HU units, unlike those that can be found in a CT. These values are based upon the device and scanning settings [15]. The absence of a standard scheme for scaling the reconstructed attenuation coefficients makes it difficult to compare values resulting from different machines [16].

Despite the inability of CBCT to precisely display Hounsfield units there is sufficient correspondence between this value and the grey level [16]. In this paper, for all materials, the same equipment and the same registration parameters were used. The image resolution was maximized by using a minimum voxel size (0.2mm) and a long time of exposure (14.7 seconds). Hounsfield units were used, as an internal tool, to predict a comparative analysis of density. Though the HU obtained may not correspond to the correct density of the objects, we can estimate their relative density and predict which are hyperdense or hypodense. These results were supported by those obtained in the specific gravity analysis.

We can discuss our results considering the heterogeneity and homogeneity of the materials in study. The difference between heterogeneous and homogeneous mixtures is the extent to which the materials are uniformly mixed. A homogeneous mixture consists of components which are uniformly distributed throughout the mixture. A heterogeneous mixture has a composition where the components are not uniformly distributed or have localized regions with different properties.

In our sample, the more heterogeneous foodstuffs had the more variable HU values. For example, the pizza had the highest standard deviation amongst the foodstuffs due to its heterogeneous and porous nature. The chocolate, which is homogeneous, had the lowest (fig.7).

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SECTION IDENTIFICATION

CORRELATION BETWEEN LIP PRINTS AND FINGER PRINTS IN SEX DETERMINATION AND PATTERN PREDOMINANCE IN 5000 SUBJECTS

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ABSTRACT
Fingerprints are considered to be the most reliable criteria for personal identification. In the past decades, lip-print studies (Cheiloscopy) attracted the attention of many scientists as a new tool for human identification in both civil and criminal issues.
The present study was undertaken to observe the correlation between lip prints and finger print pattern in sex determination and to determine the pattern predominance in a sample of 5000 individuals. The study was carried out in 5000 individuals in Department of Oral Medicine and Radiology of Maharishi Markandeshwar College of Dental Sciences and Research, M.M. University, Mullana. Of the participants, 2500 were males and 2500 females. Lip prints and finger prints of the right hand were collected then studied and analyzed statistically. For lip prints TSUCHIHASHIS Y. classification (1970) was followed; HENRYS classification(1897) was followed for finger prints. Whorls were of a high frequency in males, but females presented with a high frequency of loops. Type I, I', II lip print pattern was most predominant in females while Type III and Type IV was most predominant in males. The present study described in detail that for both males and females, the most predominant lip-print patterns showed an association with the respective predominant finger print patterns. The establishment of a database of Cheiloscopy and Dactyloscopyis recommended for all individuals in a certain locality, which could be used as a reference in civil litigations and criminal cases.
Such studies may be useful particularly in Forensic science and in justice.

KEYWORDS**:** Human identification, Civil and criminal, Cheiloscopy, Dactyloscopy

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INTRODUCTION

Forensic science is considered a modern development. Human identification is one of the most challenging subjects that man has confronted[1]. The professional obligation of the dental surgeon to mankind is not only to serve in examination , investigation, diagnosis and treatment of oral and orofacial diseases of local and systemic origin but also to serve in other community functions

With the ever-increasing demands placed upon law enforcement to provide sufficient physical evidence linking a person to a crime, it makes sense to utilize any type of physical characteristic to identify suspects guilty of a particular offense. Finger prints also play a primary role in identifying the sex of an individual, thus serving as an important tool for identification purposes. The study of fingerprints is used in identification. Fingerprint recognition is among the most widely used of biometric systems. The use of fingerprint recognition has expanded to personal authentication and government-to-citizen applications as well. [2]

Another emerging method of human identification and sex determination is human lips recognition, known as Cheiloscopy. Fischer was the first anthropologist to describe the furrows on the red part of the human lips in 1902. The use of lip prints for personal identification was first recommended by French criminologist Edmond Locard in 1932.

According to FBI and the Illiniosis state police lip print identification methodology is very similar to finger print comparison and is a known and accepted form of scientific comparison.[3] Lip prints have the same value as finger print traces. There are normal lines and fissures in the form of wrinkles and grooves present in the zone of transition of human lips between the inner labial mucosa and the outer skin.

Lip prints are unique and do not change during the life of a person. It is safe to assume that cheiloscopy in its present stage of development has surprassed the limits of its methodology and has become a means of criminalistic identification.[4]

A possible correlation between lip print pattern and fingerprint pattern of an individual may help in sex determination of an individual and may be very advantageous in criminal and forensic practice.

The aim of this study was to find a possible correlation between lip print- and finger print pattern in a group of males and females and the role of lip prints in sex determination. The objectives of the present study were: to determine the predominant lip print pattern in males and females, to determine the predominant finger print pattern in males and females ,to establish whether there is a correlation between lip print pattern and finger print pattern and to establish whether lip print pattern and finger print patterns can be of use in sex determination.

MATERIAL AND METHODS

This study was undertaken in a group of 5000 subjects between 20 to 50 years of age, comprising of 2500 males and 2500 females. The present study was carried out in the Department of Oral Medicine and Radiology of Maharishi Markandeshwar College of Dental Sciences and Research, M.M. University, Mullana. Ethical clearance from the institution was obtained to carry out the study.

Collection of prints: The subject was asked to open the mouth and a dark coloured lipstick was applied on the vermillion border with the help of brush with a single stroke. The subject was asked to rub both the lips to spread the applied lipstick. The subject was asked to keep the mouth stationary during the procedure. The glued portion the cellophane tape was applied to the lip. It was held in place by applying gentle and even pressure for a few seconds. Then the tape was carefully lifted from the lip, from one end to the other, avoiding any smudging of the print.

The strip of cellophane was stuck on to a white A4 sheet. This served as a permanent record of the lip print.
Next, the finger prints of the right hand of the subject were taken with the help of an ink stamp pad. Right hand impressions were taken as approximately 85 percent of people are right-handed and this is the side that most Government Agencies collect. The impressions of all the five fingers were taken on the same A4 size sheet as the lip prints . Each A4 size sheet was individually numbered.

Examination of prints: Both registrations were then visualized with the help of magnifying lens so as to check the respective pattern. The prints were examined with the help of a magnifying lens.
The lip pattern grooves in middle 1 cm of lower lip were noted and the grooves were classified according to Tsuchihashis Y. Classification from types I to type IV and the classification recorded on the A4 sheet.

Fig.1: Tsuchihashis Y classification (1970).
Type I: Vertical, comprising of complete [end to end] longitudinal fissures/patterns. Type I': Incomplete longitudinal fissures. Type II: Branching Y shaped pattern. Type III: Criss-cross pattern. Type IV: Reticular, typical chequered pattern, fence like.

The finger print patterns were noted according to Henrys' classification and were recorded on the same A4 sheet.
The lip print pattern and the finger print pattern obtained in males and females were recorded. The obtained data was subjected to statistical analysis using Pearson Chi-Square Test. The results were statistically significant. Chi-square test is the most used method for data comparison in a categorical nominal scale (Arango 2009). Through this method the analysis is made based on the existence of dependency between the variables under observation.

RESULTS

The mean age of the females was 29.78 years with a standard deviation of 8.127 whereas the mean age of the males was 29.89 years with a standard deviation of 8.196

The results showed that Type I lip print pattern was present in 800 females or 32% and 253 males or 10.1%. Type I' lip print pattern was present in 635 females or 25.4% and 343 males or 13.7%. Type II lip print pattern was present in 673 females or 26.9% and 440 males or 17.6%. Type III lip print pattern was present in 854 males or 34.2% and 257 females or 10.3%. Type IV lip print pattern was present in 610 males (24.4%) and 135 females (5.4%).

Fig.2: Henrys' classification (1897).

In females, the highest incidence was Type I at 32.0%, with a p value less than 0.001,Type I' was present in 25.4% of the females, with a p value less than 0.001, Type II was present in 26.9% of the females, with a p value less than 0.001.
Thus it showed that the incidence of Type I, I' and Type II lip print patterns in females were statistically significant.
Among the males, the highest incidence was Type III at 34.2%, with a p value less than 0.001. Type IV was present in 24.4% of the males with a p value less than 0.001.
Thus it showed that the incidence of Type III and Type IV lip print patterns in males were statistically significant. Hence, it was concluded that Type I, I' and Type II lip print patterns were predominant in females and Type III and Type IV lip print patterns were predominant in males.
The statistics seem poor. Only 56.6 % of males fall within Types III and IV, so 43.4% fall into the "female" group of Types I, I' and II; this seems a poor discriminator of the male sex.

The results showed that Loops finger print pattern was present in 63.4% of females and 42.2% of males. Whorls finger print pattern was present in 44.0% of males and 20.4% of females. Arches finger print pattern was present in11.5% of females and 9.5% of males. Double loops finger print pattern was present in 3.7% of males

and 3.7% of female, showing that the Double loops finger print pattern distribution was equal in both the sexes. Pocket loops finger print pattern was present in 0.3% of females and 0.1% of males. Tent arches finger print pattern was present in 0.9% of females and 0.4% of males.

The sex wise distribution showed that among the females, the highest incidence of finger prints pattern was of Loops pattern which was 7923 of 12500 at 63.4%, with a p value less than 0.001.

The sex wise distribution showed that among the males, the highest incidence of finger prints pattern was of whorls pattern which was 5499 out of 12500 at 44.0%, with a p value less than 0.003

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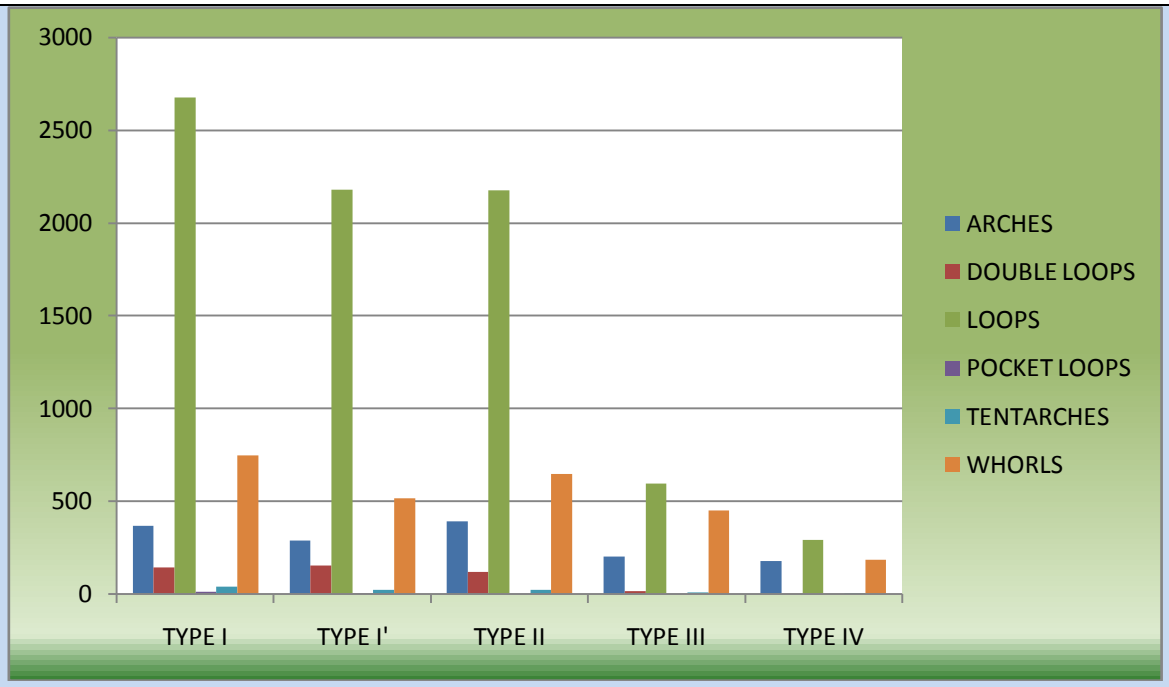

Fig.3: Correlation of lip print and finger print pattern in females

Among the sample of females, it was seen that the females with a predominant Finger Print Pattern of Loops and a predominant Lip Pattern of Type I numbered 2677 at 66.9%. Females with a predominant Finger Print Pattern of Loops and a predominant Lip Pattern of Type I'numbered 2179 at 68.6% .Females with a predominant Finger Print Pattern of Loops and a predominant Lip Pattern of Type II numbered 2175 at 64.6%. The p value was less than 0.0146 showing that these results were statistically significant (Fig 3).

Among the sample of males, it was seen that the males with a predominant Finger Print Pattern of Whorls had a predominant lip pattern of Type III with 2646 at 62%. Males with a predominant Finger Print Pattern of Whorls had a predominant lip pattern of Type IV with 1845 at 60.5%. The p value was less than 0.0001 showing that these results were statistically significant (Fig 4).

DISCUSSION

Identification is necessary for many reasons such as personal, social and legal reasons, including certification of death.[5] Historically, human identification is one of the most challenging subjects that has confronted man. The concept of identity is a set of physical characteristics, functional or psychic, normal or pathological, that defines individual.[1] Personal identification

is necessary for any unknown deceased person in cases of homicide, suicide, accident, mass disaster etc. It is also necessary for locating living individuals who are missing or culprits hiding their identity.[6]

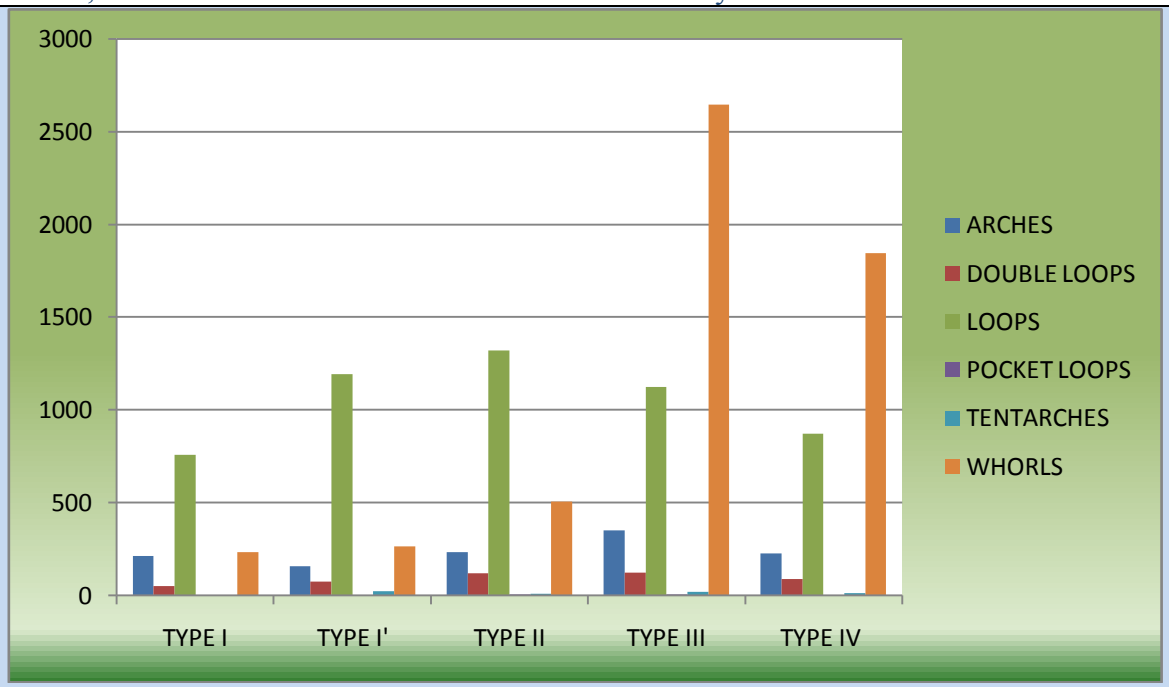

Fig 4: Correlation of lip print and finger print pattern in males

In the past, some researchers have worked on lip prints with the idea of proving that a gender difference does exist in lip print. According to a study by Sonal-Nayak , Type I and Type I' patterns were found to be dominant in females, while Type III and Type IV patterns dominant in males. In a study conducted by Dr. Harpreet Singh, Dr. Pankaj Chhikara et al in 2001, it was concluded that the Type II lip print pattern was most commonly seen in females, whereas Type IV lip pattern was seen most commonly in males. In another study by Gondivkar SM et al in 2009, it was concluded that in males, the predominant lip pattern was Type III lip print pattern, whereas in females, the predominant lip pattern was Type II lip print pattern.[5, 7]

In the case of finger prints are concerned, it was found that loops were more common in the females as compared to the males. In the males, whorls were significantly higher than in the females. This was in accordance with the study conducted by G.G Reddy et al in 1975.[8]

Similar results were obtained by Dr. Prateek Rastogi et al in 2010 and Muralidhar Reddy Sangam et al in 2009 in their studies.[9,10]

In our study, it was found that in the females Type I lip print pattern, Type I' lip print pattern and Type II lip print pattern were most commonly associated with the loop finger print pattern. In the males, Type III lip print pattern and Type IV lip print pattern were most commonly associated with whorl finger print pattern.

But no study has previously been conducted to correlate the predominant lip print and finger print patterns as a tool in sex determination. This is the first such study done with such a large sample size in India

The most predominant lip print pattern was associated with the most predominant finger print pattern in both male and female groups. With the availability of lip and finger patterns and correlation of both the types, it is possible to determine the

gender of an individual in forensic investigations.

CONCLUSSION

The correlation between lip print and finger print patterns would be helpful in various criminal cases, in law and justice. It can help in limiting wrong identifications and will act as an adjunct in forensic sciences.

Identification of an individual, living or dead is based on the theory that all individuals are unique. As more unique characteristics are noted, the comparison group becomes smaller until it reaches unity. At that point, identification can be made. Modern day criminal investigation has reached a point of sophistication requiring the involvement of many disciplines to solve a crime. Each discipline solves a part of puzzle until it is complete. It is important to understand what each forensic expert has to offer.

Many law enforcement agencies remain unaware of the usefulness of lip print and finger print correlation when attempting to identify suspects, and as a result, important evidence is lost. With increasing numbers of unsolved crimes, the criminal justice community must look seriously at any new method that provides the evidence necessary to gain convictions. Law enforcement personnel should begin to consider correlation of lip print and finger print analysis as yet another tool to use for solving crimes.

If the sex of the individual is known, it is easy to short list the array of suspects with motive for the crime. The present study is able to convey that a correlation between lip prints and finger prints would be useful in forensic science for gender determination of an individual.

The result obtained by the present study does not prove to be an infallible method but it does seem to get one step closer to the truth. Although not a 100 % accurate method, the correlation can be used as a supplementary tool in sex determination.

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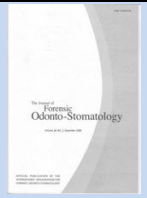


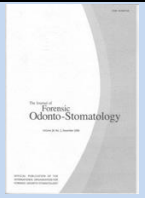

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SECTION ABUSE AND NEGLECT

CHILD PROTECTION: LEGAL AND ETHICAL OBLIGATION REGARDING THE REPORT OF CHILD ABUSE IN FOUR DIFFERENT COUNTRIES

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ABSTRACT

Child protection is the duty of every single member of the society. Health professionals who work with children, such as members of dental team, are in the unique position to recognize signs of physical, sexual and emotional abuse as well as (dental) neglect. They should report any suspected case where a child is or may be in need of welfare. The professional responsibility is regulated by legal and ethical obligations. In this preliminary work the authors investigate the legal and ethical Acts, and the similarities vs. differences in obligations regarding reporting child abuse and neglect (CAN) cases in four countries: Croatia, United Kingdom, Italy and Canada. In all four countries all health professionals have a duty to report their suspicion if a child is in a harmful situation. All of them who fail to report, or even neglect or delay to report a suspicion, are liable on conviction to a pecuniary fine which varies from country to country. Depending on the country, if a professional has reasonable grounds to suspect that a child is or may be in need of protection, must report to: CAS (children's aid society), to CSS (center for social services), to police, to a Juvenile Court, or to the ombudsman. In all four countries, dentists are not asked to diagnose 'child maltreatment', but simply report the suspicion with supportive evidence. Ethical obligation comes from medical and dental ethical codes regulated by the Chamber or Council of Dentists. In all four countries legal and ethical obligations in reporting CAN are similar. Differences are related mostly to fines for nonreporting or a delay in reporting. Expanded investigation through other European countries and standard operational procedures is needed, in order to harmonize policies and guidelines for reporting CAN and maximize children protection.

***KEYWORDS*:** Child abuse, Child neglect, Child protection, Reporting, Legal acts, Ethics

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INTRODUCTION

The United Nations Convention on the Rights of the Child (UNCRC) requires all signatory countries (USA, Somalia and South Sudan are the only non signatory countries) to establish integrated child protection systems to ensure a coordinated response to child abuse and neglect cases.[1] Mandatory reporting of suspected or confirmed child abuse and neglect represents a main strategy to address violence against children. However, health/dental professionals are in a unique position to identify child abuse and neglect cases. Legislation covering child protection can be divided in categories of civil and criminal law. Legislation mandating health/dental professionals to report concerns for child abuse and neglect is available in many countries across the world (as well as in Canada, Croatia, Italy).[2] Some countries such as the United Kingdom do not mandate health professionals to report concerns for child abuse and neglect but give guidance (NSPCC National Society for Protection of Cruelty to Children). Mandatory reporting of child abuse and neglect varies between jurisdictions. Ethical obligation comes from medical and dental ethical codes which are in all four countries regulated by the Chamber or Council of Dentists. In general, ethical obligations cover protection of children, the elderly and the disabled, in particular when the environment, family or the community in which they live is not sufficiently responsive to health care.

REPORTING CHILD ABUSE IN CROATIA

Croatia, as a signatory country of the UNCRC accepts a definition that a child is every human below the age of eighteen years.[3]

Reasonable grounds for suspicion that a child has been abused justify the assessment and decision to report to institutions in charge, which means that the professional, even if s/he does not have sufficient information, is obliged to report the suspicion. The Constitution of Croatia considers children to be a vulnerable group in need of special care and protection by the society and the state. The issue of child protection is thus included in many legal documents: Convention on the Rights of the Child, Social Care Act, Family Law Act, Criminal Code, Patients' Rights Act, Ombudsman for Children Act, Domestic Violence Act, Primary Education Act and Secondary Education Act.[4]

The Family Law Act,[5] Article 108, requires one to inform the Social Welfare Center on violation of any child's rights and especially of all forms of physical or mental violence, sexual abuse, neglect, abuse or exploitation of a child. The Social Welfare Center is obliged, immediately after receipt of the notification, to investigate the case and to undertake the measures necessary for the protection of the child's rights.

The Penal Code,[6] Article 300, requires that anyone aware of a serious criminal offense, for which long-term imprisonment is prescribed by law, that was committed and who to report it, although he knows that by reporting it the discovery of the offense or the perpetrator would be made possible or considerably facilitated, shall be punished by a fine or by imprisonment not exceeding three years.

The Domestic Violence Act,[7] Article 21, states a pecuniary fine of at least 400 € will be imposed upon a person that fails to report domestic violence to the police or the State Attorney's office while performing their professional duties.

The Act on Physicianship,[8] Article 22, states that a medical doctor is obliged to file a report to the police or to the State Attorney's office when during the performance of their duties they suspect that the death or a physical injury to a person occurred due to an act of violence. The doctor is also obliged to file a report when they suspect that the health of an underage person or a person in need of care is seriously endangered by neglect or abuse.In case of a suspicious injury which may be due to domestic violence, the professional is obliged to talk to that person and to help that person confide to them that domestic violence has occurred and to learn the exact personal circumstances of the case.

Children and parents could also consider telephoning the Croatian National Emergency for Minors Resource Center named "Brave Phone".[9] Brave Phone is a non-profit, non-government association established with the aim of the prevention of abuse, neglect and inappropriate behavior of children and youth and of direct help to abused and neglected children and their families. This Help-line is confidential, anonymous, safe and free.
This ethical obligation originates in the dental ethical code which states that doctors should protect the child, the elderly and the disabled.[10]

REPORTING CHILD ABUSE IN THE UNITED KINGDOM

England, Wales, Northern Ireland and Scotland each have their own guidance setting out the duties and responsibilities of organizations to keep children safe, but they agree that a child is anyone who has not yet reached their 18th birthday.[11]
Reporting of child abuse and neglect is not mandatory in the United Kingdom but the General Dental Council (GDC) which has the sole responsibility for protecting patients and regulating the dental team expects all registered members of the dental team to be aware of the procedures involved in raising concerns about the possible abuse or neglect of children and vulnerable adults.[12]
This is embodied in the statement contained in Principle 1.8, 'Standards for dental professional'. The standards guidance is a code of behavior that registrants agree to abide by. This is one of the main ways in which the GDC protect patients, but standards also protect the dental professional by making it clear what is expected of them as a registrant.[13]
Dental professionals have a responsibility to raise any concerns they may have about the possible abuse or neglect of children or vulnerable adults. It is their responsibility to know whom to contact for further advice and how to refer cases to an appropriate authority (such as a local health trust or board). Dental professionals are likely to observe and identify injuries to the head, eyes, ears, neck, face, mouth and teeth, as well as other welfare concerns. Bruising, burns, bite marks and eye injuries are the types of injury that could suggest a concern should be raised.
The web-based resource 'Child Protection and the Dental Team' was specifically developed as an educational resource for dental professionals in 2006. This resource assists in identifying child abuse or neglect.[14] The dental professional is advised that if they make a professional judgment and decide not to share their concern with the appropriate authority, they must be able to justify how they came to this decision and are advised to contact their legal defense organization or professional association for advice. If any dental professional is unsure of the local procedures in their area, then they have a

duty to find out what they are, whether they work for the National Health Service (NHS) or in private practice.

In the United Kingdom there is a free confidential telephone helpline called Childline that is available 24 hours a day. This is funded by the National Society for the Prevention of Cruelty to Children (NSPCC).[15]

orensic science is considered a modern development. Human identification is one of the most challenging subjects that has confronted man. The professional obligation of the dental surgeon to mankind is not only to serve in examination , investigation, diagnosis and treatment of oral and orofacial diseases of local and systemic origin but also to serve in other community functions

With the ever-increasing demands placed upon law enforcement to provide sufficient physical evidence linking a person to a crime, it makes sense to utilize any type of physical characteristic to identify suspects guilty of a particular offense. Establishing a person's identity can be a very difficult process.[1]

REPORTING CHILD ABUSE IN CANADA (ONTARIO)

The age of majority in Canada is determined by each province and territory (18 or 19 years), and for Ontario is eighteen years.[16]

Section 72 of the full legislation on Ontario's Child and Family Services makes provision for general legislation applicable to all members of society regarding duty to report child abuse and neglect. This is general legislation, but there is a specific mention of the duty of dentists.[17,18]

Ontario's Child and Family Services Act (CFSA) recognize that each person has a responsibility for the welfare of children.

All members of the dental team share a responsibility to protect children from harm. This includes situations where children are abused or neglected in their own homes.

Section 72 of the Child and Family Services Act17 states that the public, including professionals who work with children, must promptly report any suspicions that a child is or may be in need of protection to a Children Aid Society (CAS). The Act defines the phrase "child in need of protection" and explains what must be reported to CAS. It includes physical, sexual and emotional abuse, neglect, and risk of harm. Anyone who has reasonable grounds (information that an average person, using normal and honest judgment, would need in order to decide to report) to suspect that a child is or may be in need of protection must promptly report the suspicion and the information upon which it is based to a CAS. Professionals and officials have the same duty as the rest of the public to report their suspicion that a child is or may be in need of protection. These professionals are; health care professionals (physicians, nurses, dentists, pharmacists), psychologists, teachers and school principals, social workers and family counselors, religious leaders, operators or employees of child care programs or centers, youth and recreation workers (but not volunteers), peace officers and coroners, child and youth service providers and employees of these service providers and any other person who performs professional or official duties with respect to a child. The Act recognizes that people working closely with children are in a unique position to recognize the signs of child abuse and neglect, and therefore have a particular

responsibility to report their suspicions. Any professional who fails to report a suspicion is liable on conviction to a fine of up to 750 €, if they obtained the information in the course of their professional or official duties.[18] Ethical aspects are covered by the Code of Ethics of the Royal College of Dental Surgeons of Ontario.[19] In addition, in Canada there is a free confidential helpline called Canada Child Abuse Hotline and Kids Help Phone.[20]

REPORTING CHILD ABUSE IN ITALY

Law no. 39 of 8 March 1975 established that the age of majority is acquired at 18 years. Previously the threshold was 21 years.[21]

The Italian Penal Code[22], Article 572, defines the crime of maltreatment. If the act results in a serious personal injury, the penalty is imprisonment for four to eight years; if it results in a serious injury, imprisonment from seven to fifteen years; if death follows as a consequence of the serious injuries, imprisonment from twelve to twenty years. The Article does not give a definitive frame to this crime so abuse can be considered any usual behavior which leads to harm or puts an individual into danger. Harmful acts can be not only any act against integrity, freedom, and honor, but also acts of contempt, humiliation, and subjugation that offend the dignity of the victim. There is no distinction between physical or emotional mistreatment. Episodic but not systematic events are not considered maltreatment and fall into another form of crime. The crime of Article 572 penal code is prosecuted *ex officio*, thus resulting in an obligation for all health professionals to report their suspicions of maltreatment to the judicial authority (Penal Code,[22] Articles 361, 362, 365). This reporting is mandatory for dentists, dental hygienists, as for any other medical professions. To this regard there is a legal distinction between the following positions: [23,24] public officer; operator in charge of a public service; a private doctor who works only for the interest of the patient (public health) and not for the State administrative interest. Depending of their above status, a dentist will have to safeguard and protect either collectivly or for a single patient. In the first two cases, if there is a suspicion of a crime, then the dentist is obliged to report to the Police or the Juvenile Court.

A public official and any medical professional who neglects or delays to report to the Police or to the Court will be punished with a fine up to 516 € and the dentist in charge of a public service will be fined up to 103 €. The report must be done or sent within 48 hours or handed directly to the police if there is an immediate danger. Dentists are asked not to diagnose 'child abuse', but simply to report their suspicions with supportive evidence.[23,25]

The dental professionals could also consider telephoning the Italian National Emergency for Minors Resource Center 114.[26] The service is free and is sponsored by the Department for Equal Opportunities and operated by 'Telefono Azzurro'. This service is active 24 hours a day and can assist a child or adolescent who is in danger. In particular, the task of the service is to provide assistance in situations of emergency and trauma that may impair the mental and physical development of any child and adolescent, and utilize local social services resources.

Ethical obligation comes from the medical and dental ethical code.[27] Article 32 of the medical ethical code states that doctors should protect the child and the elderly and the disabled, especially when the environment, family or the community in

which they live is not sufficiently responsive to health care or they are victim of physical or psychological violence or sexual abuse.

DISCUSSION AND CONCLUSION

Reporting laws are not promulgated to punish offenders, but rather to help the children in need. Dentists and the members of the dental team are in the unique position to recognize child abuse and neglect because approximately 60% of all signs are visible in the craniofacial region (head and neck).[12] To fulfill professional, ethical, and legal duties adequately, dentists should be educated on child abuse and neglect issues in undergraduate and postgraduate dental education.[28,29]

All four countries presented in this article are signatory countries of the United Nations Convention on the Rights of the Child (UNCRC), so they are obliged to establish integrated child protection systems to ensure a coordinated response to child abuse and neglect cases.[1]

In all four investigated countries, an individual is considered a child until the age of eighteen years.[3,11,16,21]

The initial steps in prevention should be early recognition and reporting. Reporting varies between different jurisdictions and legislation mandating dental professionals to report concerns for child abuse and neglect is available in Canada, Croatia and Italy, but not in the UK.[2] However in the latter professional standards and guidance state clearly that it is their duty to safeguard children. The General Dental Council (GDC) which has the sole responsibility for protecting patients and regulating the dental team expects all registered members of the dental team to be aware of the procedures embodied in the statement contained in 'Standards for dental professional'. The standards guidance is a code of behavior that registrants agree to abide by. This is one of the main ways in which the GDC protect patients and also protect the dental professionals.[13]

The Croatian judicial system seems to be keen to demand reporting child abuse and neglect from any professional, including dentists, according to nine different acts.[5-8,10]

Unlike Croatia, Canada/Ontario, apart from general legal act titled Ontario's Child and Family Services with regulated and detailed provisions on prompt abuse reporting, also has an act which only deals with abuse reported by dental professionals.[17,18] Italy has obligation of reporting within 48 hrs which is written in detail in several legal acts. Consequences of failing to report abuse in different countries are different; varying from various fines of up to 750 € to imprisonment of up to 3 years..

All four countries have similar ethical views as stated in the Codes of Ethics and Guidance from their Dental Chambers or Dental Councils. These highlight the obligation for dentists to safeguard the child, the elderly and the disabled, thereby allowing their normal mental and physical development, and protecting their quality and dignity of life.[10,13,19,27]

It can be seen from the guidance documents of the four countries discussed that they are not completely congruent. It would be to the benefit of the child if there could be more harmonious and precise legal international policies and responsibilities that would help to maximize child protection and safeguarding. Dental professionals must take a more proactive role on behalf of children in this regard and must always act in the best interest of their young and vulnerable patients.

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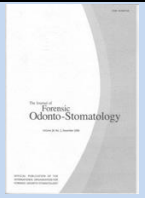


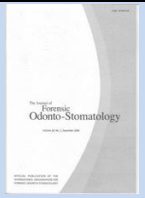

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SECTION BITE MARKS

A SIMPLE, SAFE, RELIABLE AND REPRODUCIBLE MECHANISM FOR PRODUCING EXPERIMENTAL BITEMARKS

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ABSTRACT

With improving technology it should be possible to develop an objective, reliable and valid method that can be undertaken by most forensic Odontologists without recourse to expensive or bulky equipment. One of the main factors that affect the physical appearance of bitemark is the amount of force applied during biting. There is little evidence relating the appearance of a bite mark to the amount of force applied and how that force relates to the biters maximal biteforce. This paper describes simple apparatus that can be used to inflict experimental bites on living subjects reproducibly and with minimal risk.

The aims of this study are to report on the development of a mechanical apparatus that produces experimental bitemarks on living human subjects with a known force in a safe, reliable and reproducible manner and to relate the force applied during production of the experimental bitemark to the maximum bite force of the biter. Maximum bite force of one of the authors was determined as 324N. Experimental bitemarks were inflicted on living subjects with known weights. Weights of up to 10kg were well tolerated by the subjects. The relation between forces used to inflict bites and the maximum bite force of the author is reported, with 10kg being approximately one third of the maximum bite force. The apparatus was well tolerated and the results were reliable and reproducible. The results from this study could help in determining the severity of bitemarks. This apparatus could help researchers in developing objective based bitemark analysis techniques.

KEYWORDS: *forensic dentistry, bitemark, biteforce, living subjects*

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INTRODUCTION

Bitemark (or tooth mark) evidence is relied on by legal systems throughout the world in a wide range of cases.[1] Historically, bitemarks have been examined in a subjective manner. With the increased scrutiny of courts to ensure reliable evidence it is important to develop an objective, reliable and valid method of analysing bitemarks. With improving technology it should be possible to develop such a method that can be undertaken by most forensic odontologists without recourse to expensive or bulky equipment.

Bitemark studies have used experimental bites on a variety of substrates: wax,[3] Styrofoam,[4] porcine skin models,[5-7] plastic and embalmed cadaver models.[8-11] Few studies have produced experimental bites on living human subjects.[12]

There are a number of techniques for producing experimental bites. Some studies have used a clamping mechanism connected to a force transducer to produce the bite[8,9] while others have used a vice grip linked to a load cell for monitoring the force applied.[13] The disadvantage of using a clamping technique on living subjects is that force may not be applied evenly over time and it may take some time to release the force if the subjects' pain threshold is exceeded. A load cell has the potential to malfunction which could result in increased weight being applied for longer durations causing injuries to the subjects.

One of the main factors that affect the physical appearance of bitemark is the amount of force applied during biting.[6] Using a gnathodynamometer, Sheper related the changes observed in the bite forces generated during normal and anger states of human volunteers to the resultant bitemarks on wax.[14] However, there is little evidence relating the force applied to produce a bitemark to the level of effort of the biter. Many studies within the discipline of oral physiology have measured the maximum biteforce of individuals.[15-17] This paper describes a simple apparatus that can be used to inflict experimental bites on living subjects reproducibly and with minimal risk.

The aims of this study are to report on the development of a mechanical apparatus that produces experimental bitemarks on living human subjects with a known force in a safe, reliable and reproducible manner and to relate the weight applied during production of the experimental bitemark to maximum bite force of the biter.

MATERIALS AND METHODS

The first step in the study was to construct a mechanical apparatus for production of experimental bitemarks (Fig 1).

The mechanical apparatus was a metal frame that supported a vertical rod and a loading platform. Upper and lower alginate impressions of one of the authors were taken along with a facebow recording and an occlusal record. Casts were produced in die stone (Shera premium, Sherawerkstoff-technologie®, Lemforde, Germany) and articulated on a semi-adjustable articulator (DenarMK II®, Prestige dental, Bradford, England).The articulated casts were placed within the frame under the rod allowing a load to be applied to the cast. A locating jig that ensured consistent and full transfer of the load to the articulator was constructed from self-cure acrylic (Unodent®, Witham, England). - The frame was large enough to allow entry of an arm into apparatus. Weights of 5kg, 7.5kg and 10 kg were used for production of test bites on the forearm of subjects. Positioning the subjects' forearm during the production of bitemarks in the device was done without causing any discomfort to the subject and bitemarks were easily produced.

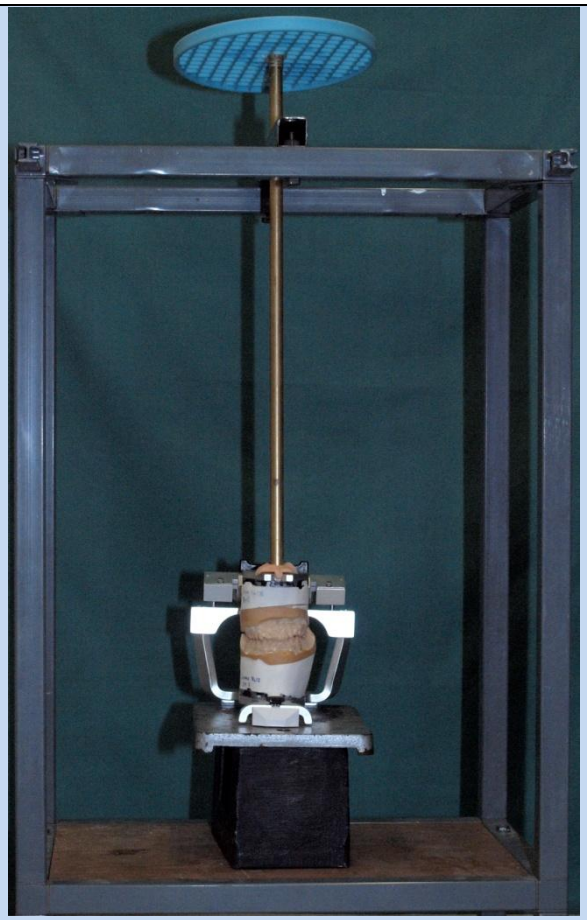

Fig.1: Biting apparatus with articulator in place

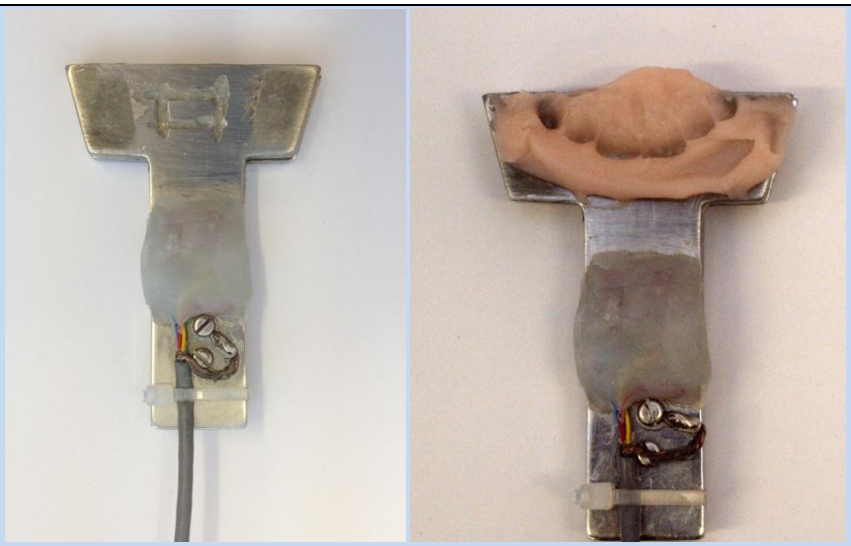

Fig.2: Left: Metal force transducer. Right: Metal force transducer with occlusal index to ensure constant positioning during experiments.

The second and major part of study, testing the apparatus, involved measuring the maximum bite force of the biter and using casts of his teeth to inflict bites on the subjects. This allowed the weight applied on the apparatus to be related to the maximum bite force. Following ethics approval two male subjects aged 25 and 45 volunteered for the study: subject 1 and 2 respectively.

The maximum biteforce of the anterior teeth was measured using a metal force transducer (Fig 2). Metal force transducers have been used in many bite force studies.[18-21] The force transducer used in this study was described previously by Lyons *et al.* (1996).[20] It consisted of two metal beams with two strain gauges attached to each side of one of the beams; the four strain gauges were connected in a Wheatstone bridge circuit. The overall thickness of the transducer was 8 mm.The change in resistance of the strain gauges that follows loading of the transducer i.e. bending the strain gauges will result in change in electric potential or voltage. This change in voltage can then be calibrated with known weights and presented on a graph or on a digital display unit. A Neurolog voltage amplification device(NL 107, Digitimer®, Welwyn Garden City, UK) was used to record and amplify the voltage changes of the force transducer. These changes were imported on to the computer screen as a voltage graph using the 1401 data acquisition interface and analysed using Signal Software (Cambridge Electronic Design®, Cambridge, UK). This technique was described by Tortopidis *et al.*[16]

The force transducer was calibrated prior to each session using a bespoke jig. Weights of 0.5 kg, 1.5 kg, 5kg, 10kg, 12.5 kg, 10kg, 5kg,1.5 kg, and 0.5 kg were sequentially applied to the transducer to produce a calibration curve. The response of the transducer was found to be linear over the above range of weights. Figure 4 shows the calibration voltage graph of the transducer.

To obtain the maximum biteforce the subject was seated in a dental chair with a head support. To make the metal biting surface more comfortable and to ensure a consistent position for biting an acrylic (Unodent®, Witham, England) occlusal index was fitted onto the transducer (Fig 2). At the start of each session the subject was asked to undertake trial clenches with the transducer. To measure the bite force the subject clenched on the transducer with maximum effort and then relaxed.The highest value of three measurements was considered as the maximum bite force for that session. The process was repeated four times with at least 7 days between each session. The highest value of the four sessions was considered to be the maximum anterior bite force of the subject. On every occasion the subject bit the transducer only with the anterior teeth.

Experimental bites were inflicted on subjects' forearms by applying weight to the apparatus for 15seconds. This was initially done with minimal weights to observe how the apparatus functioned, to optimise its handling and to ensure the comfort of the subjects.

To relate the weight applied during production of experimental bitemarks to maximum bite force of the biter in a meaningful way it was necessary to produce visible bitemarks. The minimum weight required to produce a visible bitemark was 2.5kg. This was sequentially increased to 5kg, 7.5kg and 10kg. The process was repeated three times with each weight and with a gap of at least 1 day between each bite. The marks were photographed.

RESULTS

During production of the bitemarks 5kg and 7.5kg were well tolerated by the subjects. There was some discomfort when 10kg was used but the pain was below the threshold level of the subjects. Figure 3 displays the 10kg bitemarks 1minutes, 20minutes and 40minutes after infliction of the bite on each subject.

No mark was identifiable as a bitemark 40 minutes after infliction. However, indistinct marks lasted for four to five hours with 5kg and 7.5kg, while those produced by 10kg were visible the next day. No cuts or abrasions were produced. Visually similar bitemarks were produced in a consistent and reliable manner.

Table 1 shows the maximum bite force values of the subject recorded at each of the four sessions. 323.7 N was the highest value recorded and was considered as the maximum anterior bite force of the subject. This corresponded to a voltage change of 4.2V (Fig 4).

Therefore, weights of 5kg, 7.5kg and 10kg used to produce the bitemarks represented 16%, 24% and 32% of the maximum bite force respectively

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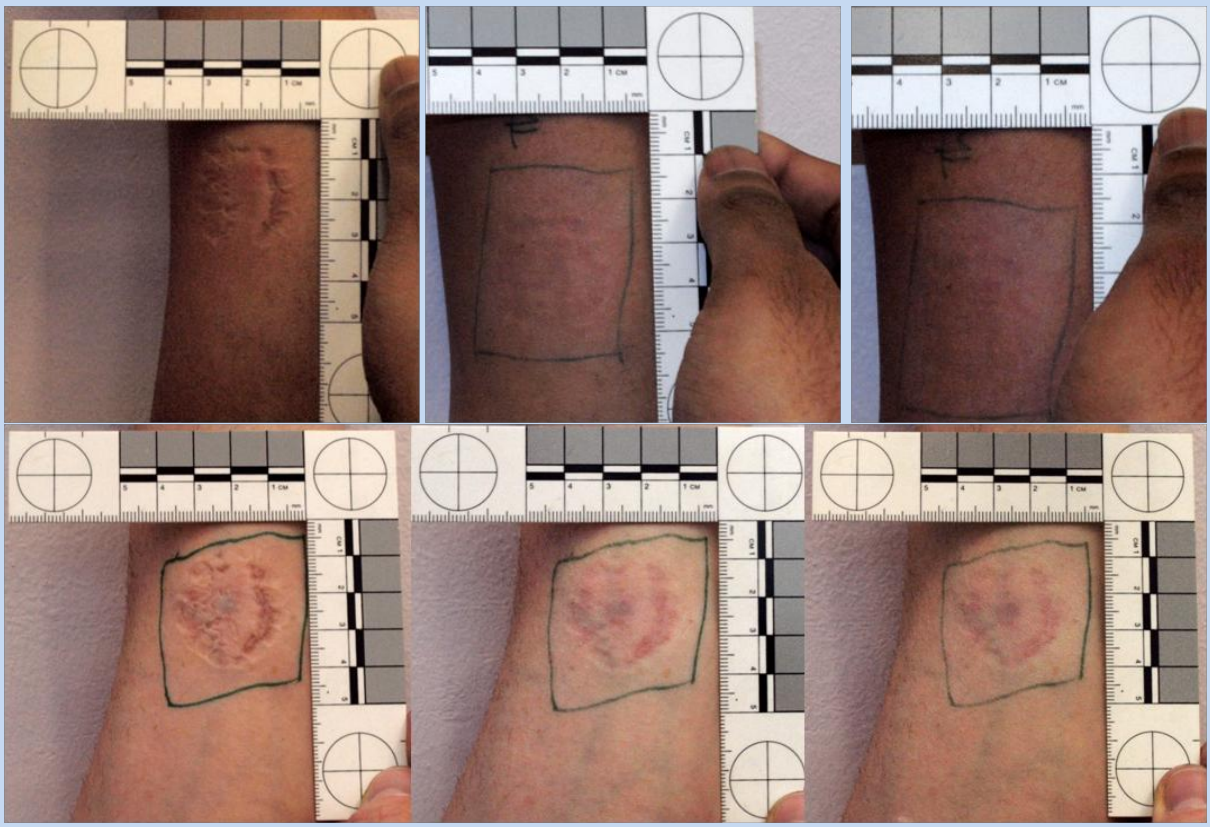

Fig.3: 10kg bitemarks 1minutes, 20 minutes and 40 minutes after infliction of the bite on each subject. Upper series: Subject1; Lower series: Subject 2.

DISCUSSION

This biting apparatus was simple, easily built, convenient to use and reliable for inflicting bitemarks on living human subjects. The weights used were known and were not used beyond the level of subjects' comfort. It was noticeable that the marks of lower teeth were clearer and more obvious than the upper teeth marks. This is likely to be a result of the fact that

when mounted on the articulator the lower cast was fixed and upper cast was movable. In future, to make replicate bitemarks the articulator could be placed upside down in the apparatus. As the apparatus relies on manual application of the loads there is no risk of equipment malfunction. It is also easy to alter the weight applied at different sessions.

Relating the force used to produce a bitemark to the maximum bite force of the biter is a difficult task. The authors chose to do this in an indirect way by measuring the maximum bite force of the subject and then produced experimental bitemarks with known weights. These weights were then related to the maximum bite force. The maximum anterior bite force value increased at each visit.This could be a result of self-motivation, increased confidence and reduced fear of injury to teeth on every occasion on the part of the biter.[15]In fact, in the final session, the biter made the beams of the transducer contact each other and saturated the apparatus. From the published literature the maximum anterior bite force can range between 120 and 350 N (Helkimo *et al.* 1977; Tortopidis *et al.* 1998).[22,23] The maximum anterior bite force recorded in this paper is within the previously reported range of maximum anterior bite force values for adults.

The relationship of force used to inflict the bite to the maximum bite force of the biter is a very important factor which helps in assessing the intentions of the biter and the severity of the mark produced to the court. In this experiment the authors produced experimental bitemarks on living subjects with known weights of 5kg, 7.5kg and 10kg with the help of a mechanical apparatus specifically constructed for this purpose. These experiments were repeated three times to ensure repeatability of results. The resultant bitemarks on the subjects gave us an idea of how bitemarks may appear different on different subjects. For example 40 minutes after infliction of a 10kg bite subject 1 showed no significant tooth marks which could identify it as a bitemark (Fig 3) whereas subject 2 showed a semi-circular arch form that is consistent with a bitemark (Fig 3) and with redness around the indentations. This study also reports on the minimum weight/force used to produce a visible bitemark (2.5kg/24.5N).

Despite controversy around the credibility of bitemark evidence, it is indisputable that bitemark evidence has already been established as an important tool in the administration of justice.[24] Considering the serious consequences of erroneous results in bitemark analysis there is a need for scientific research to underpin its principles and practice.[2,25]

Researchers have often used simulated bitemarks to study the basic principles of bitemark analysis. Artificial bites have been produced in materials like wax, Styrofoam, food stuffs and pig skin both living and dead.[3-7]None of these materials have the qualities of human skin. Some studies have been carried out on human cadavers to investigate the biomechanical properties of skin and bitemark distortion.[8-11,13] Very few studies have used living human subjects for the simulation experiments.[12] Ethical concerns concerning biting of living volunteers might have been a hindering factor.

To reduce the ethical concerns associated with using living subjects this paper has reported the construction of a mechanical but fully human-controlled apparatus to inflict experimental bites of known force. It can be constructed easily from readily available materials to help produce bitemarks in future studies by other research groups. It may even have practical applications in case work by

allowing test bite marks to be produced using conditions that replicate, as closely as possible, the initial circumstances. Having a standard method for inflicting bites will help to progress bitemark analysis so that future techniques are objective, valid and reproducible and accepted by other researchers, odontologists and members of judiciary system.

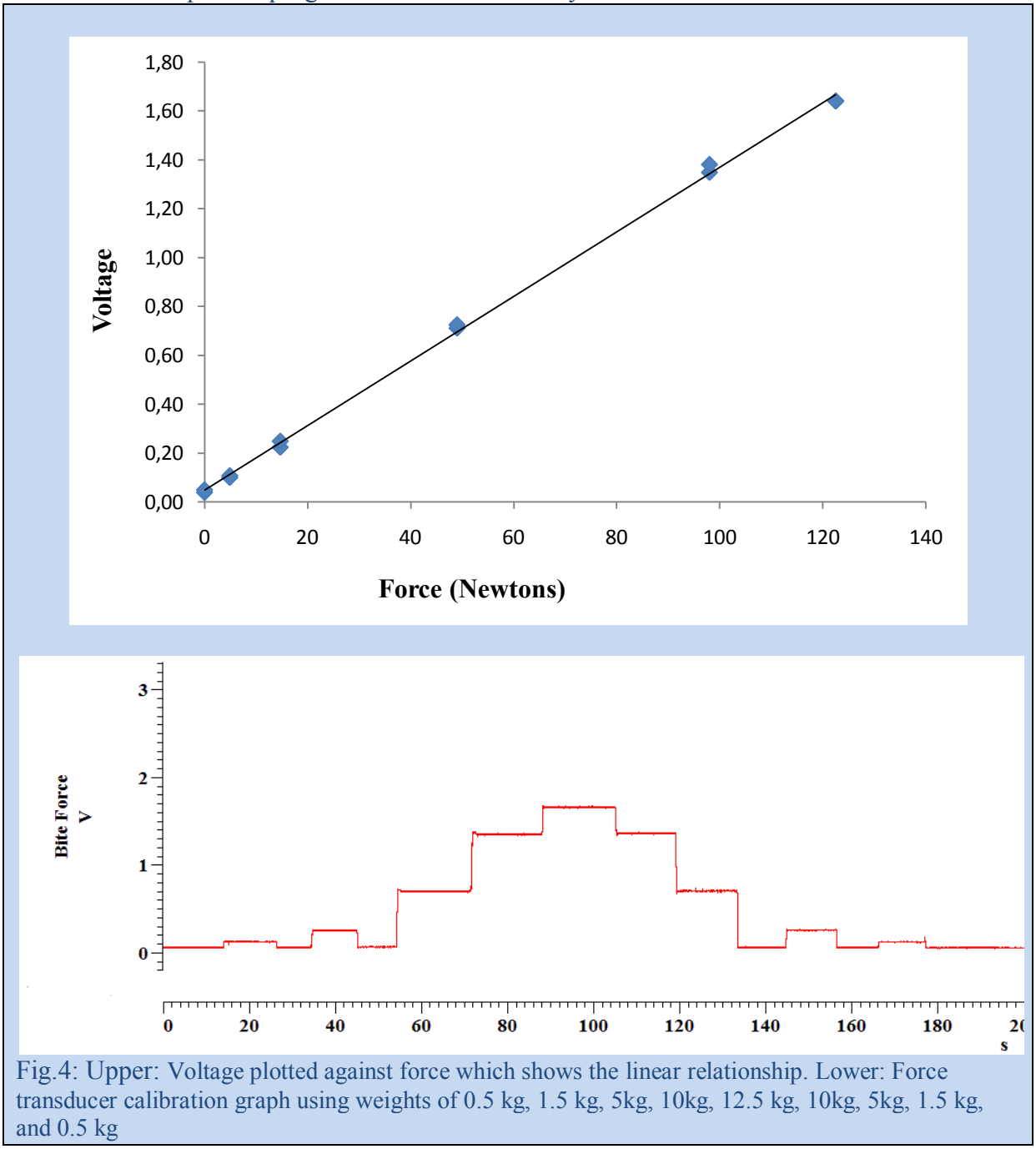

Fig.4: Upper: Voltage plotted against force which shows the linear relationship. Lower: Force transducer calibration graph using weights of 0.5 kg, 1.5 kg, 5kg, 10kg, 12.5 kg, 10kg, 5kg, 1.5 kg, and 0.5 kg

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SECTION IDENTIFICATION

ASSESSMENT OF THE UNIQUENESS OF HUMAN DENTITION

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The authors declare that they have no conflict of interest.

ABSTRACT
Comparing ante-mortem and post-mortem dental characteristics has been a reliable, accurate and quick human identification method. This is based on the assumption that each individual's set of teeth is unique; however, there is little evidence to support this assumption. This research aimed to determine the uniqueness of basic dental features in a cohort of multinational dental patients.
Dental charts were retrieved from the archives of the College of Dentistry at the University of Sharjah. Dental patterns were coded into letters representing basic dental characteristics, and entered into a computer program that was written specifically for analysing the results of this research.
Two thousand dental charts were included in this research; the average age of the sample was 31.9 years (11–87 years). The male:female ratio was 1.4:1 from 55 nationalities. One thousand one hundred and fifty-nine dental charts (57.95%) had absolutely unique dental patterns. The remaining charts (n=841 [42.05%]) were found to have identical patterns with others, the most common of which was 'all virgin' teeth (n=482 [24.1%]). Introducing a single dental modification dropped this percentage to 1.05%. This percentage was further narrowed down to 0.7% when the gender variable was introduced to the comparison.
The results of this research support the assumption that dental characteristics show a diversity that is useful for human identification, even when those characteristics are recorded in their simplest forms.

KEYWORDS: *forensic odontology; dental diversity; dental uniqueness; dental pattern; human identification*

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INTRODUCTION

Accurate human identification is of utmost importance for humanitarian, legal and social reasons. Identification of human remains can be achieved reliably by comparing certain human characteristics recovered from post-mortem remains with their counterparts collected from presumed missing persons. The human characteristics that are considered to be scientifically acceptable identifiers are fingerprints, DNA profile and medical and dental characteristics.[1,2]

Among these, dental characteristics are special because of the durability of dental tissues, which can withstand extreme perimortem and post-mortem conditions, such as decomposition, extensive trauma and intense heat.[3] This unique durability is extended to dental restorations and prostheses, which are manufactured to simulate natural dental robustness, and are therefore resistant to destruction by biological, chemical and physical challenges.[4,5]

Dental identification has proved to be the quickest and most successful method of identification in mass disasters where victims had dental records to acceptable professional standards. However, in other disasters the reported percentage is much lower due to unavailable, incomplete and/or inaccurate ante-mortem dental data.[6–14]

The use of dental characteristics in human identification in the Middle East is relatively new. There are sporadic cases reported from different countries, but the only report was found in English language literature.[14] A major challenge to forensic odontologists in this region is the absence of specifically written policies and guidelines that govern the quality of dental records and the extent of information that should be included in the dental chart.

The uniqueness of dental characteristics and how frequently certain dental modifications are found in a community have been the focus of various research papers. For example, Adams concluded that the diversity in dental patterns is large enough to identify persons even in the absence of dental radiographs. His study relied on a simple dental chart comparison of missing, restored and unrestored teeth.[15] Furthermore, dental characteristics were validated as being comparable to mitochondrial DNA as a method of human identification.[16] Diversity was observed at two levels: the morphological uniqueness of human dentition and the uniqueness of dentition after dental treatment intervention even when the genetic characteristics were the same, as in the case of identical twins.[17]

Disasters often involve victims of multiple nationalities and one of the major challenges facing identification teams is the ability to collect ante-mortem data of sufficient detail to be used for a meaningful comparison. The diversity of dental characteristics of a multinational post-mortem population has not been previously studied. Therefore, the aim of the study was to determine dental diversity, in its simplest possible form, in a multinational population sample.

MATERIALS AND METHODS

SAMPLE AND MATERIAL

A total of 6400 dental records archived at the College of Dentistry at the University of Sharjah were randomly selected and screened for inclusion in this study. Inclusion criteria included patients who were registered in the archives of the College of Dentistry academic dental centre and had signed the consent form, and whose dental charts were complete and signed by a fourth- or fifth-year dental student and by the supervising faculty member. Patients were offered comprehensive treatment after full dental charting. Dental records with incomplete demographic information, with primary or mixed dentition charts and with persistent deciduous dentition and/or illegible dental charts, were excluded. Information about age, gender and nationality was extracted and collected.

CODING

Dental characteristics recorded in the dental charts were converted into simplified dental codes according to Adams (2003).[15] Codes were put into two separate data sets: detailed and generic (Table 1).

FDI notation was used for dental charting. Dental characteristics were recorded as follows: teeth that were not restored or decayed, retained roots were coded as ‘V’ in both detailed and generic formats. Teeth that were restored with any type of dental material were coded as ‘R’ in the generic format. In the detailed format,

TABLE 1 – Dental Codes for all dataset with description

Condition	Detailed Format	Generic Format
Anterior restoration	M,D,F,L	R
Posterior restoration	M,O,D,F,L	R
Anterior crown/Implant/Bridge abutment	MDFL	C
Posterior Crown/Implant	MODFL	C
Missing tooth	X	X
Bridge pontic	XP	XP
Unrestored / active decay	V	V

TABLE 2 - Sample size and demographic composition of the detailed and generic data Database (N =2000; Male n=1198 (59.9%), Female n=802 (40.1%)

Age		Region & Nationality									
Range	n(%)	Middle East (n=846)42.3%		North Africa (n=251)12.5%		South & East Asia (n=796)39.8%		South & East Africa (n=45)2.25		North America (n=35)1.75%		Europe & Australia (n=27) 1.35	
11-14	30(1.5%)	UAE	244	Egypt	171	Pakistan	337	Somalia	11	USA	25	UK	9
15-19	114(5.7%)	Palestine	173	Sudan	56	India	156	Ethiopia	8	Canada	10	Russia	4
20-24	484(24.2%)	Jordan	113	Algeria	8	Philippenes	123	Kenya	6			France	2
25-29	417(20.85%)	Syria	104	Morrocco	7	Bangladish	56	Nepal	5			Shishan	2
30-34	282(14.1%)	Iraq	98	Libya	5	Iran	40	Nigeria	5			Australia	2
35-39	208(10.4%)	Yemen	36	Tunisia	3	Indonesia	32	Chad	3			Belgium	1
40-49	278(13.9%)	Lebanon	31	Arteria	1	Afghanistan	27	South Africa	2			Finland	1
50-59	142(7.1%)	KSA	15			Srilanka	19	Cameroon	2			Germany	1
60-69	37(1.85%)	Oman	12			Malaysia	6	Mali	1			Ireland	1
70-87	8(0.4%)	Kuwait	10					Dijibouti	1			Italy	1
		Qatar	5					Tanzania	1			Poland	1
		Bahrain	4									Netherland	1
		Turkey	1									NewZealand	1

restored teeth were coded based on the surface(s) being restored. The surfaces were coded with the initial of each surface, for example 'M' for the mesial surface and 'O' for the occlusal surface. Accordingly, there were five surfaces for posterior teeth (M, O, D, F, L) and four surfaces for anterior teeth (M, D, F, L).

Multiple restorations on a single surface of a tooth were assigned only a single code. For example, two distinct occlusal restorations were coded as 'O' in the detailed format and 'R' in the generic format. A single restoration that affects multiple surfaces or separate restorations on different surfaces of the tooth was given the same code. For example, either a mesio-occlusal single restoration or two distinct mesial and occlusal restorations were coded the same as 'M, O' in the detailed format and collapsed into 'R' in the generic format. If a tooth surface was both carious and restored, it was coded as restored.

TABLE 3–Generic-format with 28 teeth N=2000
The thirteen most frequent dental patterns from the generic data

	Dental pattern (excluding the 3rd molars)			Male		Female	
	Dental pattern	Number (n)	Percent (%)	Number (n)	Percent (%)	Number (n)	Percent (%)
1	V V V V V V V V V V V V V V V V V V V V V V V V V V V V	482	24.1%	335	16.75%	147	7.35%
2	V V V V V V V V V V V V V V V **R** V V V V V V V V V V VV	27	1.45%	18	0.9%	9	0.45%
3	V V V V V V V V V V V V V V V V V V V V V V V V V V **R** V	24	1.2%	12	0.6%	12	0.6%
4	V V V V V V V V V V V V V V VV V V V V V V V V V **X** V	21	1.05%	14	0.7%	7	0.35%
5	V **R** V V V V V V V V V V V V V V V V V V V V V V V V V V	20	1%	14	0.7%	6	0.3%
6	V V V V V V V V V V V V V V V **X** V V V V V V V V V V V V	17	0.8%	11	0.55%	6	0.3%
7	V V V V V V V V V V V V V V V **R** V V V V V V V V V **R** V	13	0.6%	6	0.3%	7	0.35%
8	V V V V V V V V V V V V V V V V V V V V V V V V V **R R**	12	0.6%	8	0.4%	4	0.2%
9	V V V V V V V V V V V **X** V V V V V V V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
10	V V V V V V V V V V V V V V V **X** V V V V V V V V V **X** V	10	0.5%	4	0.2%	6	0.3%
11	**X** V V V V V V V V V V V V V V V V V V V V V V V V V V V	9	0.45%	5	0.25%	4	0.2%
12	V **X** V V V V V V V V V V V V V V V V V V V V V V V V V V	9	0.45%	7	0.35%	2	0.1%
13	V V V V V V V V V V V **R** V V V V V V V V V V V V V V V	9	0.45%	6	0.3%	3	0.15%
	Number of patterns with matches	117 (969 charts)	48.45%				
	Unique dental patterns/charts	1031	51.55%				

TABLE 4 –Detailed-format with 28 teeth N=2000
The thirteen most frequent dental patterns from the Detailed data

	Dental pattern(excluding the 3rd molars)			**Male**		**Female**	
	Dental Pattern	Number (n)	Percent (%)	Number (n)	Percent (%)	Number (n)	Percent (%)
1	V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V	482	24.1%	335	16.75%	147	7.35%
2	V V V V V V V V V V V V V V V V V V V V V V V V V V V **X** V	21	1.05%	14	0.7%	7	0.35%
3	V V V V V V V V V V V V V V V V V V V V V V V V V V V **O** V	17	0.85%	7	0.35%	10	0.5%
4	V V V V V V V V V V V V V V V V **O** V V V V V V V V V V V V V	17	0.85%	11	0.55%	6	0.3%
5	V V V V V V V V V V V V V V V V **X** V V V V V V V V V V V V V	17	0.85%	11	0.55%	6	0.3%
6	V V V V V V V V V V V V **X** V V V V V V V V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
7	V V V V V V V V V V V V V V V V **X** V V V V V V V V V V **X** V	10	0.5%	4	0.2%	6	0.3%
8	V **O** V V V V V V V V V V V V V V V V V V V V V V V V V V V V	10	0.5%	6	0.3%	4	0.2%
9	V V V V V V V V V V V V V V V V V V V V V V V V V V V **O O**	9	0.45%	5	0.25%	4	0.2%
10	V V V V V V V V V V V V V V V V **O** V V V V V V V V V V **O** V	9	0.45%	3	0.15%	6	0.3%
11	**X** V V V V V V V V V V V V V V V V V V V V V V V V V V V V V	9	0.45%	5	0.25%	4	0.2%
12	V **X** V V V V V V V V V V V V V V V V V V V V V V V V V V V V	9	0.45%	7	0.35%	2	0.1%
13	V V V V V V V V V V V V V V V V V V V V V V V V V V V V V**X**	8	0.4%	4	0.2%	4	0.2%
	Number of patterns with matches	91 (841 charts)	42.05%				
	Unique dental patterns/charts	1159	57.95%				

Dental prostheses were coded as follows: a crown, implant and/or bridge abutment was assigned the code 'MODFL' if the tooth was posterior and 'MDFL' if the tooth was anterior in the detailed format, and 'C' in the generic format. A missing tooth, whether replaced by removable prosthesis or not, was coded as 'X' in both formats and a bridge pontic was coded as 'XP' in both formats.

DATA ANALYSIS

Data collected from dental charts were entered as codes into a Microsoft Excel® spreadsheet (Microsoft Corporation, Redmond, Washington) from which demographic distribution and frequencies were calculated. In order to facilitate comparison between each set of codes of every dental chart with all remaining charts, computer software based on Microsoft Visual Basic C++® (Microsoft Corporation, Redmond, Washington)was specifically designed by the University of Sharjah Computer Programming Unit to be used for this research.

The software was set to yield four different sets of results. The first screening was to compare the generic and detailed codes (separately) of every dental chart with all other charts and to filter out charts with identical sets of codes. Then, another screening was performed in both the generic and detailed formats to reveal charts with identical premolar and molar codes (excluding anterior teeth).

Another use of the software is to compare randomly chosen sets of codes against all other charts in either format to find identical matches and then filter that out by adding information about age, sex and nationality.

RESULTS

Two thousand dental charts satisfied the inclusion criteria. The age of the sample

TABLE 5– Generic-format with 16 teeth N=2000
The thirteen most frequent dental patterns from the generic data

	Dental pattern (Molars & Premolars)			**Male**		**Female**	
	Dental pattern	Number (n)	Percent (%)	Number (n)	Percent (%)	Number (n)	Percent (%)
1	V V V V V V V V V V V V V V V V	523	26.15%	363	18.15%	160	8%
2	V V V V V V V V V V V V V V **R** V	30	1.5%	15	0.75%	15	0.75%
3	V V V V V V V V V **R** V V V V V V	30	1.5%	20	1%	10	0.5%
4	V V V V V V V V V **X** V V V V V V	21	1.05%	14	0.7%	7	0.35%
5	V V V V V V V V V V V V V V **X** V	21	1.05%	14	0.7%	7	0.35%
6	V **R** V V V V V V V V V V V V V V	20	1%	14	0.7%	6	0.3%
7	V V V V V V V V V **R** V V V V **R** V	14	0.7%	7	0.35%	7	0.35%
8	V **X** V V V V V V V V V V V V **V** V	12	0.6%	8	0.4%	4	0.2%
9	V V V V V V **X** V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
10	V V V V V V V V V V V VV V **R R**	12	0.6%	8	0.4%	4	0.2%
11	V V V V V V V V V **X** V V V V **X** V	12	0.6%	4	0.2%	8	0.4%
12	**X** V V V V V V V V VV V V VV V	11	0.55%	7	0.35%	4	0.2%
13	V V V V V V V V V V V V V V V **X**	10	0.5%	6	0.3%	4	0.2%
	Number of patterns with matches	124 (1056 charts)	52.8%				
	Unique dental patterns/charts	944	47.2%				

ranged from 11 to 87 years old (average=31.9). The male (n=1198) to female(n=802) ratio was 1.4:1.The sample covered55 nationalities, and most of those nationalities (54.8%) came from the Middle East and North Africa (MENA) region (Table 2).

When comparing the set of codes of every dental chart with all other charts for 28 teeth,1031 dental charts had absolutely unique dental patterns based on their generic codes (51.55%). This percentage increased to 57.95% when the detailed codes were assessed (Tables 3 and 4). The remaining dental charts had repeated patterns. The most common of those repeated patterns was 'all virgin' teeth, which was seen in 482 (24.1%) charts in both the generic and detailed formats.

However, when a single dental modification was introduced (restoration or extraction), the percentage of dental charts that shared the same patterns dropped to 1.45% and 1.05% in the generic and detailed formats respectively. This percentage was further narrowed down to 0.9% and 0.7% respectively when the sex variable was introduced to the comparison.

When anterior teeth were eliminated from the analysis, 944 (47.2%) dental charts showed unique dental patterns based on their generic codes, and this number increased to 1064 dental charts (53.2%) when the comparison included the detailed codes. The most repeated pattern in the remaining charts was the 'all virgin' teeth (n=523 [26.15%]) in the detailed and generic codes formats (Tables 5 and 6).

The most common tooth to demonstrate a dental characteristic (whether restored, crowned or missing) was the lower first molar.

DISCUSSION

The dental record, also referred to as the patient's chart, is the official office document that records all treatments carried out and all patient-related communications that occur in the dental office. Normally, countries have

TABLE 6–Detailed-format with 16 teeth N=2000
The thirteen most frequent dental patterns from the Detailed data

	Dental pattern (Molars & Premolars)			Male		Female	
	Dental pattern	Number(n)	Percent (%)	Number(n)	Percent (%)	Number(n)	Percent (%)
1	V V V V V V V V V V V V V V V V	523	26.15%	363	18.15%	160	8%
2	V V V V V V V V V V V V V V **X** V	21	1.05%	14	0.7%	7	0.35%
3	V V V V V V V V V **X** V V V V V V	21	1.05%	14	0.7%	7	0.35%
4	V V V V V V V V V V V V V V **O** V	20	1.0%	9	0.45%	11	0.55%
5	V V V V V V V V V **O** V V V V V V	19	0.95%	12	0.6%	7	0.35%
6	V **X** V V V V V V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
7	V V V V V V **X** V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
8	V V V V V V V V V **X** V V V V **X** V	12	0.6%	4	0.2%	12	0.6%
9	**X** V V V V V V V V V V V V V V V	11	0.55%	7	0.35%	4	0.2%
10	V **O** V V V V V V V VV V V VV V	10	0.5%	6	0.3%	4	0.2
11	V V V V V V V V V **O** V V V V **O** V	10	0.5%	4	0.2%	6	0.3%
12	V V V V V V V V V VV V V VV **X**	10	0.5%	6	0.3%	4	0.2%
13	V V V V V V V V V V V V V V**O O**	9	0.45%	5	0.25%	4	0.2%
	Number of patterns with matches	104 (936 charts)	46.8%				
	Unique dental patterns/charts	1064	53.2%				

laws or regulations that determine how those records are handled, how long they are kept for and who may have access to the information within them.

The dental record provides continuity of care for the patient. It is considered essential for the overall healthcare of each patient, and it constitutes an important legal document in the event of a malpractice claim. Additionally, the information recorded about the conditions of teeth and dental treatments carried out on each tooth is extremely useful in human identification when other methods of identification are either slower, expensive and/or complicated.[1,9] As previously stated, a successful dental identification will depend entirely on how well dental information is documented.

Several studies have investigated the quality of dental recordkeeping from a forensic perspective. They concluded that the quality of dental records is often poor. This is manifested by incompleteness of data, inaccurate and outdated dental information, and not following the standards and guidelines recommended by national dental associations.[18–25] Charting errors can seriously undermine the use of dental records for human identification. For example, Bormann et al found that the most common error was in charting missing teeth and dental restorations, which are the backbone of forensic dental identification.[25]

In the United Arab Emirates, there are no purposely set regulations for guaranteeing the completeness of dental records. Instead, there are general codes found in the various codes of conduct in different emirates. In 2008, a new federal law on medical responsibility was passed that very briefly addressed the issue.[26] The effect this has on the quality of dental records and their usefulness in identification is not known since no studies have investigated the influence of those regulations on dental

practitioners' compliance with good record keeping in the UAE.

Our sample in this study consisted of dental charts extracted from the archives of the College of Dentistry at the University of Sharjah. Those charts were filled in by fourth- and fifth-year dental students, and were then reviewed and corrected under direct academic supervision. The academic setting under which those charts were filled in dramatically reduces the chances of human charting error, and thus makes those charts an accurate representation of patients' dental characteristics.

With the ongoing challenges of poor dental records, it is expected that dental information will not be complete. Therefore, we wanted to find out whether dental information, in its simplest form, can still show human individuality and be useful in human identification

Data analysis was achieved using Microsoft Visual Basic C++®,which is an application programming tool developed by Microsoft® for C++ programmers and simple programs can be written using it. The program written in this study has similar features used in previous studies.[11,15,27] This software can be modified, whereby additional options can be added to obtain more specific information and analyse it, in addition to the possibility of this software being operated internationally as a valuable method for identification purposes.

Our study revealed that detailed and generic dental patterns consisting of 28 teeth are close in their diversity. For example, the percentage of patients found with unique dental patterns (no other similar patterns) using generic codes and detailed codes was 51.55% and 57.95% respectively. This implies that more than half of our sample can be dentally identified, even when their dental information is written in a superficial manner. The remaining patients had dental patterns that were identical to at least one other patient.

Our results also showed that 24.1% of the sample had no previously carried out dental treatments. The 'all virgin' dental charts represent a challenge to forensic odontologists since there are no acquired dental characteristics to be used for comparison. However, a forensic odontologist can still contribute to identification by building a post-mortem profile of the victim including estimating the age at death, opining on anthropological traits such as high concentration of fluoride, occupational dental changes and morphological dental features of teeth and performing photograph-skull superimposition in order to approximate the identity by narrowing down potential matches.[28–30]

Interestingly, we noticed that this percentage drops to 1.45% when a single dental restoration is performed on a tooth and to 1.05% when a single tooth is extracted for generic coding. As for the detailed coding, the percentage drops to 1.05% when a single tooth is extracted and to 0.85% when a single tooth is restored with an occlusal filling. These percentages drop further when gender is introduced as a variable. This implies that dental identification in mass disasters should be coupled with specific demographic information, such as gender and age, in order to aid in identifying victims who have one or two similar dental features.

Frequently, dental identification is required when there are disasters with mass fatalities, and normally the disaster victims would have been subjected to perimortem and post-mortem damages. Being protected by the tongue and cheeks, posterior teeth are known to preserve their structure and characteristics despite extreme fire and extensive trauma. Anterior teeth have less protection and are thus more prone to losing their characteristics. With this in mind, we wanted to find out what the effect of losing all anterior teeth characteristics would be on the overall diversity of dental patterns.

Accordingly, when the 12 upper and lower anterior teeth were eliminated from the analysis, 47.2% and 53.2% showed absolutely unique patterns in the generic and detailed formats respectively. The percentages of those who had 'all virgin' teeth was 26.15% for both formats, which drops to 1.5% and 1.05% in the generic and detailed formats respectively when a single dental treatment is acquired. Hence, dental patterns are still to a large extent individualized, even when only posterior teeth are available for matching.

The lower first molars were the most affected teeth in the sample whether restored, missing or crowned due to the fact that they are the first

permanent teeth to erupt into the oral cavity and accordingly the most affected by caries.

Our study has several points of strength. Firstly, the multinational composition of our sample makes our assessment of dental diversity generalizable and particularly beneficial for assessing the usefulness of using the dental identification method in disasters involving multinational victims. Secondly, the data collection, being performed in an academic setting and checked for accuracy by the academic faculty, strengthens the validity of our results. And thirdly, the use of a purposely designed computer program for dental code comparison eliminates subjectivity and possible human errors.

In conclusion, dental charts are considered a valuable and useful tool in forensic human identification when combined with other characteristics such as age and gender and can lead to constructive identification of unidentified human remains.

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