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EDITORIAL

Uncertainty has been the hallmark of scientific endeavour for centuries. In fact, a lack of certainty had almost become accepted as humankind's lot. Towards the latter half of the past century, however, we increasingly came to view certainty as a scientific right. Uncertainty had become the antithesis of good science. The new knowledge explosion had resulted in a decrease or even a cure for uncertainty.

This poses a cruel dilemma for forensic scientists called upon to testify in court where good science is framed in binary thought; right or wrong, black or white. In court, the forensic scientist has to confront Hamlet's choice – to say yes or to say no. After all, statistics is about Type I and Type II errors – the former results in false positives (and hence promotes risk avoidance), and the latter results in false negatives (and hence keeps us from deciding when we aught to). Error is binary, a fork in the road. But does good science lead to certainty? Are our life decisions binary?

As we know, science and life, seldom unfold in a binary way. There are always added complexities. What opinion is the correct one, by what criteria, with what caveats or with what allowance for error? Shakespeare's tormented prince recognised that second-order complexities cloud all first order calculations; to be or not to be. Real forensic problems take time to address and current opinion always remains open to change. In the case of bitemarks for example, science cannot tell us how and when the biter struck, how to allocate intent or mitigation, or even how the skin behaved beneath the teeth. With the presence of both the biter's saliva and the victim's blood, DNA is unable to tell the two body fluids apart. How do we deal with these layers of complexity? How do we deal with doubt?

The answer is: with humility. With an acknowledgement of both the limits of our current scientific knowledge and with an acknowledgement that science is sometimes unable to solve a particular problem. Research fixes our focus on the knowable and can easily lead to an over reliance on fact-finding to solve forensic cases. We need to be ever watchful that we do not lose sight of the partiality and uncertainty of science. Again and again, good science teaches us to think harder about problems, and compels us to reflect on sources of uncertainty and ambiguity. If research is rooted in binary thinking, the result is more akin to skill than to science.

Jules Kieser

TECHNICAL NOTE

The evaluation of two radiographic methods for age determination of children in an Indian population

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ABSTRACT
The aim of the present study was to evaluate the applicability of the methods proposed by Nolla[7] and Nicodemo[9] for estimation of dental age and its correction with chronological age. Orthopantograms of 413 patients, aged 6-16 year (70-195 months) were selected to estimate the correlation between dental and chronological age. With both the Nolla and Nicodemo methods, the estimated age was lower than compared to chronological age except for the Nolla method in girls. There were significant correlations between chronological and estimated dental age (by Nolla and Nicodemo methods) in both genders.
(J Forensic Odontostomatol 2008;27:2:30-33)

Keywords: orthopantograms, Nolla method, Nicodemo method, dental age, age determination by teeth

INTRODUCTION
Dental development has been shown to be a useful method of age estimation, whose applicability decreases with increasing age.[1] While physical development can be affected by genetic, racial, nutritional, climatic, hormonal and environmental factors,[2-3] it has been reported that dental development is less affected by external factors.[4] Numerous methods have been developed to estimate dental age.[3-8] Variability may mostly relate to ethnic differences, but other factors, such as gender and age, may also play a role. The present study was designed to determine the dental age of children in North India and to correlate this with chronologic age. The use of correction factors was assessed the evaluation of the clinical application of the results obtained.

MATERIALS AND METHODS
I examined 413 orthopantomographs of patients from the Bhagwan Dental Clinic, Jind and Jain Diagnostic Centre, New Delhi (India), 207 males and 206 females between 70-195 months (6 to 16 years) of age. The criteria for inclusion in the sample was the availability of a orthopantomograph of adequate quality, and no history of disease (medical or surgical) that could affect the presence and development of permanent teeth, including third molars. The children were divided into 21, 6-months groups (at least n=24, 12M: 12 F) according to their chronological ages. Together with the radiographic examination, the chronological age was recorded. The analysis of the radiographs was applied when the result of the intra examiner test was considered adequate (by Dahlberg's formula error was less than 0.50 months). Dental age was assessed from orthopantomographs according to the methods proposed by Nolla[7] and Nicodemo.[9] Data were tabulated and subjected to statistical analysis with Student t test using SPSS version 11.0.

RESULTS
Table 1 shows that the mean chronological age for boys was 143.20 months, and for girls was 141.80 months. In both sexes the mean dental age was less than the chronological age in both methods, except with the Nolla method in girls ($p < 0.01$) and the differences were more pronounced in the older groups.

Table 1: *Mean (in months) and standard deviation (SD) of chronological age and estimated dental age using the methods proposed by Nolla and Nicodemo for North Indian boys and girls*

Groups	Age ranges (in months)	Boys (mean±SD)			Girls (mean ± SD)		
		Chronological age	**Nicodemo**	**Nolla**	**Chronological age**	**Nicodemo**	**Nolla**
1.	70 – 75	73.40±02.11	71.20±06.30	74.80±08.60	74.30±02.10	81.30±08.34	82.40±12.44
2.	76 – 81	79.20 ± 01.93	78.10±06.82	80.30±09.70	78.90±02.93	83.40±10.89	82.33±20.30
3.	82 – 87	84.50 ± 01.73	83.50±08.83	85.60±15.60	85.60±01.69	92.80±08.87	90.84±21.34
4.	88 – 93	91.10 ± 02.21	89.30±08.85	93.10±07.59	90.20±01.87	87.81±09.53	88.43±19.32
5.	94 – 99	95.50 ± 01.70	93.10±09.32	96.00±08.00	96.60±02.70	91.30±07.69	92.34±17.34
6.	100 – 105	103.10±01.85	101.20±11.30	94.99±03.89	102.80±2.85	112.40±8.90	114.36±18.70
7.	106 – 111	107.90±01.83	103.80±12.40	104.30±06.32	106.70±2.87	109.30±12.35	115.41±21.62
8.	112 – 117	114.00±02.13	107.40±12.80	101.70±08.59	113.80±2.63	109.40±11.62	116.32±21.34
9.	118 – 123	121.51±01.70	116.80±09.62	113.70±12.43	122.61±1.55	103.70±11.53	118.41±20.42
10.	124 – 129	127.80±01.69	120.40±09.69	112.84±11.08	128.20±1.53	110.89±11.63	119.32±09.54
11.	130 – 135	131.91±01.12	127.30±10.30	119.80±12.21	132.92±1.32	119.91±20.13	117.41±08.99
12.	136 – 141	138.10±01.83	133.90±09.80	128.50±11.79	139.20±2.34	121.54±11.93	118.32±09.32
13.	142 – 147	143.90±01.86	140.80±14.60	133.90±16.63	142.80±2.87	134.70±11.89	135.80±09.74
14.	148 – 153	150.50±01.10	145.80±15.50	133.82±21.32	149.40±1.89	137.50±12.87	138.60±11.87
15.	154 – 159	156.20±01.85	150.60±14.70	144.90±26.43	157.10±1.86	139.60±13.89	140.70±12.89
16.	160 – 165	163.20±01.87	160.20±13.80	151.80±12.83	162.30±1.88	142.50±14.39	143.87±13.79
17.	166 – 171	169.20±01.83	162.80±09.82	157.49±15.80	170.30±1.87	150.40±13.49	151.69±14.29
18.	172 – 177	175.30±01.69	171.90±10.80	156.50±12.30	176.40±1.70	164.32±09.77	167.82±09.63
19.	178 – 183	178.30±01.65	173.80±16.83	164.30±18.70	179.40±1.66	170.41±08.32	189.32±10.53
20.	184 – 189	187.40±01.70	182.82±09.92	171.80±19.23	188.50±1.75	176.62±14.32	192.76±11.89
21.	190 – 195	192.30±02.80	190.30±12.30	186.80±28.73	191.21±2.81	184.61±13.31	193.83±10.23
	TOTAL	**143.20±01.89**	**138.40±21.41**	**139.89±29.62**	**141.80±3.29**	**132.49±21.32**	**143.63±21.32**

Table 2 shows the difference between chronological age and dental age for both methods and for male and female subgroups using Student t test and Pearson correlation coefficient, all correlations were at the $p < 0.01$ level of statistical significance.

Table 2: *Statistical correlation between chronological and estimated dental age for both sexes*

	Chronological	Nicodemo	Nolla
Male	1.000	0.821	0.931
Female	1.000	0.923	0.931

$p < 0.01$ at all levels

DISCUSSION

Age estimation for medico legal (age at death, age of a criminal) and clinical purposes represents an important task for the forensic dental profession. Various methods have been developed for this over the years.[1-8] It has repeatedly been shown that dental development relates more closely to chronological age than skeletal, somatic or sexual maturity.[2] Tooth formation has proved more accurate than tooth eruption for assessing dental maturation because it is a progressive process that can be followed radiographically, and a number of teeth can be evaluated at the examination. There are several methods for estimating dental age, among them, the two methods proposed by Nolla[7] and Nicodemo.[9] I tested these methods because they are easy to use, accurate, and often used by paedodontists. Even if the ethnic factor appears to be most important, individual (genetic), nutritional, climatic, hormonal and environmental factors may have some influence[2,6,7]. Hence, considering regional differences in a big country region like India, establishing specific parameters for each would be important. Most recent studies point out that the individual (genetic) factors are responsible for most of the variability.[7-12] In the present study, the applicability of two methods was tested in the age estimation for a North Indian population. The 70-195 month age range was chosen because most maturity occurs during this period. In the present study, the mean dental age for boys was underestimated by both methods and the differences were larger in the older groups ($p < 0.01$, Table 1) which is in agreement with a previous study.[10] In girls, the mean dental age was also underestimated with the Nicodemo method, but overestimated with the Nolla method (Table 1, $p < 0.01$) which is contrary with to a previous study.[10] This may be due to differences in geographical or other unknown factors. It has been reported that the Nolla method overestimated the ages off younger children and underestimated the ages of older children of southeast Brazil.[11] In contrast, Davis and Hagg[12] have shown that dental age is significantly higher than chronological age among children when using the method by Demirijian.[8] Many authors have suggested that the methods of conversion to dental ages must be adjusted for the ethnicity of the individual to be aged.[10,12] Hence, correlation factors must be established to make the methods (Nolla and Nicodemo) applicable to the Indian population.

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TWO POSITIVE IDENTIFICATIONS ASSESSED WITH OCCASIONAL DENTAL FINDINGS ON NON-DENTAL X-RAYS

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ABSTRACT
The cases reported here show typical difficulties of dental identification procedure in the face of a lack of AM data for the missing person and an almost edentulous mouth in the body. In the first case the image of an included third molar found in an AM CT of the skull represented the decisive evidence for identifying the corpse; the identification of the body in the second case was possible only for an oversight of the radiologist during the performance of AM x-rays. They offer the occasion to describe the decisive importance of some occasional dental findings on non-dental x-rays and to stress the need of a comprehensive AM data collection and of a truly multidisciplinary approach to the collection and examination of x-rays. Furthermore, the cases underline that some radiographic features require skill, not only to be interpreted but also to be recognized.
(J Forensic Odontostomatol 2008;27:2:34-38)

Keywords: forensic odontology, personal identification, dental radiography, patient records, edentulous

INTRODUCTION

The importance of intraoral structures for identification purposes in severely damaged bodies is well known[1] and the relative simplicity and the low cost of the odontological techniques that compare the Ante Mortem (AM) and the Post Mortem (PM) records or radiographs, render such methods frequently used in the first place in mass disaster and in single identification cases.[2] As underlined by many authors[3] radiographic data are very useful to identify altered corpses for whom morphological features (finger prints, face traits, etc.) are lost. Furthermore, modern dentists use systematic radiographic examinations (teleradiography, panoramic, periapical, bitewing, etc.) for routine dental care and hence dental archives are often rich in radiograms, especially after the increasingly widespread use of digital x-rays.[4,5]

It is well known that dental x-rays are useful for identification and often a single intraoral x-ray may show enough details for a positive identification. Such concentration of useful traits in dental x-rays often allows the observer to overcome those difficulties due to some inevitable differences between the confronted PM and AM images[6]. Some differences consist in inhomogeneous dimensions, different accuracy or definition of the images that can be appropriately and sensibly reduced with a software elaboration. On the other hand, a factor than can affect the comparison and is not so easy to check or to improve, is the different orientation that results from geometric distortion of the represented structures. That mis-orientation is principally caused by:

- different or uncertain techniques for taking the x-rays compared to identification procedure;
- different kinds of AM and PM x-rays used for the identification.[7] Typical circumstances are the comparisons between an AM panoramic or intraoral radiogram and the images of the maxillary structures provided by a PM cranial radiography. In spite of the great difference between an OPG and a lateral x-ray of the skull, our previous research showed a high comparability of these kinds of radiographies for the lateral portion of dental arches (bicuspid and molar portion).[8]

The obvious limits to the odontological methods based upon the comparison of AM and PM dental radiographies are represented by:

1. the lack of AM x-rays to be compared with PM files obtained from the corpse;
2. the lack of those teeth represented by AM x-rays in the corpse, because the subject, during life, lost some or all teeth becoming partially or completely edentulous.

With reference to the first point, Wilcher *et al*[4] have strongly recommended the necessity of acquiring comprehensive AM files, and especially all available x-rays. The odontologist might find some images of jaws, teeth or maxillary sinus in x-rays not specifically addressed to detect these structures and could proficiently use them for comparison. Minaguchi K *et al*[9] have reported the importance of jaw-dental images included in chest radiographs. Edentulous identification is well known to be a complicated factor of dental identification, because it often carries with it both the above-mentioned difficulties and limitations. Many teeth are not available in the dead person's mouth and the AM dental records, especially dental x-rays are often scarce or absent.[10] Clearly, the edentulous require less frequent dental care and rarely x-rays compared to dentate subjects. The specific forensic difficulties unique to edentulous have been well outlined by Richmond's *et al*[11] research that showed only in 18% of the examined cases, the dental files could grant the identification of an edentulous.

CASE REPORTS

The following cases seem interesting because they show some difficulties discussed above due to the lack of AM data for the missing person and to the large number of missing teeth in the corpse's mouth.

Case 1

During the summer of 2006, a corpse in an advanced state of skeletonization was found in a wood near a hamlet on the outskirts of Florence. The skeleton was complete except for some phalanges of hands and feet. The autopsy assessed as a probable cause of death, cranial trauma due to falling on a big stone. Examination of the mouth revealed a removable prosthesis almost complete applied to the upper arch (all teeth were lost during lifetime except, the second bicuspid and the first molar on the left, and the third left molar, included and severely destroyed by caries). In the lower jaw a removable prosthesis substituted nine teeth, whereas five were missing after death. The prostheses were not labelled nor did they have serial numbers that allowed them to be identified. After the first identification screening the police were informed that the missing person was probably a Caucasoid male, over 65. A white male of 78 years of age, affected by a degenerative neurologic pathology, disappeared 15 months

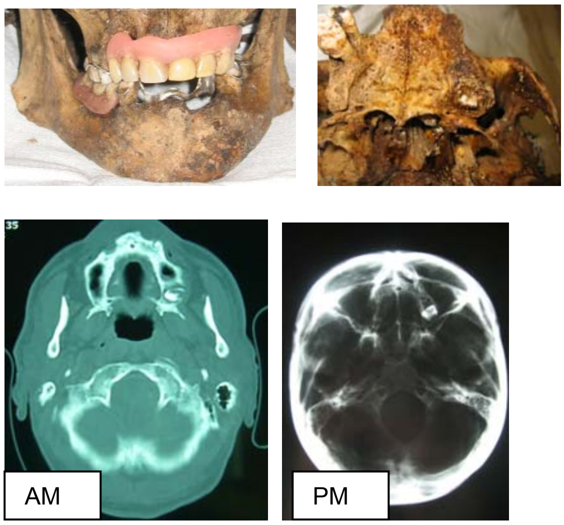

Fig.1: *Top - the jaws with both prostheses and the left third molar retained in the bone and severely destroyed by caries. Bottom - on the left, the last radiograph of the CT scan of the missing person's skull, on the right, a direct x-ray of the skeleton's skull.*

before the skeleton finding, was proposed for the comparative procedure. During the AM data collection, the relatives did not remember any past fractures or bone pathology that could have been found on the skeleton. Regarding dental information, the relatives remembered that he had lost most teeth many years before his disappearance, and during the last years he was taken to the dentist' s surgery only to repair the prostheses. The dentist confirmed the rare visits for prosthetic maintenance, that the last visit dated some years ago and he had not found it necessary to perform any dental radiographs. The dental files reported an amalgam dental filling on the first left molar. An amalgam filling was found in the correspondent tooth in the corpse's mouth, but this correspondence was judged insufficient to identify the subject. Since the lack of AM dental data or x-rays, it seemed very hard to identify the subject trough his dental features. The identification team comprisied of an odontologist and a specialist in legal medicine, addressed the AM collection to different sources (medical files, hospital archives, etc.) and a CT of the skull that the subject required for a cranial trauma 10 months before disappearance, was found in the hospital archives (Fig.1). The accurate examination of the CT revealed that the last scan (in cranial-caudal direction) had reproduced the upper left third molar, abnormally high in the bone because of the inclusion. It is to be noticed that the third molar image represented a detail inside a radiogram of a few centimetres (about 4 by 5 cm) that shows the whole skull. The concordance of the position and the morphology of the included third molar, in consideration of the infrequency of this finding at least in elderly people, plus the correspondence to the biological features of the missing person (age, gender, race, stature, etc) to those assessed for the body, allowed one to identify the unknown skeleton as the missing person.

Case 2

The remains of a severely burnt corpse were found in a completely destroyed car. The use of petrol inside and outside the car gave rise to an intense fire lasting not less than four hours with a temperature of 700-800 ° C. The long bones were calcinated and fractured in numerous fragments, the cranium teca reported an explosion and the face and nasal bones were eroded by the flames. The autopsy did not reveal the cause of death as either the result of a murder or a suicide. On both dental arches there were two removable prostheses damaged by the fire and without any label, sign or serial number: the upper was an almost complete removable prosthesis with full coverage of the palate, the lower substituted six teeth and three teeth were missing after the death. The owner of the car had disappeared; he was a male of 59 years of age, physician, in good health and without any psychological issues. A suicide motive evoked by the police for the fire was strongly denied by the relatives of the missing person. The AM data collection revealed that the subject had not required any dental care for some years and no dental files or x-rays were available at the dental office where the subject was treated during the last two decades of his life. Also in this case, the forensic team requested of the family all other x-rays of the deceased and all information about traumatic events, pathologies, hospital records, etc. and the wife remembered that some years before going missing, the subject required a attention for light cranial trauma. An inquiry was made to the hospital and double projection (anterior and lateral) x-rays of the skull were found in the archives of the emergency room. The AM lateral radiogram showed practically only the neurocranial structures (probably of interest for the traumatic event) and included just a small part of the maxilla (palate). This radiogram was used for a digital comparison through a transparent overlapping with the correspondent PM x-ray taken from the corpse,

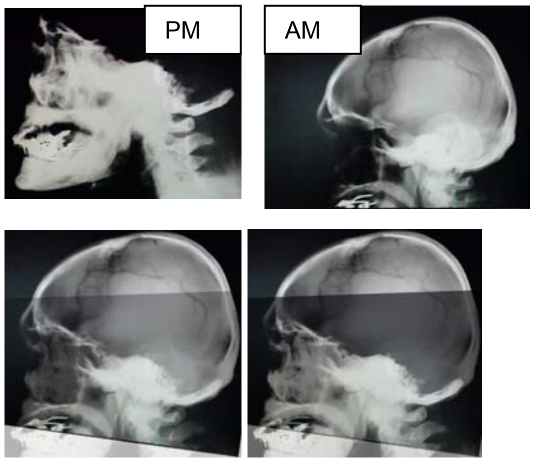

Fig. 2: *Upper on the left the PM lateral x-rays of the skull that denotes the severe destruction of cranial bones. On the right the AM lateral x-rays of the skull that reproduced only the neurocranial part of the skull. Lower the superimposition of the images (35% and 55% of transparency) that shows the perfect correspondence of the cranial base profiles.*

and it allowed one to note the perfect congruence of the cranial base profiles in the confronted x-rays (Fig.2). On the contrary it was impossible to evaluate the congruence of profiles of the cranial teca and of the anterior part of the frontal sinus, because these structures were almost completely destroyed in the corpse. The anterior projection radiogram showed the whole skull, but the tooth images were *per se* not very useful for comparison, because they were fused with the prostheses images and showed poor definition. On the other hand the x-ray revealed good images of metallic component of both removable prostheses applied in the mouth. The finding allowed three different digital superimpositions (right part, central part and left part) between the AM images of the lower prostheses obtained from the cranial radiogram, and the PM intraoral x-rays taken from the corpse. The AM and PM were analogical radiograms and, as for the lateral x-rays of the skull, they were photographed with a digital camera, homogeneously dimensioned and then overlapped using Adobe Photoshop (Fig.3). For the best appreciation of the profile correspondence, the metallic component of the prosthetic device was coloured in the AM image before the transparent superimposition. Since these prosthetic parts are hand-made and thus unique, the perfect congruence of their metallic profiles is highly significant and decisive in spite of the great diversity of the two compared x-rays.

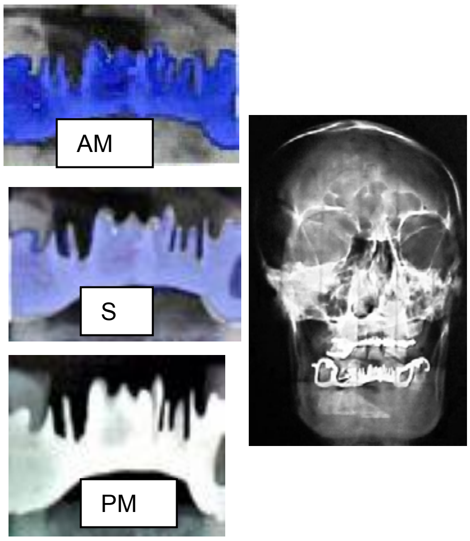

Fig. 3: *On the right the AM x-rays of the skull that shows both prostheses in the mouth. On the left the AM and PM radiographs of the anterior part of the mandible. The AM image is a detail of the x-rays of the skull. In the middle the superimposition (S) show (50% of translucency) of the AM and PM images alternatively coloured for simplifying the visualization.*

DISCUSSION

The cases presented here point out the importance of tooth, jaw radiographic images found out in non-specific x-rays. In the first case the scan of a cranial CT, that incidentally contained a third molar, and in the second case the casual mistake of a radiologist who left a removable prosthesis during the examination, allowed the identification of two subjects otherwise difficult to be identified by the odontologist. This underlines that the odontologist should not limit the AM data collection to the dental archives or exclusively to stomatognatic radiographs, but he/she has to request/examine x-rays addressed to other anatomical areas (skull, neck, chest, etc.). As recommended for other identification procedures[12,13] the radiographic approach needs a truly multidisciplinary forensic team, which includes a forensic odontologist as an active member during the collection and the examination of x-rays, at least before the individuation of the available and useful data for assessing identity. In fact we suggest that an excessively sectional management of identification procedure with strong separation between specialists causes a lack or undervaluation of the data, specially the radiographic data. The radiographic data requires high skills not only in interpretation, but also in recognition, especially when it is a tiny and specific detail in a wider radiographic contest.[14] The research of Soomer *et al*[15] stresses the importance of training and experience of an odontologist in evaluating x-rays, especially for the most difficult cases and that the best performances are achieved by private practitioners with respect to odontologists employed by the government or by the academy. We conclude that the best performances in interpreting x-rays will be assured by the forensic odontologist that practices as a dentist. Daily professional practice as a dentist improves the knowledge and the use of the current and ever more sophisticated radiographic techniques (CT, dentascan, etc.) and this practice allows the odontologist to have a developed skill in reading radiographic data.

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HOW OLD AM I? AGE ESTIMATION IN LIVING ADULTS: A CASE REPORT

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ABSTRACT
Age estimation is a common task in forensic medicine. Odontologists are frequently involved in the age assessment of human remains or living juveniles. The need to estimate the age of living individuals is becoming more frequent, because of the increasing number of immigrants (illegal or otherwise) without acceptable identification documents and with missing or uncertain birth dates. Whereas age estimation in subadults is usually performed by methods based on the physiological growth of bones and teeth, in the case of living adults age determination is more difficult, because body maturation has come to an end and the most commonly used procedures in forensics on human remains are too invasive for the living individual.

The following case report aims at highlighting the difficulties of performing age estimation in the living adult and the importance of a multidisciplinary approach including forensic odontology: a middle-aged woman from Ethiopia who was supposed to be 62 years old (according to one set of documents), was removed from employment lists as she had reached the retirement age for Italy. However another set of documents indicated a younger age (46 years). Hormonal dosage of E2 (17-β estradiol) and FSH (Follicle Stimulating Hormone) showed an age close to the begininng of menopause. An experimental dental method, based on the decrease of canine pulp chamber with age, was performed in order to obtain more information: the result was an estimation of a 47-57 age range. Combined results suggested that it was more likely that the actual age of the woman was closer to 46 than to 62.
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Keywords: forensic odontology, age estimation, adults, hormonal dosage, living, pulp chamber

INTRODUCTION
Age estimation has quickly become a very active field of research in forensic sciences; in recent years age estimation in the living has become a more frequent request from courts. Its main application has been on subadults, concerning the verification of imputability in subjects, often immigrants, lacking valid identification documents. Commonly used for this task are analyses of hand and wrist ossification according to the Greulich and Pyle atlas[1], Tanner-Whitehouse[2] and FELS methods[3], radiographic analysis of the clavicle's sternal articular surface[4,5], dental methods based on a parodontic radiograph, and an in detail analysis of third molar development, among which Demirjian[6,7,8] and Mincer[9,10] stadiation are frequently used in the juridical context. In the living special attention must be given to the most frequently indicated age thresholds for imputability provided by laws in different countries (14, 16, 18, 21 years), although ethnic and sexual variability should be considered. Difficulties in age assessment in case of the living were stressed in 2001 by *The Study Group on Forensic Age Diagnostic*[11]; the group has proposed guidelines for age estimation in the living, with a three-step procedure including a physical examination concerning anthropometric analysis and sexual development assessment, dental analysis by panoramic radiograph, and radiographic study of the left hand; if the 21 year threshold is considered, clavicle sternal end radiographic examination is also suggested.

However living adults are a greater problem for age assessment.

Age estimation in the living more and more commonly concerns adults, frequently over 50 years of age, without identification documents, and is usually requested in order to verify if they have reached retirement age limits; the subjects are often immigrants, who cannot indicate with precision their date of birth and therefore their chronological age. When they are supposed to have reached retirement age, a pension may be provided by the welfare system, sometimes with removal from employment lists. This phenomenon is destined to increase in the next few years: e.g. in Italy 2,402,157 legal immigrants were registered up to 2005, among whom only 579,714 under 20 (24.1%); 75.9% of cases are adults[14]. In order to maintain their employment, or to ask for retirement, an age estimation is required; in these cases very few methods can be used.
Age determination in the living adult is more difficult because body maturation has come to an end and the most commonly used procedures in forensics on human remains are too invasive. An attempt at age estimation in living adults was performed by Ritz-Timme *et al.* using the aspartic acid racemization technique from dentine[12,13].

Although this lacks standardization, the authors report a high precision; however, dentine biopsy is invasive, although the authors report that the technique is of low risk13. Furthermore the method is expensive and complex.

One other method may involve radiological observation of pulp chamber reduction, discussed by Kvaal *et al.,*[18]. More recently Cameriere *et al.,* have taken these notions into consideration again and suggested the use of the ratio between the pulp chamber and tooth area from canine tooth radiographs[15,16,17]. The method is based on the physiological decrease of pulp chamber volume - which, as mentioned previously - has been analyzed by other dental methods of age estimation[18], and concerns 2D metrical measurements of parameters on a radiograph; this method is based on a similar procedure to Kvaal's, but attempts to measure areas and standardize the measurements by using computer software. The ratio between the measured area of a tooth and the area of its pulp chamber is calculated on a digitalized panoramic radiograph with the aid of specific software (Photoshop®). The values are inserted in a regression formula, which provides the age of the subject with an error of +/- 5 years. The first results published by the authors are encouraging, although more research needs to be performed. At present, this may be the only feasible age estimation method for living adults, though it still has to be assessed on different populations.

This case report provides an example of age estimation in adults and highlights difficulties of the age estimation process in the living, and some possible solutions.

CASE

A woman required age estimation after she was removed from employment lists because she had reached, according to the welfare system, the retirement age threshold (65 years for men, 60 years for women) in Italy. She had arrived in Italy as a young woman with her family as a war refugee. Identification documents provided by the claimant (given to her by her father) indicated that she was born in Asmara (Ethiopia) on January 1st 1944 (giving her an estimated age of 62 years). Her father however had told her that in order for her to qualify at the time as a political refugee he had had to falsify the documents to make her appear older. In fact other documents subsequently found by her relatives pointed out a birthdate of January the 1st 1960 (an estimated age of only 46 years). The claimant did not know how to prove one or the other. She only remembered she arrived in Italy in 1984, when she was an adult. After she arrived to Italy, she gave birth to two sons, in 1985 and in 1990. Although this circumstantial evidence seemed to indicate a "younger" solution, it could not exclude that she had had her last son at the age of 46.

To verify the woman's theory the judge requested an expert opinion which involved a forensic pathologist, a forensic odontologist and a gynaecologist. During the medical examination, the woman showed an apparent age between 45 and 55 years, based on general external appearance (initial skin wrinkling and hair greying); the claimant had brought previously performed vertebral, knee and chest radiographs, which provided no indication of severe degenerative pathology. She reported she had always been in perfect health and that since 2001 her menstrual flow had come to a halt.

The gynaecological examination pointed out dystrophy of external genitalia, ectropion, and normal vaginal trophism, without pathological signs. Ultrasound revealed a fibrous uterus, with thinning of the endometrial rima, and ovaries without follicles.

A hormonal dosage aimed at E2 (17-β estradiol) and FSH (Follicle Stimulating Hormone) rate analysis, which give an indication of ovarian function, was performed. The results indicated the beginning of menopause.

A panoramic dental radiograph (PDR) was performed in order to verify the ratio between pulp chamber and dental area from canines, according to Cameriere's method[15,16,17]. A digital periapical radiograph of the right maxillary canine was also taken. The PDR was digitized using a Nikon Coolpix 5000 camera (Fig.1). With the aid of Adobe Photoshop® CS2 the forensic odontologist measured the areas of the right maxillary canine and its pulp chamber on both the PDR and periapical radiograph (Figs.2,3). Copies were sent by e-mail to another odontologist who used the same method with similar results: 47 to 57 years of age with a 52 year mean age.

DISCUSSION

In living adults, age estimation techniques commonly used in the deceased are not feasible. Aspartic acid racemization requires a dentine biopsy with consequent limits concerning the invasive procedure, possible complications, technical problems in replicability and *standardization* as well as time and costs. The only indication of age may come from the examination of sexual characteristics and hormonal dosage, although a high racial and inter-individual variability must be considered. In this case, gynaecological and hormonal tests showed that the woman was at the beginning of menopause; the mean menopausal age is reported to be 49.5 - 51 years among the South African black population[19,20], 48.28 years among the Western Kenyan black population[21], without significant variation concerning social and economic factors: these data agree with the age estimation provided by the Cameriere *et al.* method which indicated an age between 47 and 57 years, with a mean of 52 years[15,16,17].

In conclusion, gynaecological tests and the dental method indicated an age of 48-52 years; these data are more consistent with the possibile date of birth provided by the relatives (January 1st 1960). The "ageless" woman kept her employment and now has to wait 14 years to retire. This was what she wanted, as she would have considered retirement inappropriate for her lifestyle, as did not "feel" 60.

This case report has provided no real solution to the problem, but has indicated some possible paths to pursue and the importance of a multidisciplinary approach. There are currently no recommendations concerning the correct age estimation procedure to apply on living adults, and very little experience; in fact, none of the commonly used methods are reliable enough in case of adults. In this case the Cameriere *et al.* method indicated a 10 year age range. However a combination of gynaecological and dental information provided a sensible age estimation and an orientation towards one of the two hypotheses.

Fig. 1: *Detail of the right maxillary canine in the digital x-ray.*

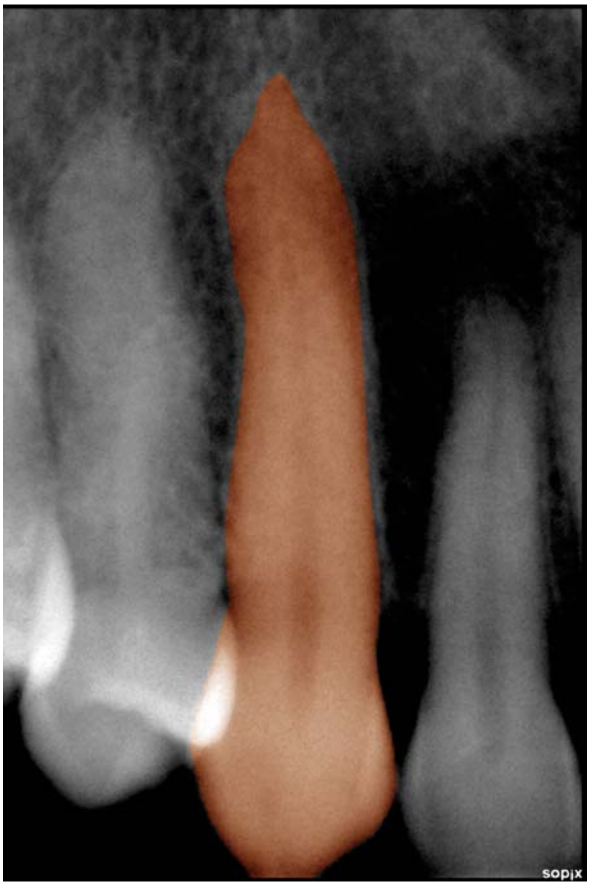

Fig. 2: *total canine area highlighted by Photoshop® computer software.*

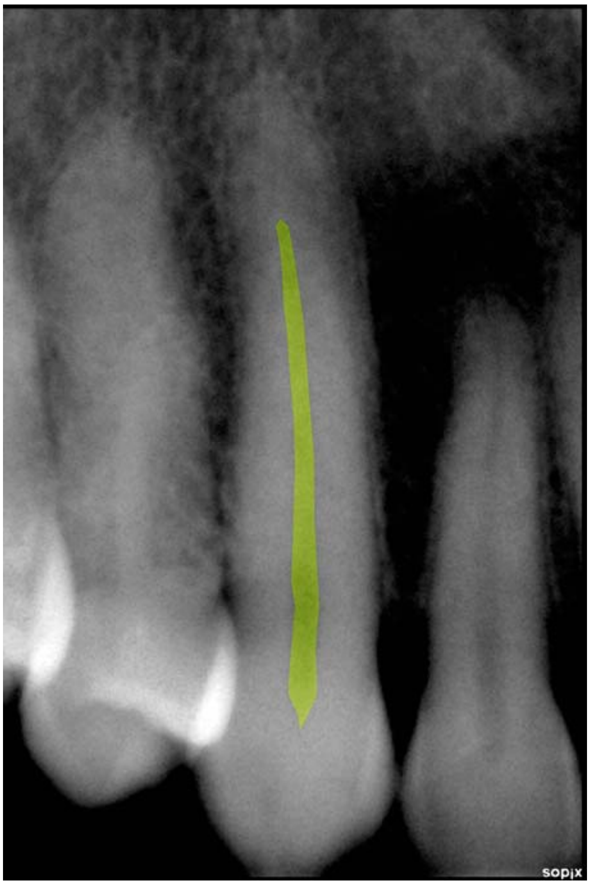

Fig. 3: *Pulp chamber area highlighted by Photoshop® computer software.*

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CHEILOSCOPY AS AN ADJUNCT TO FORENSIC IDENTIFICATION: A STUDY OF 600 INDIVIDUALS

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ABSTRACT

Cheiloscopy deals with examination of system of furrows on the red part of human lips. The present study was undertaken to classify lip prints, study their variations, determine the most common pattern in the study population, evaluate differences in lip prints between males and females and between different age groups, ascertain whether there is any hereditary pattern and thereby investigate their potential role in personal identification. Lip prints of 600 individuals, including 52 families, of ages ranging from 3 to 83 years were obtained using lipstick and two kinds of adhesive tape. The lip prints were analyzed using Adobe® Photoshop® software and classified according to Tsuchihashi classification. Patterns of lip prints occurred in diverse combinations. The patterns were similar between males and females and varied among different age groups. Some hereditary resemblance was observed between parents and offspring. Lip prints have a good potential for use in criminal investigations. They have been used only occasionally despite their frequent occurrence at crime scenes. A place for cheiloscopy is recommended within the scope of forensic odontostomatology, along with other means of forensic identification.

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Keywords: cheiloscopy, lip prints, forensic identification, forensic odontology

INTRODUCTION

Dentistry's fundamental and clinical disciplines have, from time to time, shed light on questions of civil and criminal law. Civil cases range from single malpractice suits to mass disaster insurance claims. Criminal cases involve identification both of murder victims and of suspects.[1] Latent or chance impressions located on smooth surfaces are encountered in a majority of the investigations which require comparative analysis. These impressions may arise from a number of sources, the most frequently encountered being impressions of areas of skin bearing friction ridges, predominantly those from the fingers. The possibility of impressions arising from an area of the skin devoid of friction ridges has been noted. Cases in which impressions devoid of friction ridges have been used for evidential purposes, have primarily involved lip impressions.[2]

Lip prints are similar to fingerprints, palm prints and footprints in that individual characteristics are used for identification. The creases on the vermilion border of the lips, which appear as white areas in lip prints, and the raised reddish areas outlined by these creases, which appear as dark areas, are analogous to the furrows and ridges of friction ridge skin. The creases on the vermilion border are also referred to as grooves, furrows, wrinkles and valleys.[3]

Lip prints are unique and do not change during the life of a person.[4,5] It has been verified that they recover after undergoing alterations like trauma, inflammation and diseases like herpes and that the disposition and form of the furrows does not vary with environmental factors.[6,7,8] The lip prints of parents and children and those of siblings have shown some similarities.[7,9] It has also been suggested that variations in patterns among males and females could help in sex determination.[10]

Unlike fingerprints, unanimity still does not exist between investigators to accept cheiloscopy as a method of human identification. Although lip print identification may appear in the field literature, there is very little science or research to support Suzuki's theory that lip prints are individual, or to support a methodology for the collection and comparison of lip prints, which has become

__Table 1:__ Age and sex distribution of the study population (N = 600)

		AGE				Total
			0 - 20 yrs	21 - 40 yrs	41 yrs and above	
SEX	MALE	Frequency	134	100	46	280
		Percentage	51.34%	40.00%	51.69%	46.67%
	FEMALE	Frequency	127	150	43	320
		Percentage	48.66%	60.00%	48.31%	53.33%
TOTAL		Frequency	261	250	89	600
		Percentage	100%	100%	100%	100%

accepted within the forensic science community. With this lack of sound scientific basis, the technique would fail to meet any standards of reliability.[11] The foundations of cheiloscopy, however, are the same as that of dactyloscopy, that is to say, lip prints are invariable, permanent and allow establishing a classification.

The present study was carried out to classify lip patterns and document common patterns and their variations in the population under investigation, to evaluate any differences between the sexes and different age groups, to ascertain whether there is any hereditary pattern in lip prints, and thereby, to investigate the potential role of lip prints in person identification.

MATERIALS AND METHODS

A. Selection and grouping of patients

The subjects employed for the investigation included 600 individuals (280 males and 320 females) of rural and urban localities of Aurangabad, Maharashtra, India of ages ranging from 3 years to 83 years (mean age = 23.4 years). Of these 600 subjects there were 52 families comprising of 214 persons (121 males and 93 females) of ages ranging from 3 years to 70 years (mean age = 27.87 years). To study the variation in age groups, the entire study population was divided into three groups; group I - 20 years and below, group II - 21-40 years, and group III - 41 years and above (Table 1).

B. Method of collection of lip prints

Several methods of recording lip prints were tried before the pro forma method was finally selected. Written informed consent was taken from each of the participants. The consent for participants under the age of 18 years was taken from either of the parents. The lips of each subject were first thoroughly examined clinically for any deformity, scars or abnormality and findings were noted in a preformed pro forma.

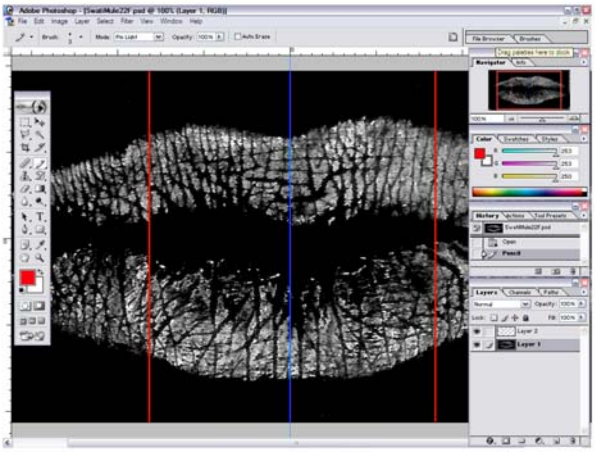
The lips of the subject were first cleaned thoroughly. The lips were then outlined using a sharp lip liner pencil. Lipstick was applied uniformly to the lips using lipstick applicator brushes starting at the midline and moving laterally. The lipstick was allowed to dry for about 2 minutes after which lip prints were taken in two ways. First, lip prints of each lip were taken separately using scotch Magic™ tape. A thin coat of lipstick was reapplied and a second lip print of both the lips together was taken using cellophane tape. These prints were stuck onto white paper in a manner similar to that described by Sivapathasundharam *et al* (2001).[4] [*]

C. Method for analysis of lip prints

The lip prints of each individual were scanned using an image scanner set at a resolution of 600 ppi. The images were inverted and scanned in grayscale. They were stored as TIFF (Tagged Image File Format) files for maximum details. The most legible prints of both lips taken together on cellophane tape were cropped and vertical lines drawn to divide the left and the right sides. Each side was further divided into two equal parts using Adobe® Photoshop® 7.0 software (Fig. 1) as suggested by Bowers and Johansen (2001).[12]

[*] For proprietary details refer Table 2

Fig. 1: Adobe Photoshop software used for analysis of lip prints



I. Criteria for classification of lip prints

The lip prints were classified using the classification given by Suzuki and Tsuchihashi (1970) (Fig. 2).[13,14,15] The determination of the pattern in each segment of the lip was based on the numerical superiority of properties of the lines on the fragment. In cases where there were two dominant patterns, the second dominant pattern was noted alongside the most dominant pattern.

II. Method for comparison of lip prints in families

To ascertain the inheritance of lip prints, 52 families with 112 offspring were studied. The lip prints of each member of a family were recorded together in a separate pro forma method. Each lip of the 112 offspring was compared with the corresponding lip of his or her parents. The number of segments of each lip of the offspring that matched with those of both parents was noted and the higher resemblance of the two was recorded. Comparisons of all the other offspring in the family with their parents were made. Similarly, both the lips of each sibling were compared with the corresponding lip of one of his or her other siblings. Similar comparisons were made with all the other siblings in the family. Resemblance was considered positive if three or more segments of a lip matched with the corresponding lip of the other individual. This suggested that there was a resemblance of 75% or above between the two lips.

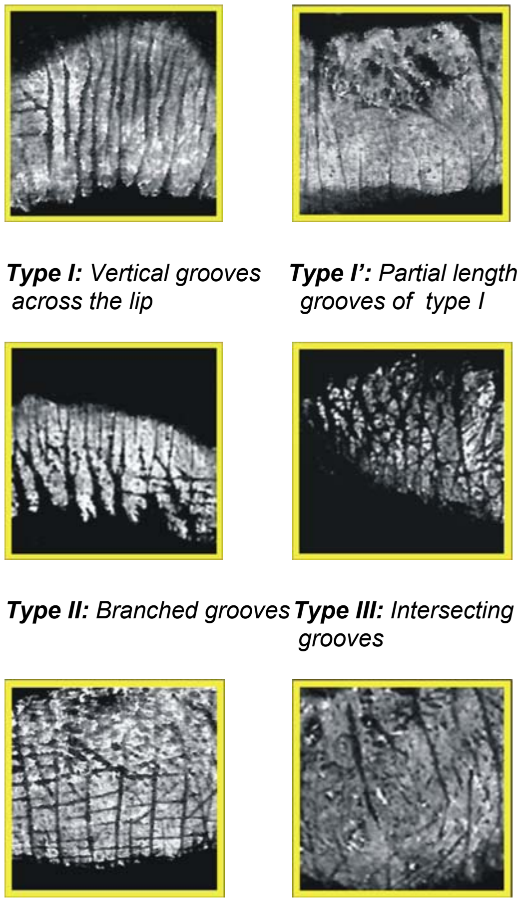
D. Statistical analysis

Comparison of lip prints was done using chi-square test. Z-test was applied to test the significance of positive resemblance of lip prints in the family.

RESULTS AND DISCUSSION

Human identification has always has been of paramount importance to society.[16] Worthy of note as providing an additional tool for personal identification is the series of studies on the morphology of the lips and the pattern produced when they are impressed onto a variety of surfaces.[6] The considerable identifying possibilities of the trace of the red part of the lips determine the evidential use of it.[17]

Fig. 2: Tsuchihashi's classification of lip prints



Type I: *Vertical grooves across the lip* ***Type I':*** *Partial length grooves of type I*

Type II: *Branched grooves* ***Type III:*** *Intersecting grooves*

Type IV: *Reticular grooves* ***Type V:*** *Other patterns*

The method described by Sivapathasundharam *et al* (2001)[4] was selected for this study for the accuracy of details achieved, the ease of obtaining such details and the protection and preservation provided by the adhesive tape to the impression once it was stuck onto the paper. Two 'sets' of lip prints were useful for confirmation of pattern in cases where details were diminished. The obtained lip prints were scanned. The scanned images could be preserved safely with minimal loss of details, divided into equal parts using the ruler in the software, adjusted for brightness and contrast and magnified as much as necessary for clear visualization of details. These images could be filed systematically and stored as a database for further use as and when necessary.

Table 2: *Proprietary details of materials used*

Material	Proprietary name	Company
Dark red coloured lipstick	Lakmé enrich lip color classics, no. 353.	Hindustan Lever Ltd., India
Lipstick applicator brush	Vega™	Tristar Products Pvt. Ltd., India
Lip liner pencil	Davis® no. 14	Davis, India
Scotch tape	Scotch Magic™ tape, 19mm width	3M India Ltd., Bangalore, India
Cellophane tape	Wondertape™, 36mm width	Wondertape, India
Software	Adobe® Photoshop® 7.0	Adobe Systems Inc., USA

The lip prints were classified using the classification proposed by Suzuki and Tsuchihashi in 1970,[6,13,14,15] also known as Tsuchihashi's classification. This is the most widely used classification in literature. It was found to have a clear description of nearly all of the commonly encountered lip patterns and was easy to interpret. Its resemblance to the dental formula was also familiar to the forensic dentist. The fact that a minimum number of type V patterns were observed in the present study was evidence to the complete coverage of patterns in this classification.

It was observed that the medial and lateral parts of the lips frequently had different patterns. A detailed observation revealed that each type never occurred singly, but in combination with other types. It was observed that type III and type IV were the most commonly superimposed patterns, which were difficult to differentiate at times.

In the present study, the most predominant pattern in the entire study population, taking both the upper and lower lips together, was type III which constituted 48.2% of all patterns. This was followed in order by type II (18.92%), type IV (17.44%), type I (11.10%), type I' (2.54%) and type V (1.58%). Similar results have been reported by Suzuki and Tsuchihashi in an investigation of 64 Japanese individuals. They found type III to be the most common, followed in order by type I, type II, type IV and type V. Their study, however, considered type I pattern as inclusive of type I' which they later separated in their improved classification.[6]

Hirth *et al* (1975) observed that branched pattern was more frequently present in the upper lip and simple pattern was commonly seen in the lower lip.[7] Our results show similar variations, with type II constituting 25% of all patterns on the upper lip as against 12.83% in the lower lip. On the other hand, type I and type I' collectively constituted 16.5% of all patterns in the lower lip as against 10.79% in the upper lip. Our results differed from those obtained by Vahanwala and Parekh (2000)[10] who found type I and type II to be the most common in the upper right quadrant. They considered the most predominant pattern in the entire quadrant for classification, whereas the quadrants have been divided further into two segments in our study.

In our study, the upper lip showed a predominance of type III pattern (45.17%) followed in order by type II (25%), type IV (17.5%), type I (8.79%), type I' (2%) and type V (1.54%). This pattern differed from that seen in the lower lip. While type III pattern was even more predominant in the lower lip (51.67%), it was followed by type IV (17.38%), type I (13.42%), type II (12.83%), type I' (3.08%) and type V (1.63%) in that order.

In the upper lip, both type III and type I patterns were found to be more common in the lateral segments than in the medial segments while type IV, type V and type I' were more common in the medial areas than the lateral. The lower lip, in contrast, showed a predominance of type I pattern in the medial segments as compared to the lateral. Type III pattern showed a predominance of almost 80% in the lateral segments of the lower lip while the upper lip showed a frequency of less than 55% in this region. The medial segments of the upper lip showed a predominance of type III followed by type IV and type II patterns. The lower lip, on the other hand, showed type IV to be the most predominant in the medial segments followed by type I and type III. Type II pattern was more commonly observed in the upper lip and was evenly distributed in all segments, while in the lower lip it was found to be more common in the lateral than in the medial segments. Chi-square test results showed a statistically significant difference in pattern between the entire upper and lower lips and their medial and lateral segments.

Sivapathasundharam *et al* (2001)[4] stated that the uniqueness of patterns depended on the way the lip muscles relaxed to produce a particular pattern. Lévêque and Goubanova (2004)[9] suggested that the furrows and grooves on the lips seemed to be privileged routes for saliva to spread over the lips and maintain good hydration. They also found the upper lip to be more hydrated than the lower one. The variations in pattern between the upper and lower lip may be attributed to these factors and might have a functional significance. Lévêque and Goubanova also noted that some continuity appeared to exist between the lips and adjacent skin lines and suggested a common origin. The predominance of type III pattern, in our study, especially in the lateral segments of the lower lip, might just be a result of this continuity as the lines on the skin adjacent to the lips in these areas were often found to intersect.

A comparison of the lip print pattern between males and females showed type III pattern to be the most predominant pattern in both males and females accounting for 49.15% and 47.78 % of all patterns respectively. The next most common pattern in males and females was type II (approximately 19%) which occurs in the same percentage in both sexes. This was followed by type IV pattern which, however, was more common in females (19.15%) than in males (15.45%). Chi-square test results showed that a statistically significant difference (P<0.001) existed between the lip prints of males and females. Vahanwala and Parekh (2000)[10] made suggestions as to the differences in lip prints as an aid to sex determination.

Lévêque and Goubanova (2004)[9] studied lip prints of 100 women and classified them into three types: the first, corresponding to Tsuchihashi's type I, type I' and type II, which accounted for 35% of their observations, the second constituting a thin network located at the extremity of the lip, corresponding to type III, accounted for 50%, and the third corresponding to type IV, accounting for 15% of their observations. The lip prints of the women in the present study showed a similar pattern. Type I, type I' and type II taken together for women, accounted for 31.8% of all observations. Type III accounted for 47.78% and type IV accounted for 19.18% of all observations.

The upper lip of both males and females showed type III to be the most predominant pattern constituting 45.63% and 44.77% of all patterns respectively. This was followed by type II (25.63% in males and 24.45% in females), type IV (14.82% in males and 19.84% in females) and type I (10.54% in males and 7.27% in females). Type IV pattern was more common in the lateral segments of females than in males while type I was more common in the lateral segments of males than in females (Table 3). Chi-square test results revealed a statistically significant difference (P<0.01) between the sexes in the lateral segments while this difference was not significant (P<0.10) in the medial segments. The reason for this difference is not known.

The lower lip of both males and females showed type III pattern to be the most common (52.68% in males and 50.78% in females) followed by type IV (16.07% in males and 18.52% in females). In males, this was followed by type II (12.14%), type I' (2.59%) and type V (1.96%) and in females, this was followed by type II (13.44%), type I (12.42%), type I' (3.52%) and type V (1.33%) (Table 4). Chi-square test results showed that the difference between lip prints of males and females in the medial and lateral segments of the lower lip were not statistically significant (P<0.20 and P<1 respectively). Our results are in agreement with those of Rubio and Villalain (1980) [8] who did not find significant differences in lip prints based on sex, age or race.

Table 3: *Distribution of lip print patterns in different segments of the upper lip of males (N=280) and females (N=320)*

TYPE		URL	URM	ULM	ULL	TOTAL
TYPE I	Males	38	18	16	46	118
	Females	29	12	15	37	93
TYPE I'	Males	1	9	5	1	16
	Females	9	12	7	4	32
TYPE II	Males	67	73	79	68	287
	Females	77	76	87	73	313
TYPE III	Males	156	99	105	151	511
	Females	174	110	113	176	573
TYPE IV	Males	17	68	68	13	166
	Females	29	103	92	30	254
TYPE V	Males	1	13	7	1	22
	Females	2	7	6	0	15
TOTAL	Males	280	280	280	280	1120
	Females	320	320	320	320	1280

URL- Upper Right Lateral, URM- Upper Right Medial, ULM- Upper Left Medial, ULL- Upper Left Lateral

Table 4: *Distribution of lip print patterns in different segments of the lower lip of males (N = 280) and females (N=320)*

TYPE		LRL	LRM	LLM	LLL	TOTAL
TYPE I	Males	8	75	72	8	163
	Females	8	75	69	7	159
TYPE I'	Males	1	13	15	0	29
	Females	1	21	21	2	45
TYPE II	Males	39	31	22	44	136
	Females	50	31	35	56	172
TYPE III	Males	229	63	78	220	590
	Females	254	70	77	249	650
TYPE IV	Males	3	84	85	8	180
	Females	6	114	112	5	237
TYPE V	Males	0	14	8	0	22
	Females	1	9	6	1	17
TOTAL	Males	280	280	280	280	1120
	Females	320	320	320	320	1280

LRL- Lower Right Lateral, LRM- Lower Right Medial, LLM- Lower Left Medial, LLL- Lower Left Lateral

The study population was divided into three age groups: group I – aged 20 years or below, group II – aged 21 to 40 years and group III - aged above 40 years. A statistically significant difference existed between the lip prints of the upper and lower lips among these age groups. This indicates the diversity in pattern of lip prints among different persons of all age groups in the community. Thus, age groups have no relevance for any similarity of lip prints.

The present study also aimed to investigate the role of heredity in lip prints. Among lip prints of 112 offspring studied, 63% were seen to have a positive resemblance with either of the parents. Z-test was applied and this observation was found to be highly statistically significant ($z=3.89$, $P<0.01$). The lip prints of the offspring were compared with those of their siblings for resemblance in pattern. Of the 92 sibling-sibling combinations studied, 45.66% had a positive resemblance with each other. This percentage of resemblance was not found to be statistically significant (z=1.08, P>0.1). Hence, in accordance with previous studies, our results provide further evidence to the role of heredity in lip prints. Comparison of lip prints with members of the family might give valuable indications for the identification of the suspect. However, failure of resemblance with family members might not rule out the possibility of the suspect being a member of the family and vice versa.

The resemblance of patterns of lip prints between mothers and offspring was found to be positive in 60.65% cases while positive resemblance between fathers and offspring was found in 65.68% of cases. Z-test applied to these observations showed them to be statistically significant (z=2.34, P<0.05 and z=3.17, P<0.001 respectively). The difference of positive resemblance between mothers and offspring and between fathers and offspring was not found to be statistically significant (z=0.75, P>0.1). This indicates that while a positive hereditary pattern does exist between parents and offspring, there does not seem to be a particular paternal or maternal influence on the pattern.

The positive resemblance of lip prints was found to be greatest between fathers and sons (69.35%) followed by that between mothers and sons (63.16%). Z-test showed these observations to be statistically significant. Father to daughter positive resemblance was found to be 60% while mother to daughter resemblance was found to be 56.52%. Z-test results showed that these observations were not statistically significant (z=1.26, P>0.1, z=0.88, P>0.1 respectively). Therefore, it was observed that sons inherited lip prints more often from their parents than daughters do. However, further studies will need to be conducted before such a conclusion may finally be drawn.

As early as 1950, Snyder suggested that the normal lines and fissures of the lips were an individual characteristic, much the same as finger ridges. [18,3,11,19,6,20] Since then, numerous studies give evidence to the fact that lip prints are unique and characteristic of an individual. However, at the initial classification stage, as in the case of fingerprints, there are similarities among the broadly classified groups of lip prints. Classification is useful in categorizing the lip prints and narrowing the range for detailed investigation. It helps in creating an organized database for retrieving information easily. It is essential as a basis for comparison, for instance, between families and the sexes. The classification in the present study did narrow down the database into small groups that could be easily compared using individual characteristics, as is done in dactyloscopy.

Further detailed examination of these lip prints would be required to establish identity, if found matching at this level. Evidences such as photographs, cigarette butts, drinking glasses, cups, letters, window panes and other items that could bear lip prints should be closely examined. A trace of this kind carries a huge amount of information which can be used in the reconstruction of the events, establishing versions, checking them and identifying suspects.[17,21]

Great strides have been made in the collection, analysis and interpretation of lip prints. Lip prints have been studied in postmortem identification.[22] Advances have been made in the techniques and dyes for developing lip prints.[23-30] Software has been developed for the analysis of lip prints.[31] However, limitations still exist in the use of lip prints. The permanent nature of lip prints requires more long term studies to be substantially documented. Advanced methods of developing lip prints at a scene of crime are still confined to research laboratories. Full utilization of lip depends to a high degree on the skill of members of law enforcement agencies. The problems involved in cheiloscopy are relatively little known and thus, so far lip prints have been used only occasionally despite their frequent occurrence at the scene of crime. The only possible solution is to place cheiloscopy within the scope of criminalistics, side by side with dactyloscopy and other means of person identification and to introduce it into the syllabus of training of forensic odontology.

The classification and observation of patterns in the population, and the investigation of heredity of the lip print have resulted in some useful data. Progress in research in this area will contribute not merely to its direct use in personal identification in forensic medicine and odontology, but will also open up a new field that can contribute extensively to criminal investigation and identification, the establishment of parenthood and studies on human genetics.

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ARE DENTAL INDEXES USEFUL IN SEX ASSESSMENT?

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ABSTRACT

This study describes sexual dimorphism in dental indexes derived from the permanent dentition. Three dental indices—'crown area,' 'crown module' and 'crown index'—were calculated from the buccolingual (BL) and mesiodistal (MD) measurements of 123 permanent dentitions (58 females and 65 males) belonging to young Nepalese adults (age-range 19–28 years). Sex differences in the dental indexes were assessed using univariate and multivariate statistics and compared to that of linear measurements reported previously on the same sample. Univariate sex dimorphism exhibited by crown area and crown module was similar to that of linear measurements whereas crown index displayed marked variation. The unusual results shown by the latter is explained as the result of it not being a representation of tooth size per se; rather, crown index is an expression of the *difference* between BL and MD dimensions and may be better suited as an indicator of tooth 'shape'. Stepwise discriminant analyses undertaken for the indices gave moderate to high accuracy rates in sexing (69.8–81.1%). However, this is lower to the classification accuracy reported for linear measurements. Therefore, it is concluded that dental indexes have no added utility in forensic sex assessment.

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Keywords: forensic odontology, sex determination, odontometrics, crown area, crown module, crown index

INTRODUCTION

Sex assessment from tooth measurements is a useful adjunct to identifying forensic and anthropological skeletal specimens. Sexual dimorphism in tooth size has been explored over the past half-century, with odontologists and anthropologists[1–3] focussing on the use of buccolingual (BL) and mesiodistal (MD) dimensions—termed linear measurements. Recently, some investigators have used diagonal measurements where tooth crowns were measured 'corner-to-corner'.[1,4] According to these authors, diagonal measurements allow measuring rotated, crowded and proximally restored teeth. The advantages notwithstanding, diagonal measurements have technical limitations.[4] Therefore, it is anticipated that linear measurements will continue to find favour in odontometric sex assessment owing to the relative ease with which they are obtained. While one recent study has revealed high levels of sexual dimorphism in linear measurements,[2] gender differences have not been consistent enough to warrant the use of linear tooth dimensions as the sole indicator of sex. Therefore, efforts to improve sex assessment outcomes from linear tooth dimensions are required. An option which could prove useful is the calculation of dental indexes. Dental indexes are derived from simple mathematical combinations of linear measurements. They include 'crown area,' 'crown module' and 'crown index' and are defined as follows:

Crown area—Crown area or tooth robustness is the product of BL and MD dimensions and derived for each tooth by multiplying the linear measurements (i.e. BL $\times$ MD).

Crown module—Crown module for each tooth is taken as the average of BL and MD dimensions, i.e. (BL + MD)/2.

Crown index—Crown index, on the other hand, is the ratio of the two linear measurements expressed as percentage, i.e. (BL/MD) $\times$ 100.

Dental indexes are shown to have evolutionary,[5] developmental[6] and clinical significance.[7] However, their use in forensic sex identification has not been explored fully. Townsend and Brown[8] presented statistical summaries for these indices in males and females, but did not comment on sexual dimorphism per se. Others limited their assessment of sex differences to crown index.[9,10] Introna *et al.*[11] undertook the solitary study that examined sex differences for all dental indexes, but restricted the assessment to maxillary deciduous molars. They did, however, perform discriminant analysis as an aid to sex identification. Garn *et al.*[12] have also undertaken discriminant analysis for tooth ratios of the permanent dentition. In fact, some believe that sex differences in dental indexes exceed those in linear dimensions and has the potential to improve sex differentiation when assessed by means of discriminant analysis.[9] Indeed, dental indices may serve as a measure of the ‘whole’ tooth crown, rendering them more amenable to sex assessment. The present study has, therefore, ventured to explore sexual dimorphism in dental indexes. In particular, the objectives of this study were to assess univariate and multivariate sex differences in dental indices derived from the BL and MD dimensions of the permanent dentition and determine their utility in sex assessment vis-à-vis linear measurements.

MATERIALS AND METHODS

The sample consisted of 123 dental casts from young Nepalese adults (58 females and 65 males) aged 19–28 years. Following verbal consent, impressions of the teeth were made using irreversible hydrocolloid material and casts poured in dental stone. MD and BL measurements of all teeth (excluding third molars) were obtained using a digital calliper* with calibration 0.01 mm. Dental indexes were calculated from BL and MD measurements of these teeth. The MD measurements were defined as the greatest dimension between the contact points on the approximate surfaces of the crown measured with the calliper beaks placed occlusally along the long axis of the tooth.[8] In cases where the teeth were rotated or malposed, measurements were taken between points on the approximate surfaces of the crown where it was considered that contact with adjacent teeth would have normally occurred. The BL measurements were defined as the greatest distance between the labial/buccal surface and the lingual surface of the tooth crown measured with the calliper held at right angles to the MD dimension.[8] A few tooth variables in some of the casts could not be measured due to impediments such as restorations, caries, excessive wear or casting defects. Consequently, dental index values were not always available for all teeth in the 123 dental casts. Univariate sex differences in the dental indexes were assessed using the independent samples *t*-test. Stepwise discriminant analyses were performed on 53 complete sets of dentitions belonging to 22 females and 31 males (the remaining 70 dental casts had at least one missing tooth variable and could not be included in the discriminant analysis since the analysis cannot take up incomplete data). Separate stepwise discriminant analyses were undertaken for crown area, crown module and crown index. All analyses were performed using the SPSS 10.0 software package.†

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RESULTS

Univariate sex dimorphism

Tables 1–3 depict the descriptive statistics and *t*-values of crown area, module and index, respectively, for the measured teeth. For crown area (Table 1) and module (Table 2), canines showed the greatest sex dimorphism followed by the maxillary first molar, maxillary central incisor and mandibular second molar. Thirteen of the 28 tooth variables (a majority of which pertained to the maxilla) showed statistically significant sex differences ($p < 0.05$) for crown area and module. However, a different picture emerged for crown index (Table 3): the second molar and first premolar exhibited the greatest univariate sex difference while canines revealed none. Four crown index variables namely, tooth 37, 42, 46 and 47 showed greater mean values for females, the latter being statistically significant ($p < 0.05$).

Stepwise discriminant analyses

Table 4 illustrates the tooth variables for crown area, module and index that contributed to the stepwise discriminant analysis. Wilks’ Lambda denotes how useful a given tooth variable is in the discriminant analysis and determines the order in which the variables entered the analysis; the Exact *F* Statistic determines how much variation exists between the sexes and the significance level of the variance.[13] Identical teeth entered the analysis undertaken for crown area and crown module. Only maxillary teeth contributed to the analysis performed for crown index, with no contribution what-so-ever of the canines. The cross-validated accuracy of the discriminant analyses in sex differentiation is presented in Table 5. The highest accuracy rate among the three dental indexes was obtained for crown module followed closely by crown area. Crown index exhibited lower classification accuracy.

DISCUSSION

Accurate sex assessment of skeletal remains has great importance in forensic and anthropological investigations. For optimal outcome, as many criteria as are available must be utilised.[14] Teeth are the strongest structures in the human body and are known to resist postmortem destruction. They are usually retained in skeletal specimens and, hence, can be used in sex differentiation.

†SPSS Inc., Chicago, Illinois, U.S.A.

Table 1: *Descriptive statistics and t-values for crown area (BL×MD)*

Tooth Number[*]	Female				Male				t-Value[†]
	N	Mean	SD	CV	N	Mean	SD	CV	
11	56	61.16	7.31	11.95	62	65.12	8.04	12.35	-2.79[§]
12	57	43.18	6.35	14.70	63	44.90	7.37	16.42	-1.36
13	58	59.99	7.11	11.85	64	66.52	7.62	11.46	-4.88[‖]
14	58	64.57	7.54	11.68	65	66.83	7.14	10.68	-1.70
15	56	60.34	7.03	11.66	64	62.80	6.63	10.56	-1.98
16	57	115.70	10.21	8.83	62	123.14	12.02	9.76	-3.63[‖]
17	48	108.37	12.25	11.31	62	112.69	12.34	10.95	-1.83
21	57	61.07	7.01	11.47	65	65.13	7.92	12.17	-2.98[§]
22	57	43.29	6.46	14.92	62	45.03	6.82	15.15	-1.43
23	57	59.58	6.93	11.63	64	65.71	7.66	11.66	-4.60[‖]
24	57	65.03	7.46	11.48	64	67.14	6.25	9.31	-1.69
25	56	59.92	6.61	11.03	65	62.77	6.57	10.46	-2.38[‡]
26	57	115.30	9.83	8.52	63	120.91	10.91	9.03	-2.94[§]
27	47	106.71	10.58	9.91	56	112.87	12.46	11.04	-2.68[§]
31	56	32.17	3.96	12.31	62	33.24	3.85	11.58	-1.49
32	58	37.80	3.67	9.70	59	39.21	4.08	10.40	-1.97
33	58	48.57	5.05	10.39	64	54.74	5.98	10.93	-6.12[‖]
34	55	55.84	6.62	11.86	64	57.21	6.34	11.09	-1.15
35	56	59.45	6.45	10.85	63	60.48	5.55	9.17	-0.94
36	58	116.97	11.19	9.56	57	119.73	9.90	8.27	-1.40
37	48	105.01	12.30	11.71	62	111.71	12.55	11.23	-2.80[§]
41	54	32.44	3.60	11.09	59	33.45	3.68	11.00	-1.48
42	57	37.53	3.43	9.14	62	38.90	3.92	10.08	-2.02[‡]
43	58	48.25	5.02	10.40	65	54.64	6.09	11.14	-6.31[‖]
44	56	55.81	5.93	10.62	63	57.51	6.09	10.59	-1.54
45	51	58.78	6.50	11.06	62	60.09	5.49	9.13	-1.17
46	55	117.12	11.46	9.79	59	119.57	10.47	8.76	-1.19
47	48	105.83	11.88	11.23	63	110.83	11.63	10.49	-2.23[‡]

[*]FDI tooth notation
[†]Statistically significant at [‡]$p < 0.05$; [§]$p < 0.01$; [‖]$p < 0.001$ level

Table 2: *Descriptive statistics and t-values for crown module ((BL+MD)/2)*

Tooth Number[*]	Female				Male				*t*-Value[†]
	N	Mean	SD	CV	N	Mean	SD	CV	
11	56	7.84	0.47	5.93	62	8.09	0.50	6.16	-2.79[§]
12	57	6.57	0.48	7.35	63	6.69	0.56	8.40	-1.23
13	58	7.74	0.46	5.96	64	8.15	0.47	5.74	-4.91[‖]
14	58	8.11	0.47	5.82	65	8.26	0.44	5.34	-1.90
15	56	7.87	0.46	5.86	64	8.05	0.43	5.35	-2.13[‡]
16	57	10.76	0.48	4.44	62	11.10	0.54	4.85	-3.65[‖]
17	48	10.42	10.64	5.66	62	10.64	0.58	5.43	-1.93
21	57	7.83	0.45	5.71	65	8.09	0.50	6.13	-2.98[§]
22	57	6.57	0.51	7.72	62	6.70	0.51	7.65	-1.37
23	57	7.71	0.45	5.87	64	8.10	0.47	5.80	-4.62[‖]
24	57	8.13	0.47	5.73	64	8.28	0.39	4.70	-1.93
25	56	7.85	0.43	5.46	65	8.05	0.42	5.25	-2.55[‡]
26	57	10.74	0.46	4.30	63	11.00	0.50	4.52	-2.98[§]
27	47	10.35	0.52	5.00	56	10.66	0.59	5.51	-2.81[§]

31	56	5.67	0.36	6.27	62	5.77	0.33	5.77	-1.53
32	58	6.15	0.30	4.91	59	6.26	0.32	5.16	-1.94
33	58	6.97	0.37	5.26	64	7.40	0.41	5.53	-6.11[‖]
34	55	7.48	0.45	5.96	64	7.57	0.42	5.57	-1.21
35	56	7.74	0.42	5.41	63	7.82	0.36	4.58	-1.11
36	58	10.81	0.52	4.81	57	10.94	0.45	4.14	-1.43
37	48	10.23	0.60	5.86	62	10.56	0.59	5.57	-2.82[§]
41	54	5.70	0.32	5.70	59	5.79	0.32	5.45	-1.52
42	57	6.13	0.29	4.69	62	6.24	0.31	5.00	-1.98
43	58	6.95	0.37	5.28	65	7.40	0.42	5.64	-6.29[‖]
44	56	7.48	0.40	5.38	63	7.59	0.40	5.30	-1.60
45	51	7.70	0.43	5.56	62	7.79	0.35	4.54	-1.32
46	55	10.81	0.53	4.92	59	10.93	0.48	4.41	-1.21
47	48	10.28	0.57	5.58	63	10.52	0.55	5.21	-2.25[‡]

[*]FDI tooth notation
[†]Statistically significant at [‡]$p < 0.05$; [§]$p < 0.01$; [‖]$p < 0.001$ level

Table 3: *Descriptive statistics and t-values for crown index ((BL/MD)×100)*

Tooth Number[*]	**Female**				**Male**				***t*-Value**[†]
	N	**Mean**	**SD**	**CV**	**N**	**Mean**	**SD**	**CV**	
11	56	84.02	6.85	8.15	62	84.42	7.09	8.40	-0.31
12	57	93.29	11.29	12.11	63	95.24	9.15	9.61	-1.04
13	58	103.56	6.91	6.67	64	105.31	7.02	6.66	-1.38
14	58	133.22	5.99	4.49	65	136.31	6.27	4.60	-2.78[§]
15	56	141.13	6.58	4.66	64	143.52	7.65	5.33	-1.82
16	57	107.92	5.02	4.65	62	109.30	4.74	4.34	-1.54
17	48	115.32	7.26	6.30	62	118.32	6.46	5.46	-2.30[‡]
21	57	84.77	6.29	7.42	65	84.99	6.74	7.93	-0.19
22	57	94.31	11.09	11.76	62	94.74	8.88	9.38	-0.24
23	57	104.15	7.02	6.74	64	105.37	7.04	6.68	-0.95
24	57	132.64	5.73	4.32	64	135.84	6.00	4.42	-2.99[§]
25	56	141.64	7.52	5.31	65	143.98	7.84	5.45	-1.67
26	57	108.09	4.78	4.42	63	110.33	4.57	4.15	-2.62[§]
27	47	114.85	6.58	5.73	56	119.74	7.24	6.04	-3.57[‖]
31	56	110.77	9.06	8.18	62	111.88	9.15	8.18	-0.66
32	58	105.98	9.17	8.65	59	106.33	8.33	7.83	-0.22
33	58	110.52	6.34	5.74	64	111.85	7.30	6.52	-1.07
34	55	112.84	7.08	6.27	64	115.41	5.81	5.04	-2.17[‡]
35	56	121.24	5.99	4.94	63	123.91	7.15	5.77	-2.20[‡]
36	58	97.24	4.50	4.63	57	97.34	4.90	5.04	-0.12
37[¶]	48	102.61	5.27	5.14	62	100.81	4.89	4.85	1.85
41	54	110.99	8.47	7.63	59	112.84	8.76	7.76	-1.14
42[¶]	57	107.01	9.34	8.73	62	106.65	9.07	8.50	0.21
43	58	111.43	6.06	5.44	65	112.75	7.29	6.46	-1.08
44	56	113.07	6.46	5.71	63	114.62	7.58	6.61	-1.19
45	51	122.24	5.45	4.46	62	124.33	7.79	6.27	-1.61
46[¶]	55	97.55	4.80	4.92	59	96.98	4.50	4.64	0.66
47[¶]	48	103.27	4.88	4.73	63	100.60	5.05	5.02	2.80[§]

[*]FDI tooth notation
[†]Statistically significant at [‡]$p < 0.05$; [§]$p < 0.01$; [‖]$p < 0.001$ level
[¶]Larger in females

Table 4: *Stepwise discriminant analysis of dental indexes*[*]

Variables Entered	Wilks' Lambda Statistic	Exact *F* Statistic	d.f.1	d.f.2	Sig.
Crown Area[†]					
Tooth 33	0.719	19.969	1	51	0.000
Tooth 34	0.594	17.075	2	50	0.000
Tooth 16	0.549	13.424	3	49	0.000
Tooth 36	0.505	11.754	4	48	0.000
Crown Module[†]					
Tooth 33	0.715	20.301	1	51	0.000
Tooth 34	0.596	16.956	2	50	0.000
Tooth 16	0.552	13.279	3	49	0.000
Tooth 36	0.507	11.677	4	48	0.000
Crown Index[†]					
Tooth 14	0.786	13.910	1	51	0.000
Tooth 26	0.713	10.081	2	50	0.000

F values are all significant at $p < 0.01$ level
[*]At each step, the variable that minimises the overall Wilks' Lambda is entered. Minimum partial F to enter is 3.84; maximum partial F to remove is 2.71
[†]All 28 variables (i.e. 28 teeth) were included in the analysis

Table 5: Classification results of the cross-validated discriminant analysis* for all 28 teeth

	Male		Female		Total Average (%)
Stepwise Discriminant Analyses	**N**	**%**	**N**	**%**	
Crown Area	24/31	77.4	18/22	81.8	79.2
Crown Module	25/31	80.6	18/22	81.8	81.1
Crown Index	21/31	67.7	16/22	72.7	69.8
Linear Measurements[2]	28/31	90.3	21/22	95.5	92.5

[*]Cross-validation (or jackknifing) is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

The dentition takes precedence particularly when preferred parameters such as the pelvis are unavailable and cranial and long bones fragmentary. However, since linear tooth measurements usually give moderate levels of accuracy in sex identification,[3,12] alternative means of assessing sex within the realm of linear measurements needs investigation. This study investigated whether univariate and multivariate sexual dimorphism in dental indexes derived from the permanent teeth offered a solution.

Univariate and multivariate sex differences in crown area and module

The results of univariate sex dimorphism for crown area and module (Tables 1 and 2) were largely consistent with those reported for linear measurements on the same sample,[2] where canines and molars showed the greatest sex difference. Also, more maxillary variables showed statistically significant sexual dimorphism ($p < 0.05$), reinforcing the observation that maxillary teeth have a greater tendency to be larger in males.[2]

Crown area and module of tooth 33 and 16 showed statistically significant univariate dimorphism (Tables 1 and 2) and also contributed to their respective stepwise discriminant analysis (Table 4). However, a number of teeth with significant univariate dimorphism did not enter the discriminant analysis. On the other hand, tooth 34 and 36 showed no significant univariate dimorphism for crown area and module yet, contributed to the stepwise discriminant analysis. These contradictions are the result of tooth correlations not being utilised in univariate statistical analysis such as the independent samples *t*-test, which compares the teeth individually between males and females.[15] Hence, some of the information useful for sex differentiation is unavailable in such analyses. On the other hand, multivariate analysis such as stepwise discriminant analysis takes into consideration tooth inter-relationships and the combined ability of a set of teeth to differentiate the sexes.[15] Hence, although a tooth may not show significant univariate sex differences, it could still contribute to sex identification on virtue of its potential to differentiate the sexes when used in combination with other teeth.

Univariate and multivariate sex dimorphism in crown index

The results for crown index differ from crown area and module reported in this study as well as those for linear measurements reported previously for the same sample:[2]

Foremost, the crown index of canines makes no contribution to sex dimorphism (Tables 3 and 4). This is a unique finding, considering that canines have shown the greatest univariate sex differences, and also contributed to discriminant analysis of other dental indices (Tables 1, 2 and 4). Canines have also displayed significant univariate and multivariate sex differences in linear[2,3] and diagonal measurements.[1,4]

Additionally, fewer teeth showed significant univariate dimorphism for the crown index (Table 3). Among these, premolars did not show significant statistical differences for crown area or module. Moreover, four variables - tooth 37, 42, 46 and 47 - showed greater mean values for females, of which the latter was statistically significant. It is interesting to note that crown index values reported by Townsend and Brown[8] had similar deviations where, females had larger means for the mandibular canines and first molars. However, in terms of linear measurements per se, both these teeth were significantly larger in males, with mandibular canines showing the greatest univariate sex dimorphism.[8] Crown index values for mandibular canine and first molar were also greater in females in a North American sample, the differences being statistically significant.[9] In a compilation of crown index data of posterior teeth for six West-Asian populations, 35% of the tooth variables were found to be larger in females.[10] These high levels of reverse dimorphism are seldom reflected in linear dimensions. Furthermore, sex classification accuracy of the discriminant analysis undertaken for crown index was recognisably lower to those performed for crown area and module (Table 5).

Crown index, therefore, presents a picture of univariate and multivariate sex dimorphism different to crown area, crown module and linear measurements. The contrasting result brings into question its validity as a measure of tooth size. According to Kondo and Townsend,[5] crown index "indicates the relative size of mesiodistal and buccolingual diameters," i.e. it expresses one linear measurement in terms of the other. While male linear dimensions are generally larger than females' in absolute terms, this may not be true when they are taken as a relative measure. Indeed, some consider crown index to be independent of the absolute values of linear dimensions.[10] We believe that, being a measure of the ratio of BL to MD dimensions expressed as percentage, the crown index value for any given tooth is affected by the *difference* between linear dimensions. The greater mean values in females or, for that matter, larger male values, merely imply proportionally greater differences between BL and MD dimensions for the respective sex and, unlike crown area or module, are not the result of greater tooth dimensions. Therefore, crown index does not quantify male tooth size vis-à-vis female tooth size as crown area, crown module and linear measurements do. Consequently, it reveals sex differences different to what one would 'normally' anticipate. Indeed, some consider crown index to be a representation of tooth shape rather than tooth size[9,16] and tooth shape is considered to be a more relevant measure of population variations and not sex differences.[17]

Utility of dental indices in sex differentiation

Introna *et al.*[11] reported 80% accuracy in sexing from discriminant analysis of dental indexes of maxillary deciduous molars. In the present study, classification accuracy of the stepwise discriminant analyses ranged between 69.8–81.1% (Table 5). This is lower to the 92.5% classification accuracy reported for linear measurements on the same sample[2] (comparison in Table 5). The sex classification accuracy of tooth ratios was also found to be lower to those of linear measurements in another study.[12] Moreover, calculating dental indices requires additional time and necessitates that both BL and MD dimensions are measurable for any given tooth - a requirement which may not always be fulfilled in forensic scenarios. Therefore, dental indexes are neither ideal nor provide information that can be used as a substitute for linear measurements and should probably be disregarded as a tool in odontometric sex assessment.

CONCLUSION

The present study has described sexual dimorphism in dental indexes derived from the permanent dentition using univariate statistics and stepwise discriminant analyses. While crown area and crown module showed univariate sex dimorphism similar to that of linear measurements, crown index depicted a marked variation. Stepwise discriminant analyses undertaken for the three dental indices produced sex assessment accuracy levels lower to that of linear measurements reported previoulsy. Hence, dental indexes do not provide additional information for sex differentiation. Linear measurements afford better sex discrimination and investigators examining sex differences in the teeth may confine themselves to analysing BL and MD dimensions per se.

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