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EDITORIAL

A changing of the guard is about to occur, with production of JFOS moving away from Australia. After four years, I relinquish the role of editor and am delighted to announce that Dr Jules Kieser from the University of Otago, New Zealand will continue the tradition. We wish him well with the move to a new electronic format.

Production of any journal relies on a number of people working as a team. My thanks goes to the Presidents of IOFOS who have been in charge through these four years, to the Editorial Board, elected by IOFOS from 10 countries, for their direction and support, and to the Board of Management for providing advice on management issues and keeping the production within budget. In particular I would like to thank Mrs Elaine Formenti. Elaine has been associated with the Journal for 20 years – it is her care and attention to detail that has given polish to each issue and I am sure we all wish her well in her retirement.

In my term as editor, we have published a variety of papers in the categories of research, technical note, reports, short report and case reports Thank you to all the authors who have prepared and submitted these papers. The Journal is pleased to provide a forum for publication in this limited field. I hope readers have enjoyed the opportunity to focus on trends in forensic odonto-stomatology.

Finally, I would like to extend my thanks to all the reviewers who have given their time to peer review articles in a very constructive way. I am sure that requests from me often came at inconvenient times, but cheerful and timely reviews have almost always materialised by the appointed deadline.

Disasters within very recent memory have shown that international co-operation and, importantly, international standards are required if we are to continue to be of value to forensic investigations. Let us all strive to support such endeavours.

Helen

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THE ACCURACY OF DENTAL PANORAMIC RADIOGRAPHY AS AN INDICATOR OF CHRONOLOGICAL AGE IN IRANIAN INDIVIDUALS

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ABSTRACT

Growth rate is dependent on genetic and environmental factors and varies between the sexes, between individuals of the same population and between populations themselves. There is strong concern over the dental and bone testing procedures conducted to determine the age of young individuals for legal reasons. Inaccurate results would lead authorities to imprison some children in adult prisons, which are unsafe and inappropriate for minors.

This study was designed to determine the relationship between dental age, the age from dental panoramic radiography, skeletal age and chronological age in patients referring to dental clinics of Yazd, Iran, for third molar surgery. The sample for the study consisted of 58 subjects between 15-25 years of age. The results indicated that estimating the age by examination of extracted lower wisdom teeth was most accurate. However, as use of this method i.e. extraction of tooth or dental surgery is not possible in normal individuals. Estimating the age from dental panoramic radiography showed high accuracy when applied to the patients.
(J Forensic Odontostomatol 2007;25:30-5)

Key words: Dental age, chronological age, panoramic radiography

INTRODUCTION

Growth rate is dependent on genetic and environmental factors and varies between the sexes, between individuals of the same population and between populations themselves. The underlying basis of this variation is genetically determined but the expression of the growth process is under the influence of environmental factors.[1,2] These differences demonstrate in the timing of calcification and mineralization of teeth.[3,4] Postnatally, skeletal maturation is more developed in girls than boys but bone mineral density is less in girls than boys, the latter having larger and longer bones.[5-9]

Chronological age is the actual age of the individual. However, the relationship between growth and chronological age is not linear and therefore the concept of 'biological' age is used which may be expressed as either skeletal age or dental age. Kullman[10] reported that documentation of birth is one of the most important factors determining chronological age in most developed countries. When the birth date is not known, there will be a strong need to estimate the biological age. The times of appearance and fusion of ossification centres and the size and morphology of different bones such as the neck and wrist are used for estimation of skeletal age.[11] Dental methods for determining biological age are more acceptable than other methods and most of the researchers have used these methods for determining age. These methods have been based mostly on the subjective prediction of radiological stages of dental age.[10]

Dental age may be expressed in terms of the time of emergence of teeth or the state of maturation of their mineralization. Some studies have suggested that growth and development of the third molar can be

determined easily. Usually, the third mandibular molar tooth can be visualized radiologically at 9 years of age.[12] Kullman *et al.*[13] showed that only wisdom teeth are useful for determining age as their maximum developmental age is only after 14 years of age. In Hispanics, the completion of the third maxillary molar is after the completion of third mandiblar molar.[14]

Eruption of the teeth and their stage of mineralization have been used in dental ageing. It is accepted that the process of mineralization is genetically determined,[15,16] whereas eruption appears to be affected by systemic influences such as nutrition or local conditions.[17,18] Mesotten *et al.*[19] performed a study and showed the relation between the root of the third molar and chronological age. Similarly, the Arany *et al.*[20] study indicated that the direction of radiographic completion of the third molar is related to chronological age in a young Japanese population.

In dentistry, awareness about the growth potential of a patient is one of the most important factors determining the success of orthodontic treatment. In addition, occasionally the legal system requires an assignment of age so that appropriate procedures may be observed, for example, where there is a legal age for criminal responsibility. In certain countries, criminals lacking birth certificates may be obliged to prove under-age status in order to avoid the death penalty.

Human dentition follows a reliable and predictable developmental sequence, beginning about four months after conception and continuing to the beginning of the third decade of life when development of all the permanent teeth is completed.[21]

Owing to a comparatively low variability of tooth formation in relation to chronological age,[22] it seems that methods based on stages of tooth formation are more appropriate in assessment of chronological age than those based on other indicators of somatic development.[23]

Experience has shown that panoramic radiography is very important for certain diagnoses. It is also useful for determining the completion of the stages of wisdom teeth, viewing all the four regions of the jaw in a single radiograph and to know the position of the third molar teeth.[24] The use of radiographs is based on the degree of formation of root and crown structures, the stage of eruption, and the intermixture of primary and adult dentitions.[25]

Thorson and Powell[26] indicated the value of completion of third mandibular molars in panoramic radiographs for determining age for young foreigners in Scotland whose exact birthdates were not known. Willershausen *et al.*[27] showed that developmental stages of the third molar are a lone indicator of age in the young but not so in matured individuals where other guidelines and factors about age are needed.

The aim of this study was to explore the connection between chronological age and biological age estimated by using radiography of the wrist, panoramic radiographs and examination of extracted wisdom teeth.

MATERIALS AND METHODS

This study was conducted as a cross-sectional and diagnostic study with the cooperation of the Forensic Medicine Department and Dental Medical College of Yazd in the year 2004-2005, at the Faculty of Dentistry, Shahid Sadoughi Medical University, Yazd, Iran. The ethical committee of the university approved this research.

The sample consisted of 58 patients, randomly selected from patients of the age group of 15-25 years known chronological age, referring to dental clinics in Yazd for extraction of third molars. Chronologic age of an individual was calculated by subtracting the birth date (based on their official birth certificate) from the date on which the radiographs were exposed for that particular individual. Decimal age was taken for simplicity of statistical calculation and ages were estimated on a yearly basis e.g. 9 years 9 months as 9.75 years. From the total of 58 patients, 36 were women and 22 were men. The average age was 19.85+/-2.6 years with a range of 14.4-25 years. The distribution of the samples in different age groups was similar as follows: four individuals were in 15-16 years old group, five were in 16-17 years, six in 17-18 years, nine in 18-19 years, five in 19-20 years, seven in 20-21 years, seven in 21-22 years, seven in 22-23 years, seven in 23-24 years and eight were in the 23-25 years old group.

The criteria for selection of cases for the present study were as follows:

a. Subjects were clinically free from any developmental, endocrine or nutritional disorder.
b. Subjects were clinically free from any past prolonged illness.
c. Subject should be clinically free from any special dental diseases such as dysplasia of enamel or dentine.
d. Those who had broken teeth during surgery were excluded from the study.

The patients' biological age was estimated by three methods:

1. use of panoramic radiographs for all wisdom teeth seen in radiographs (Demirjian's method[28,29])
2. the state of the apex of the extracted wisdom teeth roots (based on the criteria of Peterson[30])
3. radiography of the hand (Greulich and Pyle classification[31]).

All the panoramic radiographs were taken in one clinic by one technician under similar conditions. The radiographs were taken on T Mats with dimensions 15x30 cm by a Planmeca 2002 EC Proline machine* with a maximum of 80 mili amps and timing of 18 seconds. The films were developed by automatic machines; Velopex Extra-X** with a timing of four minutes at 27°C . On visualization of the wisdom teeth, the radiographs were given a code and then the shape of the radiograph and the teeth was drawn with a soft B2 pencil on a size A4 tracing paper. Then, these papers were given to two oral and maxillofacial radiologists for confirmation of age. These confirmations of ages were repeated again at an interval of three weeks. In case of difference between the two estimates, the average age was calculated. To test the agreement between these radiologists the required test was performed and the agreement and reliability was confirmed.

The extracted wisdom teeth were placed in 10% formalin and were examined by one dental surgeon to estimate the age on the basis of root formation.

A hand-wrist radiograph was taken after informed consent was obtained from patients. These radiographs were taken at the same radiology clinic under similar conditions. A Varian Medical system§ with 100 mili amps, 46 kilo volts and 40 miliseconds with Kodak§§ film in two sizes; 18x24 and 24x30 cm was used in the study. Two radiologists examined the radiography of the wrist and estimated the biological age based on their observations.

In all three methods, the age estimation was repeated by the same person (without the knowledge of previous age estimate) at an interval of one week for 15 randomly chosen samples to test the reliability of these methods.

Statistical analysis was carried out by paired t-test using SPSS software version 11¶.

Table 1: *The results of the estimated ages by different methods*

Method	Details	Number	Mean of age (years)	Standard deviation
Chronological age	Birth certificate	58	19.846	2.599
Panoramic radiography	Upper left	33	19.106	1.819
	Upper right	33	18.864	2.220
	Lower left	53	19.123	2.002
	Lower right	46	19.330	2.050
Extracted wisdom teeth	Upper left	30	19.567	2.123
	Upper right	25	18.940	2.123
	Lower left	49	19.745	2.232
	Lower right	40	19.550	2.342
Wrist radiography	1st radiologist	58	18.716	1.478
	2nd radiologist	58	17.708	0.683

Table 2: *Statistical analysis of the differences between the chronological age and estimated age by different methods*

Method	Details	Coefficient correlation	p-value
Panoramic radiography	Upper left	0.554	0.001
	Upper right	0.589	0.000
	Lower left	0.613	0.000
	Lower right	0.697	0.007
Extracted wisdom teeth	Upper left	0.715	0.000
	Upper right	0.756	0.000
	Lower left	0.823	0.000
	Lower right	0.798	0.000
Wrist radiography	1st radiologist	0.763	0.000
	2nd radiologist	0.235	0.107

RESULTS

The results of the estimated ages are shown in Table 1. These results were compared with the actual chronological age in order to determine the best method for estimating age. All of the estimated ages were lower then the chronological age of patients (Table 2). Estimating the age by examination of lower jaw wisdom teeth was most accurate, but as use of this method (extraction of teeth or dental surgery) is not possible in most cases, other methods were studied more accurately. In panoramic radiographs, the least age difference between the estimated age and real age was seen in the right lower wisdom teeth (5.5 months) and right upper wisdom teeth (6.6 months). Overall, in panoramic

* Planmeca, Helsinki, Finland
** Medivance Instruments Ltd, London, England
§ Varian Canada Inc., Montreal, Canada
§§ Kodak Industrie Laboratories, Chalon-sur-Saone, France
¶ SPSS Inc., Chicago, USA

radiographs, we can estimate the age from any of the four wisdom teeth or from all of them as a group.

The average difference between the age estimated by examination of wisdom teeth and chronological age was calculated (Table 3).

The maximum recorded errors were in connection with radiography of the wrist and both the radiologists estimated the age less than the chronological age (p value=0.000). The minimum errors recorded were for the estimated age of the wisdom teeth extracted from the right lower side (mean 1.6 months).

Table 3: *The average difference between the chronological age and estimated age by different methods*

Method	Details	Mean difference (months)	Standard deviation	Confidence interval 95%	p-value
Panoramic radiography	Upper left	7.8	25.4	16.8	0.087
	Upper right	6.6	25.8	15.8	0.151
	Lower left	9.7	24.7	16.5	0.006
	Lower right	5.5	22.6	12.2	0.104
Extracted wisdom teeth	Upper left	5.1	21.2	13	0.198
	Upper right	5.1	19.2	11	0.423
	Lower left	2.6	17.4	7.6	0.296
	Lower right	1.6	19.2	7.8	0.602
Wrist radiography	1st radiologist	13.6	21	19.1	0.000
	2nd radiologist	27.1	29.3	35.6	0.000

By use of the appropriate statistical analysis for estimating the percentage of prediction errors for each method, it was shown that the number of individuals with a chronological age not included in the 95% CI provided by age estimation were less than 5% in all three methods. Our results indicated that there is no significant difference in the age estimate by using age on the basis of visualization of any of the wisdom teeth. To find the best method for estimation of the age in panoramic radiography, different combination of images from wisdom teeth were investigated. For example, two of these combinations are as follows; by combination of the right-sided wisdom teeth in panoramic radiographs, the mean difference of the estimated error from the chronological age was 2.54+/-23.1 months with confidence interval of 95% ranging between -4.17 and +9.24 months (p value = 0.45). Furthermore, by using age on the basis of the combination of four wisdom teeth, the mean difference of the estimated error from the chronological age was 1.67+/-23.60 months with confidence interval of 95% ranging between -4.54 and +7.87 months (p value=0.592).

In panoramic radiographs, the maximum percentage of similarity between the chronological age and estimated age was an estimate from the upper right wisdom tooth (39.4%), followed by the age calculated from the average of estimate from the right upper and lower teeth (33.3%). In cases where there is no upper right wisdom tooth, the lower wisdom teeth could be used with less accuracy (left lower 24.5% and right lower 23.9%).

Therefore, the age estimated from the right upper wisdom teeth is the best method used. All the said methods were estimated according to the sex and there was not any statistical difference between men and women (p value>0.05).

DISCUSSION

Estimating age from the teeth has several advantages over skeletal ageing. The development of both the deciduous and permanent teeth can be studied from the embryonic period until early adult life. In addition, it is commonly observed that, for a given chronological age, dental age shows less variability than does skeletal age.[28,32] Dental development is less affected than bone by adverse environmental circumstances such as nutrition and disturbances of endocrine function.[16,28] The reasons of less variability in dental age are not fully understood. A possible reason is that the development of all the deciduous dentition and part of the permanent dentition takes place before birth in a protected environment whereas skeletal growth and development, even though having a strong genetic basis, is exposed for an increasing length of time to external factors such as variations in nutrition, socio-economic status and possibly climate.

In a study of 197 panoramic radiographs of the teeth from 94 boys and 103 girls, randomly selected from various schools in Belgium from the age group of 6-13 years known chronologic age, significant positive correlation was found between chronological and dental age.[33]

There is strong concern over the dental and bone testing procedures conducted by dentists and physicians who are attempting to determine the age of young individuals for legal reasons. Inaccurate results would lead authorities to imprison some

children with adult prisoners, which is unsafe and inappropriate for minors.

It is important to know the stage of maturation of a patient, which can have a considerable influence on diagnosis, treatment goals, treatment planning, and the eventual outcome of orthodontic treatment. The technique for assessing skeletal maturity consists of visual inspection of the developing bones. Various areas of the skeleton have been used: the foot, the ankle, the hip, the elbow, the hand-wrist, and the cervical vertebrae.[19]

The hand-wrist radiograph is commonly used for skeletal developmental assessment. Most investigators have found significant correlation among maturation stages derived from hand-wrist radiographs, changes in height during pubertal growth period, and facial growth.[10,13,20]

The last physiologic measure is dental maturity, which can be determined by the stage of tooth eruption or the stage of tooth formation. The latter is proposed as a more reliable criterion for determining dental maturation.[11,34,35] Relationships between the calcification stages of individual teeth and skeletal maturity have been previously reported. Racial variations in the relationships have also been suggested. Unfortunately, little is known of this relationship in Iranian children and adolescents. The objective of this study was to investigate the relationships between the stages of calcification of various wisdom teeth and skeletal maturity stages among Iranian individuals. The findings from this study will establish a valid clinical tool for indicators of the pubertal growth period in Iranian children, adolescents, and young adults without the necessity of resorting to hand-wrist radiographs.

Panoramic radiographs were used to assess dental maturity because they are routinely available in orthodontic clinics, and the mandibular region is clearly visible. There are a number of standard scales for rating the tooth calcification stage.[34] The method described by Demirjian *et al.*[29] was chosen in the present study because its criteria consist of distinct details based on shape criteria and proportion of root length, using the relative value to crown height rather than on absolute length.

The findings of this study indicate that tooth calcification stages might be clinically used as a maturity indicator of the pubertal growth period. However, because of the small size of samples in this study, we must be conservative in the interpretation of these results and therefore further studies are recommended in a larger sample size, and they should address development of the canines and second molars as well.

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APPLICABILITY OF THE DIMODENT EQUATION OF SEX PREDICTION IN A LEBANESE POPULATION SAMPLE

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ABSTRACT

Background: Sexual dimorphism represents a group of morphologic characteristics that differentiate a male from a female. Among these dimorphic traits, tooth size has been evaluated in various populations for its interest in anthropologic and forensic applications. Recent studies have shown that dental dimorphism is population-specific and that the most dimorphic tooth is the mandibular canine. In addition to the dimension of single teeth in dimorphic dental assessment, dimorphism has been evaluated, using equation of prediction, applying various dimensions of one or more teeth or indices. **Purpose:** The objective of this preliminary study was to evaluate the applicability of the Dimodent predictive equation in sex determination in a sample of Lebanese young individuals. **Materials and Methods:** Mesiodistal widths of the mandibular canine and lateral incisor were measured from dental casts of the permanent teeth of 60 Lebanese University dental students (30 males and 30 females), aged 18-25 years. The sex-predictive equation of Fronty was applied to calculate the percentage of accurately-diagnosed sexes. **Results:** Accuracy of sex prediction ranged from 63.3% for males and 90% for females. Overall, the Dimodent equation enabled a correct sex determination in 76.7% of the cases. When compared to the accuracy obtained with this equation in a French population sample, the accuracy was significantly different (Z=3.1225). **Conclusions:** This research supports earlier studies that sexual dimorphism is population specific. The difficulty or lack of dimorphism seems to originate from male subjects. Further investigations should include the preparation of population-specific prediction tables and testing their accuracy in a larger sample with a strongly-established Lebanese background.
(J Forensic Odontostomatol 2007;25:36-9)

Keywords: Dimodent equation, sexual dimorphism, Lebanese population sample

INTRODUCTION

Sexual dimorphism represents a group of morphologic characteristics that differentiate a male from a female.[1,2] Sex-related morphologic differences in the human skeleton have been extensively evaluated in several living and prehistoric populations.[3] However, tooth-associated odontometric differences have been less investigated[4] and mostly derive from the dentition of extinct populations.[5-8] Several studies have demonstrated that male teeth are generally larger than those of females in various populations.[9-11] According to a study evaluating the odontometric sexual variations of various species of living and fossil mammals, as well as of human beings, Fronty[2] reported that dental sexual dimorphism is always present in living humans although in process of regression in hominoids. Stroud *et al.*[12] evaluated sexual dimorphism in mesiodistal diameter, enamel thickness and dentin thickness of the permanent posterior mandibular dentition in a sample of 59 males and 39 females aged between 20 and 35 years using digitized bitewing radiographs. The authors concluded that significant sex differences exist in mesiodistal diameter favoring males over females. This discrepancy was attributed to differences in dentin thickness and not to enamel thickness. Alvesalo *et al.*[13] indicated that amelogenesis is promoted by both X and Y chromosome genes, and sexual dimorphism in average tooth size is determined by a promoting effect of the Y chromosome on dentin growth, probably through cell proliferation.

Dimorphism was reported to be more pronounced for the molars than for the premolars[12] but posterior teeth are generally less variable than anterior teeth.[11] Canines have been demonstrated to display greater sexual dimorphism in crown size than any other tooth

class in the permanent dentition in various populations.[4,9,11,14,15]

In contrast with differences in single tooth dimensions, various authors have selected to apply equations of prediction using multiple dimensions of one or more teeth or indices such as the mandibular canine index (MCI),[16] the quadratic discriminant analysis,[17] functions combining various crown indices and modules[18] and the Dimodent method.[1] The application of such equations in different populations has yielded different degrees of predictability in sex determination as sexual dimorphism in tooth dimensions has been reported to vary between populations.[4,9,19-24] Hattab *et al.*[9] showed that Jordanians have tooth sizes close to those of Iraqis, but significantly larger than those of Yemenite-Jews, Caucasians and Chinese. Iscan and Kedici[4] demonstrated that dental differences between sexes were not highly dimorphic in Turks. The application of the mandibular canine index for sex determination in India allowed the correct detection of males and females in 83.3% and 81% of the cases respectively. Tooth sizes of Southern Chinese were reported to be, in general, larger than those of the Caucasians, comparable with Northern Chinese, but smaller than those of Australian Aboriginals.[11] Sherfudhin *et al.*[17] concluded that in Indian subjects, the percentage of correct classifications of sex was higher when using quadratic discriminant analysis compared to the MCI. Currently, there are no published data related to sexual dimorphism in the Lebanese population. The purpose of the present preliminary investigation was, therefore, to evaluate the applicability of the Dimodent sex prediction equation in a sample of the Lebanese population.

MATERIALS AND METHODS

Study Sample

The sample studied included 60 students (30 males and 30 females) from the School of Dentistry of the Lebanese University, Beirut, aged between 18 and 25 years. The students recruited from different Lebanese regions were selected based on the following inclusion criteria:

1. Parents and grandparents of Lebanese origin;
2. Presence of the lower canines and lateral incisors;
3. Absence of morphological tooth abnormalities, crowding or malposition;
4. Absence of carious lesions or fillings involving the interproximal aspects of the studied teeth (mandibular lateral incisors and canines); and
5. Absence of severe abrasions, attrition or fractures on the involved teeth. Patients with ongoing orthodontic therapy were excluded from the study.

Mandibular dental casts were obtained using polysiloxane in a double mixture* base. Casts that did not allow accurate measurements of the teeth were excluded and the impressions repeated.

Measurement Method

Since the differences in crown diameters between the right and left sides of the same dental arch are not significant,[9,25] the left-side measurements were taken arbitrarily to represent the tooth size of the study population. The following measurements were carried out on the mandibular canine and lateral incisor directly on the dental casts according to the technique described by Seipel[26] and Moorrees.[27]

1. Maximum mesiodistal (MD) width defined as the greatest distance between the proximal surfaces of the crown;
2. Maximum bucco-lingual (BL) crown diameter measured as the greatest distance between the buccal and lingual surfaces of the crown at right angles to the mesio-distal crown diameter of the tooth.

All measurements were carried out by one operator using a digital caliper** that had been calibrated prior to measuring. All measurements were to a precision of 0.01 mm. Subsequently, the measurements were subjected to the Dimodent sex prediction equation of Fronty *et al.*[1] formulated as follows:

$$P = 1/(1 + e^{-y})$$

where P stands for the probability of being present in a male or female dentition, whereas the parameter **y** is obtained from the linear combination of selected variables multiplied by the coefficients specifying their importance. **y** is calculated as follows:

$$y = 24.2 + (1.54\ ILI\text{-}MD) + (1.92\ ILI\text{-}VL) - (2.84\ CI\text{-}MD) - (3.38\ CI\text{-}VL)$$

ILI-MD represents the mesio-distal diameter of the lateral mandibular incisor;
ILI-VL is the vestibulo-lingual diameter of the lateral mandibular incisor;
CI-MD is the mesio-distal diameter of the mandibular canine; and
CI-VL is the vestibulo-lingual diameter of the mandibular canine.

The four odontometric measures of all subjects are introduced in the equation. According to the values of P, three alternatives are possible:

1. If P tends to 100% (i.e. P>50%), the dentition with the calculated probability belongs very likely to a female;

* Zetaplus, Indurent Oranwash L, Zhermack, Italy
**Absolute Digimatic, Mitutoyo, United-Kingdom

2. If P tends to 0% (i.e. P<50%) , the dentition is very likely to be masculine;
3. If P = 50%, discrimination is null and sex can not be determined.

Statistical Analysis

The application of the sex predictive equation was considered to be successful if sex determination was correct (P values above or below 50% for females and males respectively); otherwise it was regarded as a failure. The overall success rate in sex determination in the Lebanese population sample was determined and compared to that of the French population[1] using the Z value (test of equality of two rates in the two studied populations) to confirm or refute the null hypothesis (success rates in sex determination are similar in both Lebanese and French populations).

RESULTS

The accuracy of sex prediction in the present study ranged from 63.3% for males to 90% for females. Overall, the application of the Dimodent equation was successful in sex prediction in 76.7% in the Lebanese population sample (Table 1).

When compared to the accuracy obtained with the Dimodent equation in the French population, the difference in accuracy was highly significant. The application of this equation in the French and Lebanese populations yielded a Z value of 3.1225 (superior to the threshold of 2.58) which allows rejecting the null hypothesis and confirming that the overall rates of success in sex determination in the two populations are significantly different. The difficulty or the lack of dimorphism seems to originate from male subjects.

DISCUSSION

The applicability of the Dimodent equation was successful in sex determination in 90.6% of the French sample and 76.7% in the Lebanese population sample. The percentage of Lebanese men and women where the sex was successfully determined by the Dimodent equation was lower than that obtained by Fronty *et al.*[1] in the French population. Previous studies have demonstrated that sexual dimorphism in tooth dimensions varies between populations and that the application of sex predictive equations yields different degrees of predictability in different populations.[4,9,17,19,24] Because of the limited study sample included in this investigation, it may be suggested that application of equations to determine the sex of young Lebanese individuals is less useful than when applied to other populations. Differences can most likely be attributed to sample size and/or to odontometric differences.

The use of the Dimodent equation was suggested by the high degree of sex discrimination obtained with the mandibular canine and the high correlation coefficients between the mandibular canine and lateral incisor widths.[1,25] The selection of the population sample was based on the inclusion of individuals of similar age, of Lebanese descent and representing different regions of the country. It remains to be investigated if a random and larger sample of the Lebanese population has specific odontometric values that can be better predicted with customized equations. Further investigations should include the preparation of population-specific prediction tables and testing their accuracy in a larger sample with a stronger Lebanese background.

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Table 1: *summarizes the percentages of correct and failed sex prediction in the Lebanese sample compared with those reported for the French population sample.[1]*

Population	Success in Males	Success in Females	Failure In Males	Failure in Females	Overall Success	Overall Failure
French	—	—	—	—	317 *(90.6%)*	33 *(9.4%)*
Lebanese	19 *(63.3%)*	27 *(90%)*	11 *(36.7%)*	3 *(10%)*	46 *(76.7%)*	14 *(23.3%)*

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THE STABILITY OF LIP PATTERN CHARACTERISTICS OVER TIME

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ABSTRACT

This paper studied the lip prints of 85 subjects over a seven-month period. The patterns of the vermilion zone were shown to be stable with the passage of time. The number of matching features needed to prove concurrence between two prints was determined to be eight. Features of the lip print relative to the surrounding anatomy were also examined and found to be stable, recordable and to contribute to the usefulness of lip prints as a forensic tool.

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Key words: lip pattern

INTRODUCTION.

In early 1998 a jury in the U.K. convicted a man of murder, based in part, on the identification of the assailant by the pattern left by his ear on the victim's window.[1] Suzuki and Tsuchihashi[2] documented three cases in which they used lip prints to further criminal investigations. Thomas and Van Wyk[3] identified human remains by matching the rugae pattern of his palate with that imprinted in his spare upper denture. Kasprzak[4] used lip prints to identify and subsequently convict numerous criminals in Poland. Kennedy[5] described a criminal case solved by matching the patterns on a suspect's feet. Fingerprints have been in use with police around the world for decades.[6] These examples have been based on the individuality of soft tissue patterns of the human body. While fingerprinting has been well documented and accepted universally the other techniques have yet to be fully validated scientifically[7], which is crucial if they are to be of use in court.

The pattern of lines and creases that comprises the human lip was first discussed in 1950 by Snyder[8] and by Santos in 1962.[9] In 1970 Suzuki and Tsuchihashi[2] examined the lip patterns of 280 subjects and concluded that no two individual patterns were identical.

They established a classification of lip print types which consisted of 6 types:

Type 1 clear-cut grooves running vertically across the lip.
Type 2 as above, but disappearing partway across the lip.
Type 3 the grooves fork in their transit of the lip.
Type 4 the grooves intersect at an angle.
Type 5 the grooves form a net pattern.
Type 6 the grooves cannot be identified as any of the above.

These Types were then applied to defined regions of the lip and recorded in the form of a "Palmer's Notation". Comparison of this notation was used to determine the uniqueness of individual's lips not the lip details themselves. Tsuchihashi[10] expanded the database to include 1364 individuals and, as in 1970, determined that no two patterns were identical. Both papers of Suzuki and Tsuchihashi[2] and Tsuchihashi[10] included a study of twins. Both concluded that although their pattern Types were the same, closer study always revealed differences in the detail. These twin studies and the results of Tsuchihashi's larger group revealed what is possibly the major down fall of the current classification. Firstly, many lip prints do not consist of areas of purely one Type, commonly several Types were superimposed. Secondly, it was possible for two or more individuals to bear the same pattern of Types but differ in the detailed morphology. This suggests that the classifications may assist in searching through large databases, which as yet do not exist, but are of limited use in distinguishing or identifying individuals. This must be done by a comparison of the fine details.

Tsuchihashi[10] then studied the stability of an individual's pattern over time. For three years he collected monthly prints from a total of three males and four females. No comment was made at the time regarding the small size of the study pool.

Suzuki and Tsuchihashi[2] and Tsuchihashi[10] collected data by both photography and/or direct contact prints, which were then traced by hand onto cellophane. This technique ignores the networks of fine detail in favour of the gross lines. The operators' value judgement, as well as their physical adeptness makes this process extremely operator dependent and poorly reproducible.

The final forensic paper devoted to lip prints was by Kasprzak[4] in 1990. In a long paper, significantly lacking in supporting evidence, he propounded the individuality and longevity of the lip pattern.

Other papers by Endris *et al.*[11] and Hirth *et al.*[12,13] approached lip patterns from a genetic and anthropologic perspective.

It is clear from the literature that three fields need further clarification before lip patterns can be of forensic use. Whilst accepting that a body of data existed regarding the individuality of lip pattern, there is no credible research on the stability of the lip detail over time.The timescale in question could be measured in weeks and months or years. The former would be of use to police investigations and the latter of more significance to geneticists. Tsuchihashi[10] attempted this but the small sample size, while common in human studies of this era, is far too small to be credible scientifically or in a court of law.

Past papers have limited themselves totally to the line patterns of the vermilion region. Many other features that appear on a lip print may be of relevance to individualisation and should be explored. Techniques need to be developed to allow the recording of lip prints from suspects to create a database and to collect evidential prints for comparison with those on file. Recording techniques must be developed which are scientifically valid, safe for use on live human subjects and consistent with the legal constraints on evidence gathering and feasible in a forensic situation.

This paper aims to explore the first two issues. The development of collection techniques is equally large and the subject of a separate paper.

MATERIALS AND METHODS

SUBJECT GROUP: The subjects were drawn from four groups in an attempt to provide a spread of sex and ages.

1. The core group was composed of the dental students of the 1998 Clinical intake at the University of Wales College of Medicine. This consisted of 56 students, 23 female and 33 males with an average age of 20 years at commencement of the study.
2. Twelve staff members from the Dental School, five females, and seven males aged between 27 and 57.
3. Ten dentists and staff from a dental practice, two males and eight females ranging in age from 18 to 58.
4. The author and immediate family, one male aged 44, one adult female aged 43, one male child age two years, and three female children aged five, seven and 11.

This resulted in a total subject pool of 41 females and 44 males, and excludes three individuals who withdrew during the study period. The majority of subjects were European in origin with the exception of five of Indo-Pakistan decent, two of African decent and two of Asian decent.

MATERIALS

Following a series of pilot studies exploring the possible methods raised by past papers, a protocol was devised for this study based on a transparent overlay system and contact prints enhanced by powder dusting. This technique proved most reliable and reproducible in the experimental situation and was readily adaptable to a range of circumstances. The method of Suzuki and Tsuchihashi[2] was upgraded with the use of computerised image gathering and enhancement to avoid the vagaries of tracing. Contact prints were used to record both evidential and comparative prints, thus removing the variability inevitable with two different mediums, i.e. photography and contact prints.

1. Prints were collected by direct contact of both lips onto a recording medium held in the sagital plane. For this glass photographic slide mounts, specifically "GEPE" brand 40 x40,* were used. These come as two halves; one is optically clear glass in a grey metal frame. The inner surface of this was pressed lightly against the subject's lips. The second part is a matching, white frame containing slightly frosted anti-Newton glass. These sections are then snapped together to seal and protect the print in transit. The inner metal frame provides a surface for recording subject's details. In addition it bears two indents measuring fifteen millimetres apart, which act as a scale. These slides provide a good-sized recording surface with the ability to be sealed against contamination of evidence before and after use and to be permanently identified on the frame.

* GEPE Producte AG. Zug, Switzerland

2. After collection the print was enhanced by dusting with a proprietary fingerprinting powder. "K9 MAGNETA FLAKE"** was used in this study. This differs from the normal aluminium fingerprinting powder in colour and consistency. It consists of an iron powder, coated with amino acid and black pigment. Unlike most powders whose particles are spherical this material is composed of flakes. The manufacturers claim this produces an image whose dimensions more accurately reflect those of the original. MAGNETA FLAKE's dark colour enhances the visibility and contrast of the print. Conventional powders are applied with a fine, puff shaped brush. Unfortunately it was found this could leave scour marks across the face of the delicate print. The ferrous nature of the chosen material allows it to be applied with a magnetic wand. Powder is lifted with the wand and then lightly brushed over the glass surface until the lip image appears. Only the powder touches the print surface and damage is almost eliminated. The powder deposits on the areas of glass that have been roughened by adherent lip products but not on the otherwise smooth glass. Excess material in these areas is blown off with compressed air. This can be critical as powder resting on any "unprinted" regions greatly reduces the subsequent contrast. It is mandatory to wear surgical gloves throughout the handling phase to avoid contaminating the slide with fingerprints. Similarly great care was taken to avoid touching the image both prior and following dusting.

3. The print was then recorded digitally via a computer scanner. For this paper a "BIO RAD 690 MOLECULAR ANALYSER"¶ was used. Excellent results were also obtained using both a photographic quality scanner and an office document scanner. A protocol was developed which ensured uniformity of size and processing**.** The scanner was set to scan a 50x50mm area to produce standard sized images with minimal cropping of the print area, even if the slide was misaligned slightly. The resolution was 800 dpi, in reflection mode and to maximise contrast a red background was used in conjunction with blue filtration. When using simpler scanners that did not contain electronic filtration a black velvet cloth was used to overlay the scanner bed. This provided a high contrast background and eliminated the entrance of extraneous light. This was critical in obtaining good quality images.

** CSI Equipment, Northampton, UK
¶ BIO-RAD Laboratory, Hercules, USA
¶¶ Adobe Systems Inc., San Jose, USA

Once the image was captured enhancement was achieved using a commercially available graphics software packages. ADOBE PHOTOSHOP 4¶¶ was the software of choice but other graphics packages were tried with similar success. These enabled standardisation of the size and enhancement of the clarity, contrast and brightness of the image. The final image was then printed at 20 x 20cm by a laser printer onto high-resolution paper.

5. To enable comparison of each successive set of prints one good quality clear print was collected from each subject early in the study. This was scanned, enhanced and finally the image was printed onto clear acetate via a laser printer. This produced an overlay matching in size to the hard copies made earlier. Both normal images and inverted images i.e. the dark and light areas are reversed were tried, but no great advantage was found with either.

DATA COLLECTION:

The subjects' lip prints were recorded monthly, commencing in November 1999 until June 2000. During this period 6 series of lip prints were recorded in November and December 1999, and January, February, March and June 2000. April and May were omitted due to holidays and examinations amongst the student subjects. In total 326 prints were recorded and studied.

The initial series of prints were transferred onto clear acetate for use as the standard with which subsequent prints were compared. The later series were printed conventionally onto paper.

METHODOLOGY

These features were examined to determine if they could provide relevant data.

1. GENERAL APPEARANCE of the lips can quickly differentiate between many individuals. This is an important difference between lip and fingerprints. There is relatively little variation in size and physical shape between fingertips but a great deal between individual's lips. There is considerable variation in the lip's overall shape, i.e. full or thin, straight or curved, and size, both the absolute dimensions and the relative size of upper versus lower. Some of these characteristics may vary over time due to muscle posturing or recording conditions but the overall shape should be recognisable and help to distinguish one from another (Fig.1 and Fig.2).

2. FACIAL CONTOURS and PROFILE: A good print gives a clear three-dimensional visualisation of much of the subject's lower facial third. A significant feature

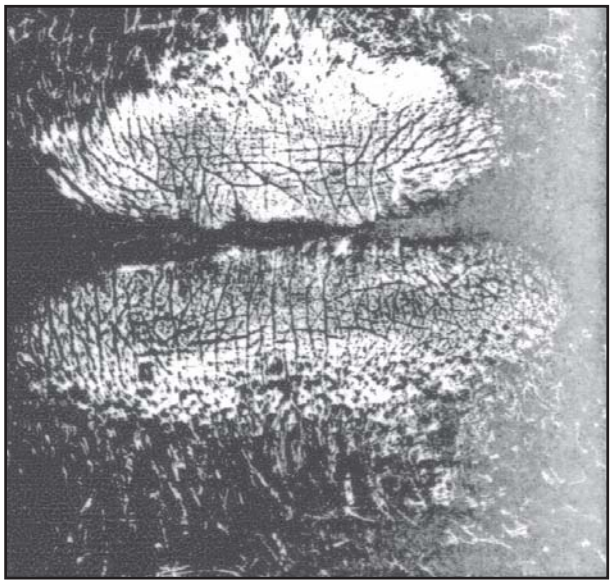

Fig.1: *These lips are narrow in width, especially the upper, but full in height. The overall shape is ovoid and lacking in features. Facial hair is prominent.*

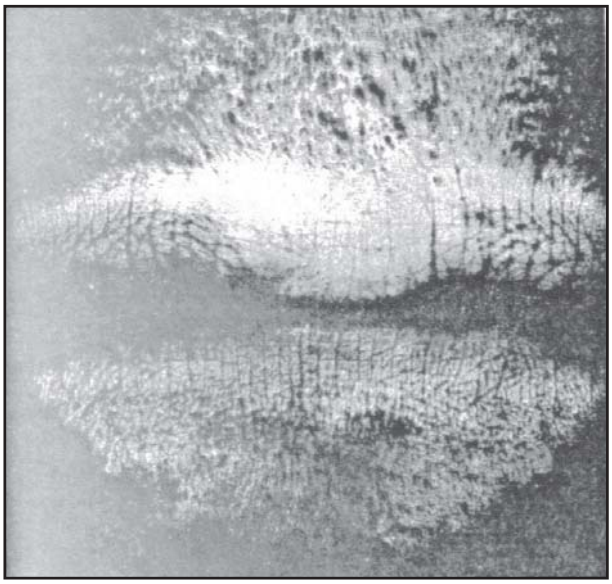

Fig.2: *These lips are noticeably wider in comparison to Fig.1. However, they are thinner in absolute terms and relative to their width.*

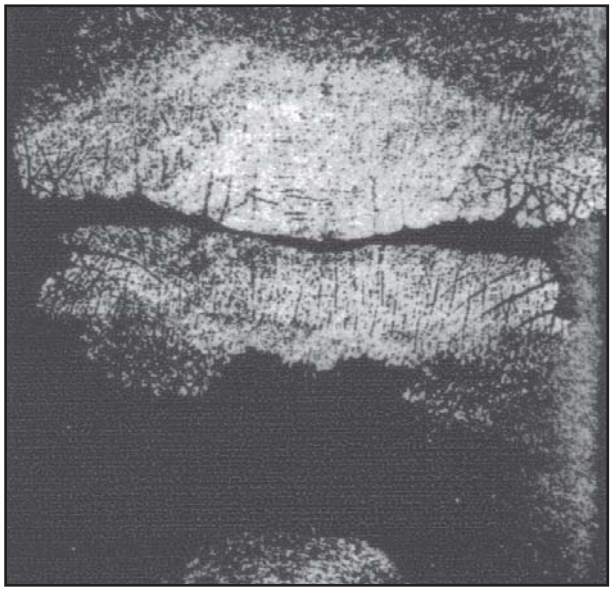

Fig.3a: *In this subject we see a large upper lip contact with a lack of detail and contrast of the middle third. This is due to increased contact pressure resulting from a pronounced upper lip compared with lower. This is also suggested by the downward curvature of the contact line. The chin is also pre-eminent suggesting a concave profile running from a prominent upper lip, retruded lower onto a prominent chin*

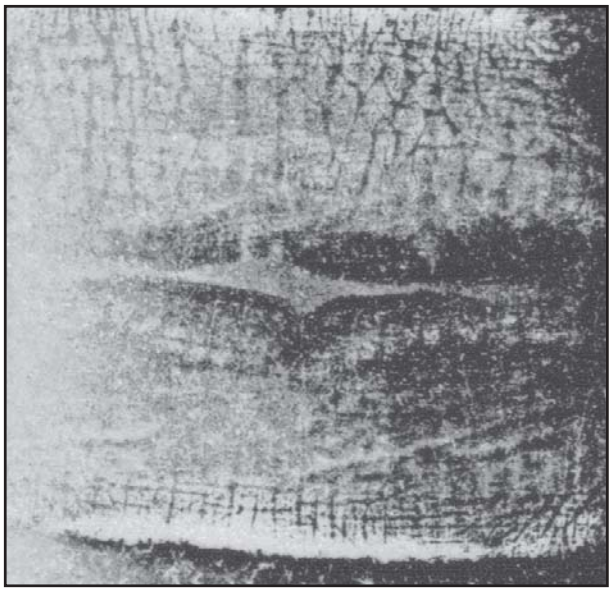

Fig.3b: *These prints are of such a large size exceeding the dimension of the slide, that the prominence is in no doubt*

of this is the profile, the relative prominence of upper to lower lip and the immediately adjacent soft tissue. On a sufficiently large surface most people will leave some print of nose, philtrum, upper and lower lip and possibly chin. As muscle posturing and tone can disguise the lip shape the extreme orthodontic class I and III show most clearly. The soft tissue profile is seen and only limited conclusions can be drawn with regard to the underlying bone structure. Burstone[13] and Weinstein *et al.*[14] noted that a protrusive lower lip would tend to rotate as it is displaced by contact,

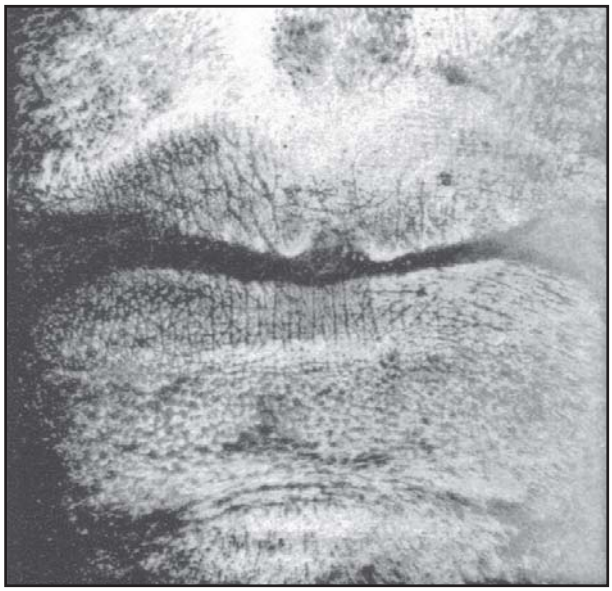

Fig.4a: *A moderately deep fossa with very prominent vertical ridges merging with the upper border of the lip*

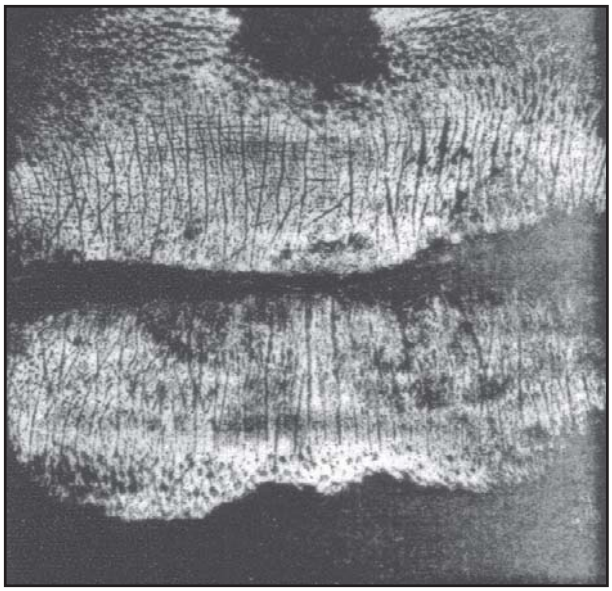

Fig.4b: *A markedly deeper fossa which lacks obvious vertical ridges and appears distinct from the upper border of the lip*

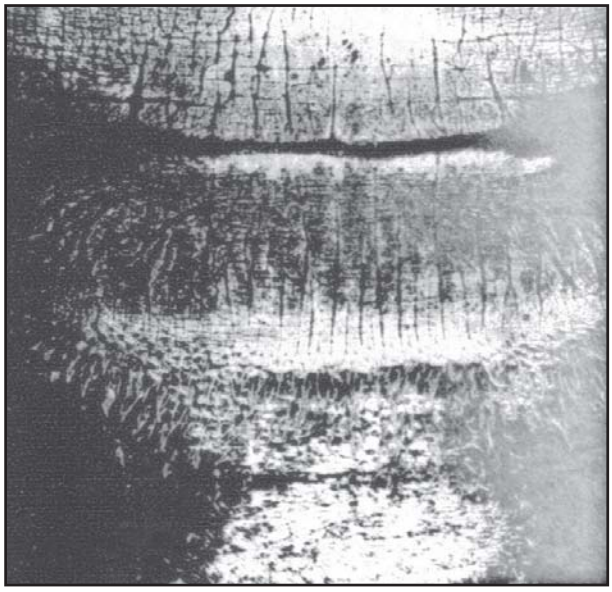

Fig.5: *Notice female facial hair pattern - lower lip*

rather than compress the tissue below. Thus pressure may change the perceived profile (Fig. 3).

3. PHILTRUM: Most prints of the upper lip show some detail of the philtrum. Initially this serves as an orientation landmark, which is vital when aligning the overlays. The width and appearance where the philtrum joins the upper lip may also provide identification data (Fig. 4).

4. CHIN: At the lower end of certain individual's print is an impression of the chin.

This aids visualisation of the profile but in some cases is so distinct an anatomical feature it may be regarded as a characteristic in its own right. Of note are its dimensions, the distance from the lips and apparent height.

5. FACIAL HAIR: The presence, distribution and density of follicles may provide guidance as to the sex of the subject. The nature of any visible hair i.e. close shaved stubble, mature hair or otherwise will also aid this. Facial hair can be removed quickly but grows slowly. The importance of its presence or absence on a suspect may well relate to the time elapsed between the crime and the examination of the suspect (Fig.5).

6. PATHOLOGIES and PECULARITIES: Occasionally major individual characteristics can be observed. These can be either short-term pathologies such as herpetic lesions, permanent pathologies such as scars or blood varicosities or characteristic intense 'whirls'. More frequently the individual characteristics are limited to rare pattern shapes or pressure induced patterns (Fig.6).

7. PRINT SURFACE: This refers to the deposits on the recording surface itself, e.g. lipstick, medication or food residue. In addition to these artificial substances it was noted in trial studies that there seemed to be a great variation in the amount of natural moisture deposited. Certain individuals produced dry, minimal prints. This may prove to be a seasonal variant or an individual characteristic.

8. VERMILION PATTERNS: The final area of study was the grooves and lines of the lip pattern itself. It was decided to avoid the existing classification types devised by Suzuki and Tsuchihashi[2] as being too complicated and confusing. Instead study was confined to major pattern types i.e. "linear", reticular" and "mixed" and the fine pattern details.

a) "Stars", these consist of several intersecting lines. They are usually well reproduced, consistent and as they are composed of several lines, are usually resistant to distortion. Star patterns are easily aligned with patterns on the overlay.
b) "Y", caused by the branching of a line, they may lie vertically or horizontally and open in any direction. They can be recognised even if suffering some distortion. The bifurcation point provides a good reference point when comparing their relationship with other pattern groups.

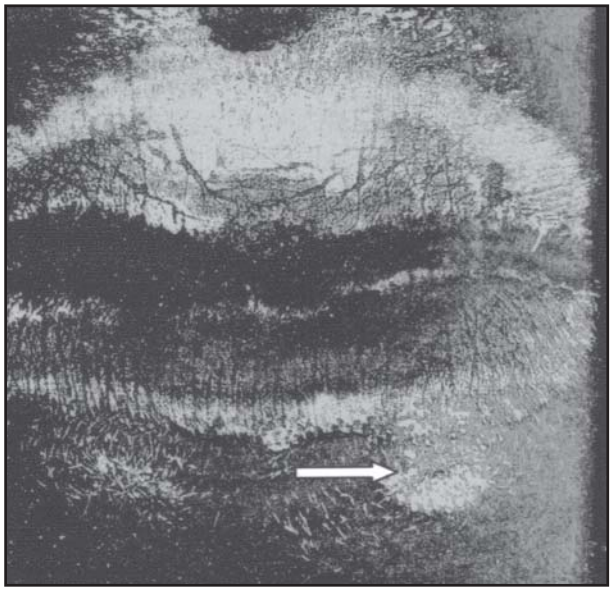

Fig.6a: *Mole on lower lip*

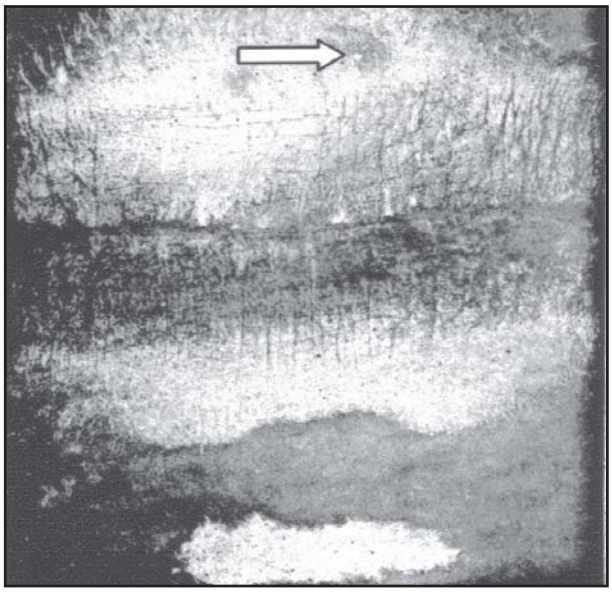

Fig.6b: *Transient lesions on upper lip*

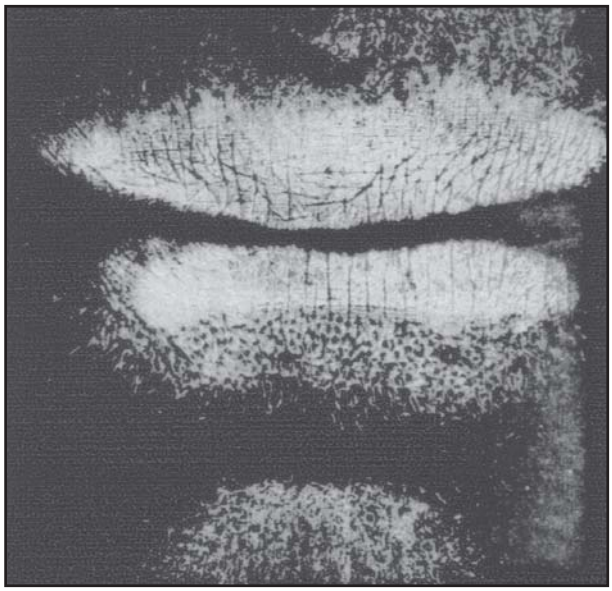

Fig.7a: *Mixed pattern type. Reticulated areas on upper distal. Vertical linear pattern distributed over lip*

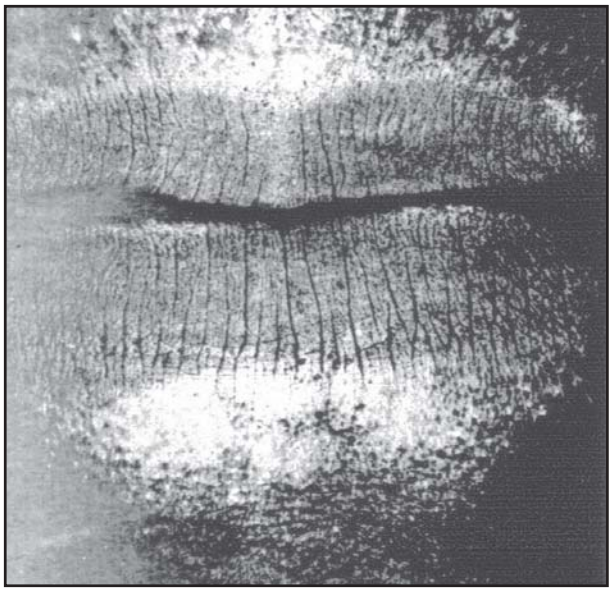

Fig.7b: *Linear pattern on both lips*

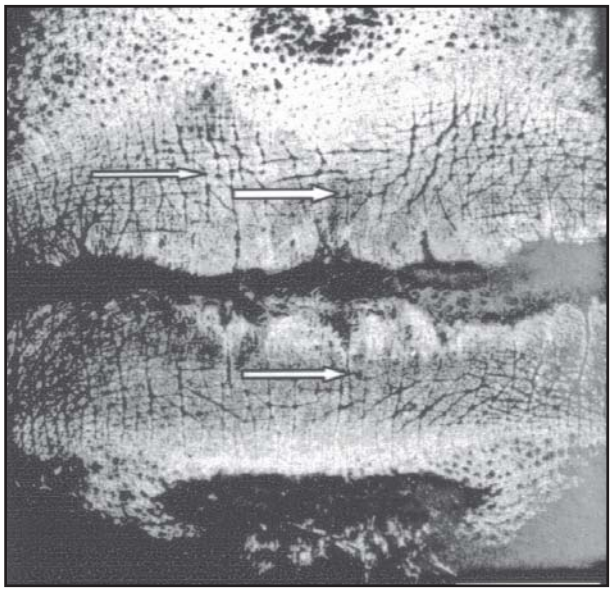

Fig.8a: *An image showing predominated by "star" details. The shape of the sub-labial region is also distinctive*

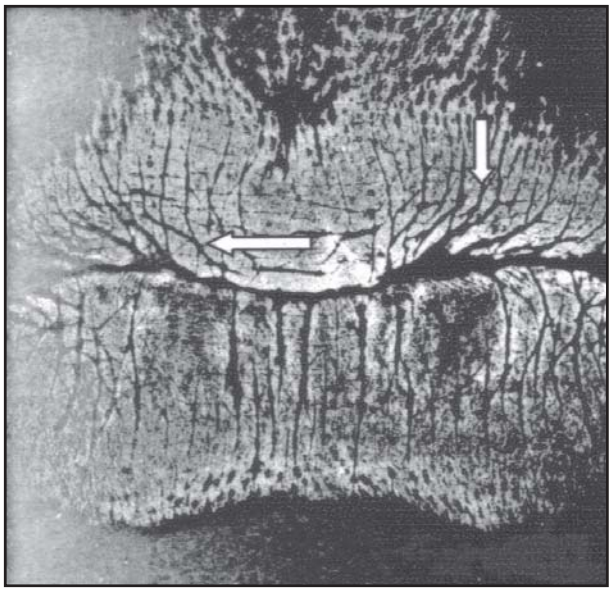

Fig.8b: *The upper lip shows a heavy concentration of "Y" details. The lower has numerous "Parallel lines"*

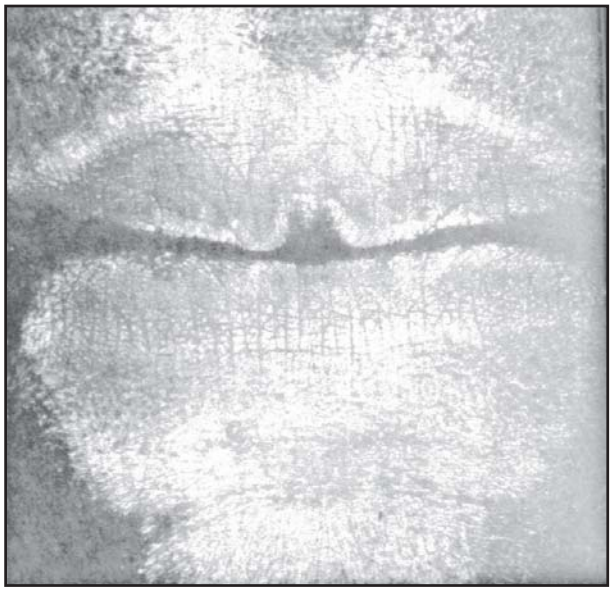

Fig.9: *Two images showing conformity of contact pattern over the several months*

c) "Parallel lines". Vertical lines are present in all subjects, either as the major pattern or as minor lines in a more complex system. These lines may be related to neighbours in a measurable ratio of distances, and similarly groups of lines can relate to others. Trial prints raised the suspicion that many horizontal lines could be artefacts caused by creasing or buckling of the lip surface when contacting the recording glass. They were therefore avoided where possible.

d) A final pattern that was thought worthy of study may be a variation of the vertical line pattern. In some lip prints the upper and lower lips fail to meet tightly. This leaves a curved contact line and a clearly defined margin where the lip surface angles inwards towards the oral cavity. Any major patterns, especially heavy vertical lines and functional creases, traversing this region are clearly displayed as dark triangular notches in the lip surface. Whilst changes in contact pressure or lip posture may alter the exact region recorded the horizontal relationship i.e. the intervening distance between these notches seems relatively stable. Possibly this is because these notches are of considerably greater size

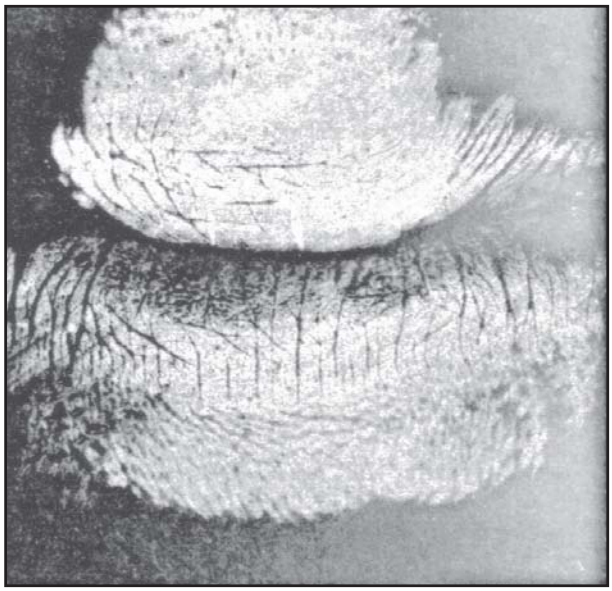

Fig.10a: *A distinctively curved contact line*

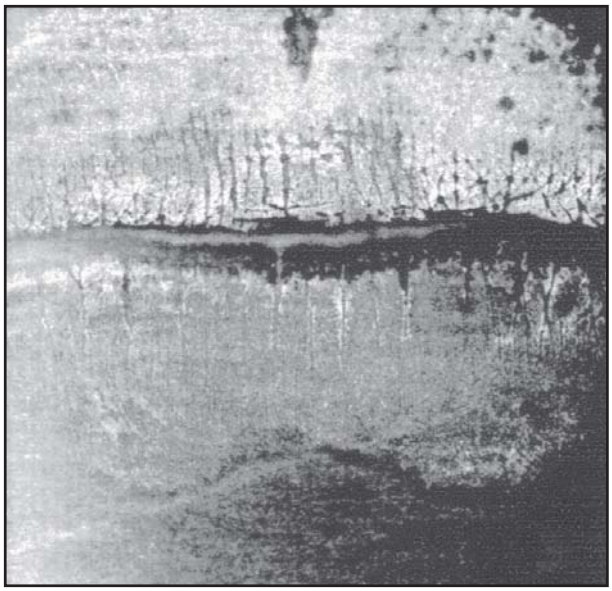

Fig.10b: *An example of a relatively straight contact line*

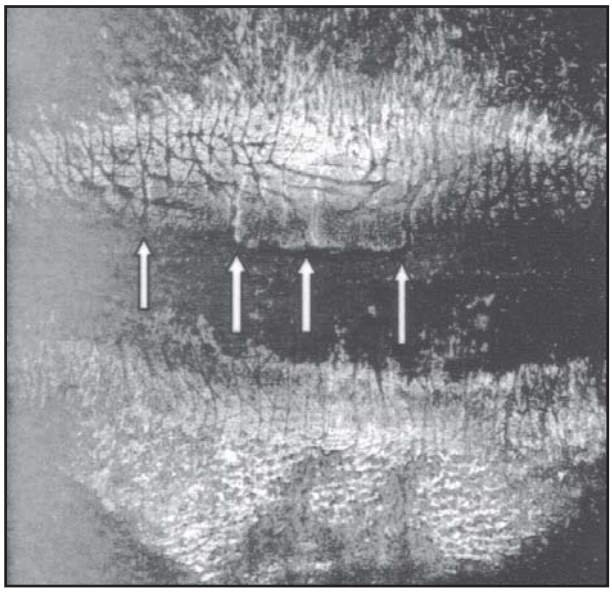

Fig.11: *Notches in lower border of upper lip*

than the minor patterns. Many in fact seem to be "flexion" lines (Figs.7–11).

EXAMINATION AND COMPARISON: This protocol was followed in the examination of each lip print.

1. Collect lip prints.
2. Dust with powder and blow off excess.
3. Scan into computer and optimise contrast, density and size.
4. Print image on paper. (*Can print onto acetate to produce overlay)*.
5. Position paper image on slide viewer and overlay acetate image.
6. Use landmarks such as philtrum and skin-vermilion border to align images. Upper and lower lips need to be aligned separately to allow for varying degrees of lip closure.
7. Note correspondence of surrounding anatomic features, general appearance, contact line shape, facial hair etc.
8. Identify and count the superimposed vermilion patterns, e.g. "stars", "Y" and "notches". Minor adjustments to acetate may be required to compensate for lip flexibility.
9. Enter observations on the Record Chart.

The features discussed above were given the following numerical score:

a) general appearance, matching of "size" and "shape", 2 for "good", 1 for "fair".
b) contact line shape, "good" 2, "fair" 1
c) number of notches matching
d) number of pattern matches.

These scores were then totalled. The other characteristics were not scored as their reliability was yet to be established, until then they were of relevance as descriptive functions. The lip print is a record of the surface characteristics of soft tissue and as such these shapes are all subject to some degree of distortion. This can be due to lip muscle action and recording pressure. The features will not match the overlay exactly but will correspond in general type. What is important is the spatial relationship of several identifiable patterns. Their individual shapes may change but the type, the distances and angles between groups will not.

Papers on dental uniqueness (Rawson *et al.*[16]), tool marks (Murdock[17]), lip prints (Kasprzak[4] and Hirth *et al.*[12,13]), and many fingerprinting departments[18] all regarded between six and eight matches as the significant number in their fields to decide what number of similarities would be used to indicate if two prints matched. To validate using this number in lip print study all the scores for the collected prints for the duration of the trial were plotted on a simple graph. All prints scoring below eight were re-examined. In all these prints the low score was due to poor image clarity. In no case involving a clear print was it possible to find fewer than eight corresponding features.

Ten good quality prints were then chosen at random and attempts were made to match to a further ten random acetates. In was impossible in these cases to approach eight points of similarity. Eight was determined to be the significant number when counting points of concordance for this study.

INTER-EXAMINER VARIABILITY: Two colleagues, both dentists with an understanding of forensic dentistry but no exposure to lip prints, were used to test the reliability of the examiner's results. They were both provided with ten sets of prints consisting of a 20 x 20cm paper copy, a clear acetate overlay of the same image and a paper image of the same subject recorded several months later. These prints covered a range of pattern types varying in complexity and print quality. The operators were also provided with the outline technique for matching prints. They were then asked to use this to determine whether the two prints in each set were the same individual. The responses could be graded from positive, cautiously positive, unsure to no match.

Of the ten subjects there was absolute concurrence on eight prints, a cautious match on one and the remaining set was deemed not to match. It was interesting that the rejected print was the first examined. After an hour of studying other prints and familiarising themselves with the technique this print was reintroduced. On this occasion both examiners were still hesitant to give absolute recognition due to a large apparent dimensional difference in the size of the lower lip. However both saw points of similarity previously overlooked, especially in the vermilion region and upgraded their rating. This does suggest a degree of exposure to the task is useful to fully recognise the similarities in the minor detail. The high degree of concurrence of both operators in matching these ten sets confirmed the protocol was usable.

INTRA-EXAMINER VARIABILITY: From the original series approximately half the lip prints were chosen at random. After an interval of six months these were then re-examined using the same protocol. The total scores as well as the decisions regarding the individual features were then compared with those from earlier. Of the 30 cases reassessed 22 were 100% compatible, nine were 90% and two were 80% compatible with the initial results. The line patterns provided no difficulties. It was not possible to ascertain if exactly the same lines were compared but in all cases a similar number of matching patterns was found. The discrepancies arose with the subjective decisions regarding the anatomic features. The second assessments varied both sides of the initial decisions. This seemed to suggest that experience had not shifted the decision making to a higher or lower level of accuracy. Generally this investigation did not cast any significant doubt on the overall reliability of the project.

RESULTS

VERMILION REGION: The study concentrated first on the number of matching characteristics of the vermilion region. Assessed monthly, looking for a minimum of eight points of correspondence, an average of 88.9% of the study matched their standard print (Table 1).

Table 1: *Percentage of pop$^{n.}$ matching standard print for each month*

Month	% of pop^{n}
December	90.9
January	86.7
February	91.8
March	86.4
June	88.7
Average	88.9

Table 2: *Percentage consistency vs number of subjects*

% consistency	Subjects
100	44
80-99	9
60-79	15
40-59	10
20-39	2
1-19	0
0	5
Total	85

The figures for the trial as a whole were expanded to reveal the consistency of this matching. Table 2 shows the number of individuals verses the consistency of matching over the seven months of the trial. These figures demonstrate that in over half the subjects the lip prints matched the original sample on every occasion for the duration of the seven months trial. Those months where individuals failed to match invariably were due to poor image quality.

LIP PATTERN DETAILS: To determine if any noticeable changes had occurred over the duration of the study a monthly distribution graph of the matching score was plotted. Only the scores from the line details (i.e. *, // lines and **Y**) were used. It was reasoned if there was a change occurring over time the number of matching features would decrease with each monthly series and this should be visible as a shift in this distribution pattern of each graph. Table 3 shows the mean and range. Study of the combined distribution graphs for each month failed to highlight any noticeable shift in scores.

GENERAL APPEARANCE: The general appearance of the lip print was assessed with regard to the size and shape of the lips as presented on the glass. The group was limited to those subjects for whom 3+ consecutive prints had been collected. Initially they were scored as either a "good", "fair" or "poor" match. The small number of results in the latter category made it simpler to amalgamate these into one. The size and shape of the lip print was highly consistent throughout the trial period, especially the size (Table 4).

CONTACT LINE AND NOTCHES: Initially all prints were graded as to whether their resemblance to their standard print, (November 1999), was "good", "fair" or "poor". To avoid being too subjective the later two groups were combined into "poor". Only those who provided a minimum of three consecutive monthly prints for study were included. This left a study group of 69 individuals. First studied was the individual's consistency of positive matching (%) over the successive series (Table 5). A total of 72.5% of the study group matched their standard print on more than half the series. Each series was compared as a unit for positive matching against the standard, thus showing any changes with time (Table 6). These figures suggest a relatively consistent matching of above 50%, with elapsed time not decreasing this figure. The percent matching may have risen dramatically if shades of grey were considered rather than the restrictive absolute of "good" or "poor" matches.

One hundred and forty prints were of sufficient quality to study the notches. The number and spacing of notches was studied each month using the acetate overlays. The number of notches varied from one to seven with four being the most frequent at 30.7%.

Table 3: *Mean score for each month and range of scores for central 50% of population*

Month	25th percentile	Mean	75th percentile
December	8	10.6	15
January	8	11.2	14
February	8	12.2	16
March	6	11.1	14
June	6	9.6	12

Table 4: *Rate of consistency of general appearance*

% consistency	Size		Shape	
	good	poor	good	poor
100	56%	0%	44%	0%
50-99	32%	20%	36%	26%
0	0%	56%	0%	44%

Table 5: *Rate of consistency vs percentage of Pop^n*

% matching	Rate of consistency
100	23.2%
80-99	8.7%
60-79	27.5%
40-59	14.5%
20-39	17.4%
0	4.3%

Table 6: *Percentage of Pop^n matching per month*

Month	% of pop^n
June	50.8
March	61.2
February	55.0
January	67.3
Dec 99	64.9

Table 7: *Rate of consistency vs pattern type*

level of consistency	linear	reticulated	mixed
100%	20.3%	5.0%	7.6%
50%	12.7%	15.2%	17.7%
total of pop^n	33.0%	20.2%	25.3%

Table 8: *No. of matches vs percentage Pop^n, percentage of this group Female*

X fine. Score	% of pop^n	% female	X coarse. Score	% of pop^n	% female
3+	12.7	66.7	3+	18.3	84.6
2	16.9	33.3	2	18.3	46.1
1	35.2	60.0	1	40.8	44.0
total	64.8			77.4	

Table 9: *Contact line notches vs pattern type*

Contact / pattern	%	Contact / pattern	%
high count / linear	36.9	low count / linear	8.7
high count / retic.	10.9	low count / retic.	8.7
high count/ mixed	23.9	low count / mixed	10.9

Sixty three point five percent of the prints studied had three, four or five notches. It was possible for notches to be discernible even though the contact line match was poor. This was the result of variations in quality over the print reducing the length of visible contact sufficiently to render shape matching unsafe. The number of individuals and the number of notches they showed increased noticeably as the line match rose from "poor" to "fair" to "good".

PATTERN TYPE AND COARSENESS: Firstly the patterns were categorized into "linear", "reticulated" or "mixed". There was a study group of 79 individuals available for this, some having been eliminated as they failed to leave a visible print or it was impossible to determine their pattern type.

The rate of consistency compared to pattern type is shown in Table 7. These figures indicate that in almost 80% of the population the pattern type was consistent in over half the prints. This was especially noticeable for those with "linear" patterns. The lip patterns were next classified into two extreme groups of "extra coarse" and "extra fine", the middle ground was ignored to avoid too subjective an opinion. The consistency was measured by the percentage of subjects who where similarly graded on 1, 2 or 3+ occasions (Table 8). Although a large percentage of the two groups overlapped in the two lower classes the "coarse" pattern was significantly more frequent and reliable in the 3+. The disturbing feature was the disproportionately high number of females in this class. A possible explanation could be the coarsening effect of lipstick on the recorded pattern.

Finally the lip pattern type was compared with the contact line discussed in the previous section (Table 9). Individuals with a high notch count for contact line and low counts were divided according to their pattern type. What is evident from these figures is that a large percent of those with multiple notches fall into the linear group with a smaller but still significant number showing a mixed pattern.

PATHOLOGIES: This proved a very unrewarding area of study with almost no pathologies visible on the vermilion region or surrounding tissue. One individual had a mole adjacent to the lower vermilion border and this was consistently present and recorded in good detail. Visual examination of another subject's lips showed two highly apparent varicosities in the centre of their lower vermilion region. Surprisingly these failed to register on the contact lip prints. No evidence of "whirl" patterns as described by Endris and Poetsch-Schneider[11] was found despite a claimed 38% frequency in his German population.

PRESSURE PATTERNS: In this section the consistency of the print density was studied to determine if the variations in intensity could possibly reflect underlying dental features. Possibilities include missing or irregular anteriors or individualistic and reproducible muscle function. It soon became obvious that an unusually low level of malocclusion among the subject group hampered this task. One individual did, however, present with an upper central incisor that was severely displaced buccally. This consistently showed as a rectangle of heightened contact, i.e. whiter, adjacent to a darker region of reduced contact over the relatively retruded neighbour. This was a very promising result, albeit in a single case with an extreme malocclusion.

Study of the remaining prints was inconclusive,

a) 29.4% of subjects showed one print with a region of altered contact.
b) 37.6% showed multiple prints
c) 32.9% showed no pressure points in their prints.

As previously mentioned none of these subjects had obvious malocclusions with which to associate these pressure points. What may have been causing many patterns in the recording medium was the behaviour of the underlying lip muscles under contact pressure. This is difficult to statistically prove from the available data but most of these patterns fell into the following groups:

1. An elongated, narrow region of paler print, indicating increased pressure, along the upper and/or lower borders between the skin and vermilion zone. This was a consistent pattern, over the study period, in approximately 10% of

Table 10: *Rate of consistency vs print surface type*

consistency	lipstick	wet	dry	poor
100%	11 (13%)	1 (1.2%)	2 (2.4%)	1 (1.2%)
50-99%	3 (3.5%)	2 (2.4%)	2 (2.4%)	3 (3.6%)
total	14 (16.5%)	3 (3.6%)	4 (4.8%)	4 (4.8%)

Table 11: *No. of months vs sex*

no. of prints	female	male	% of study
3+	11	2	15.1%
1,2	10	8	20.9%
total	21	10	36%
% of study	24.4%	11.6%	

subjects and possibly due to muscle tensing during function.

2. A notch or cleft in the central line of contact between upper and lower lip. This appeared to be where the inner aspect of the lip has twisted out of contact with the slide when pressure was applied. This was evident in 5% of the group.
3. The remainder who demonstrated regional variations in pattern density showed high pressure contacts over the anterior teeth, usually the uppers, but not exclusively. Whether this is due to muscle tone or the underlying arch shape was impossible to determine.

PRINT SURFACE: It was noticeable early in the study that the quality of prints deposited on the glass slide varied enormously between individuals and that, in many cases, this quality of print was consistent. The surfaces deposited were categorised as being either “lipstick”, “wet”, “dry” or “poor”. This last umbrella group contained those subjects whose image was difficult to read but the cause could not be discerned from the scanned image. Table 10 shows results were derived from a study of those subjects with three or more prints. The most noticeable surface type was that of lipstick or similar when applied to the lip surface. It was detectable on 16.5% of subjects in excess of half their prints and when all prints where included it was detectable on an additional 20.9% in one or two prints. What was not surprising was the sex distribution of the subjects (Table 11). Those individuals showing a high level of consistency were overwhelmingly female, but amongst the occasional appearances the sexes were more evenly divided. One possible explanation for this is the use of moisturising lip salves on occasions during the winter by both sexes. On the basis of these figures sex determination was not advisable, but it must be remembered that the scanning technique utilised was in black and white, scanning in colour would possibly have identified the moisturiser compared with lipstick, and facilitated sexing. The impact of lipstick on the visible print varied enormously with the volume applied. A very light veneer deposited on the slide enhanced the uptake of the dusting powder creating a clearer image, but more than this resulted in over adherence of the powder progressively obliterating all detail. The resulting prints were usually evident as opaque featureless slides.

Of greater interest was the range in quality of prints recorded from those not using any cosmetics or medication on their lips. One extreme of this was the small group of subjects (4.8%) whom rarely, if ever deposited a print of readable quality for the duration of the study. Most of this group had chronically dry lips which left no print or at best a sketchy mark devoid of detail.

An occasional finding was a surface produced by excessively wet lips (17.4%). This appeared as an irregular, darkly stained print. The moisture, having dried, showed no lip detail, only the outline of what

Table 12: *No. months vs surface type (wet or dry)*

no. of prints	dry	wet
3+	3	2
1,2	19	13
total (% of study)	21 (24.4%)	15 (17.4%)

Table 13: *Reliability of Chin Print*

chin reliability	%
always continuous	16.8
always distinct	8.4
always absent	18.0
variable*	56.6

*variable subjects	%
distinct/continuous	7.2
absent/continuous	25.3
absent/distinct	15.6
all types	8.4

*Variable subjects subdivided according to combination of images

Table 14: *Reliabilty of philtrum print*

philtrum reliability	%
always visible	30.5
always absent	1.2
always vague	0.0
variable*	68.2

*exclusion of vague images	%
always visible	44.8
always absent	6.9
variable	48.3

*50% of this group showed a single vague result, this was invariably due to poor image quality. When the “vague” images were excluded from this section and the results recatagorised.

Table 15: *Correlation of print profile with ortho profile*

Percentage correlation	% of population
100	18.6
80-99	3.4
60-80	15.3
40-60	6.8
20-40	11.9
1-20	5.0
0	38.9

Table 16: *% of times perceived profile is consistent*

Percentage of times	Perceived profile consistent
100	34.8
80-99	10.1
60-79	40.5
50-59	14.5
	99.9

appeared to be bubbles. Other subjects always produced clear, detailed prints covering their complete lips. In between were the majority who produced readable prints, but of variable quality (Table 12). It was evident from the chart that the number of highly consistently "wet" or "dry" lips was very small with a significantly larger number appearing infrequently. Among those subjects who produced inconsistent results their prints were spread evenly between all surface types.

PERIPHERAL FEATURES: The features peripheral to the vermilion region, but still recorded on the lip prints were then studied.

CHIN PRINT: The image of the chin was categorised as either a distinct mark, a continuance of the lower lip or absent. This was noted for each of the 83 individuals, in the six series. Over the seven months of recording, the reliability of the chin as an individual characteristic was noted. These "variable" subjects were subdivided according to the combination of images they displayed (Table 13).

THE PHILTRUM: It was recorded whether the philtrum was clearly present, a vague image or not visible. These recordings were then summed to give an indication as to the reliability of this landmark being found in the lip prints (Table 14). Fifty percent of this group showed a single vague result, this was invariably due to poor image quality.

When the vague images were excluded from this section and the results again categorised they were as follows:

a) always visible - 44.8%
b) always absent - 6.9%
c) variable - 48.3%

PROFILE. All subjects with fewer than three results recorded were excluded. This feature was studied to determine both its accuracy and reliability.

ACCURACY: This section was designed to study the accuracy of the author's perceived profiles compared to that derived by direct observation of the subjects. To achieve this each print was classified as to whether the lips appeared equally prominent, or whether either the upper or lower predominated. This was noted for the duration of the trial and then compared with the Orthodontic Classification noted during the final series. Data was available on a group of 64 subjects who were recorded sufficiently frequently and about whom an Angle Orthodontic Classification had been deduced from their profile. Table 15 shows the percentage of subjects who correlated with their Orthodontic Profile.

When the results at either extreme were further subdivided they showed an interesting trend. Study of the actual profiles of those subjects in the 80-100% category showed 83.8% to be C I and the remaining 16.6% were CII. When expanded to include the 60-80% group the same trend was evident, i.e. 85% were C I and 15% were C II. There were no subjects with C III, prominent lower lips, evident in either high correlation group. This contrasts with the actual distribution figures in the U.K. population of 50% for CI, 40% for CII and 10% for CIII.[14] The reverse trend held true amongst those exhibiting extremely poor correlation. Of those showing less than 20% accurate correlations between their perceived and actual profiles 76% were individuals with a noticeable prominent lower lip, 20% were CI and only 4% CII.

CONSISTENCY: In addition to the above it was hoped to discover if the perceived profile of the subject, as inferred from the lip print, was constant over successive prints, regardless of the individual's actual profile. The profile was recorded for each print and the distribution of these over the categories of CI, CII and CIII was noted. They were subdivided according to the consistency with which their profile was reproduced over the 3-8 month period (Table 16).

Relating those subjects with a reliability in excess of 80% to the profiles recorded showed 81.5% were CI and 18.5% were CII. Eleven (15.9%) of the subjects showed at least one CIII profile, but these were highly inconsistent results, never occurring in more than two prints out of a possible six. This compared with the true profile breakdown of CI 51.6%, CII 18.7% and CIII 29.7%.

FACIAL HAIR: This was a simple matter of studying the individual prints, at considerable magnification, and recording on which subject facial hair was present. It was also noted whether it was minimal, moderate or well established, and if this was so on successive prints. The results were then correlated with the known sex of each subject.

It was apparent that on a clear print the presence or absence of facial hair was very evident. Although comments on volume were difficult the only subject with a moustache was readily detectable. This study was hampered by a shortage of bearded subjects. Hair was noted on the lip prints of the following individuals:

a) detected in the majority of prints (4/6) 33.8%
b) detected infrequently 28.8%
c) never detected 37.5%

Of greater interest was the relationship of facial hair to sex:

a) 90% of female subjects showed visible facial hair, which was extremely consistent over successive prints.
b) 31% of male subjects showed facial hair, of these only four were present in 4/6 months and the remainder mainly single occurrences.

DISCUSSION

SCORES FOR VERMILION CHARACTERISTICS: Over half the study group matched their standard print on every occasion, with a further 10% matching in over 80% of cases. Poor matching seemed to be due totally to poor image quality. Removing those subjects whose consistency was low due to poor image quality would have improved the percentages greatly.

To investigate possible change, the distribution for each series of prints was calculated. Taken as a whole the wide distribution was due to a significant disparity between individuals rather than between successive monthly prints of each individual. This in itself strongly suggests a consistency in the pattern detail over time.

Over the eight months of the trial the range of scores fell and then rose, while the mean rose and then fell. All movements were small. If change were occurring with time, this could be expected to be reflected as a gradual decrease in matching scores. To some extent this can be seen between December and June but when taken as a whole the pattern is not clear. A trial of greater duration would perhaps show if this was the beginning of a drift away from the initial score in a fluctuating response to other factors such as time of year and weather.

GENERAL APPEARANCE: This was by far the most consistent of any of the features. More importantly it was sufficiently visible in all but the poorest prints to allow comparison. The size and shape of the lips forms a good basis for initial comparison. Each can be viewed as an overall shape and dimensions, an upper and lower lip shape, width and thickness plus any peripheral features.

CONTACT LINE AND NOTCHES: This is a continuation of the external physical appearance and as with the general appearance there was a high degree of consistency for such a potentially fluid feature. Seventy two point 5 percent of subjects matched their standard print's shape in over half the series and 23.3% always matched.

PATTERN TYPE: The lip patterns were categorised as "linear", "reticular" and "mixed", and almost 80% of those tested were consistent in at least half their prints. Bearing in mind that this feature has been the basis for all preceding papers on lip print individuality and stability it is not exceptionally good. Linear patterns were noticeably more stable than either of the other types. Of those subjects who were not 100% consistent they tended to vary between all the pattern types. Some of this variability must be due to operator error in classification and possibly the blurring effects of lipstick or recording pressure. This study failed to find the discrete regions of pattern types which form the backbone of previous authors' classification systems, Suzuki and Tsuchihashi[2], Tsuchihashi[10] and Endris and Poetsch-Schneider[11]. In general the pattern types were far removed from the reliability other workers had suggested.

Of greater significance was the study of the pattern detail from month to month. Relating the individual "Y's", "stars" and "vertical lines" from one month to the next month's print was more viable than a system that categorises regions and bases the individualisation on the pattern these categories

make. Of the three line features the "Y" was the most frequently used. It was identifiable and robust in the face of distortion. The "star" was also a useful feature, stable and visible, especially when rare. On certain subjects the number of these features was overwhelming and locating a particular "star" difficult. On occasions a "star" would transform into a "Y" if the image quality was sufficiently poor to obliterate several of it's points. Parallel (//) "lines" had to be viewed as a group, assessing the distance between as much as the total number. This was to ensure the correct pattern of lines was being matched. Lower lips appeared to show a higher number of vertical lines, confirming Endris and Poetsch-Schneider[11]. Care was needed to correctly identify the lines. The shape of the junction between lip and skin and the distance from this and the contact line helped relate groups of parallel lines on successive prints. In general horizontal lines tended to be inconsistent, possibly arising as fold due to pressure on the lip.

A high percent of the study pool showed as a "very coarse" or "very fine" pattern on a single occasion. Less than half this number was consistent. This could be a significant warning when attempting to match two prints as the extremes; especially "coarse" are readily noted, but very variable. It would be important in such a case to study carefully for any signs of lipstick or similar as the very large percent (84.6%) of this group who are female suggests a link. Studying a print made by lipstick shows that the fine details appear frequently to be occluded by the cosmetic, leaving only the coarsest, major lines visible.

PRINT SURFACE: Lipstick was the most frequently encountered variant of the print surface. Not surprisingly these subjects were predominantly female, some males used lip salves in the winter months and the print appearance was similar. The lipstick was detected:

a) as a coloured deposit on the slide.
b) when dusted, the plain surfaces attracted the powder, obliterating large areas.

The deposited pattern appeared to change as a result of the lipstick obliterating the fine detail on the lip. Features clearly visible on one slide were missing on another. Only heavy line patterns seemed to survive.

CHIN PRINT: Anatomically a person's chin may either retrude behind the vertical line of the lip, lie in a similar plane or stand as a small protrusion distinct from the lip. On contacting a vertical surface either no print is left, a continuous mark is made running from the lower lip margin down to encompass the chin, or a distinct, usually circular chin print is left some distance below the lips. These types of chin print were consistently found in 18%, 16.8% and 8.4% respectively. Unfortunately just over half the subjects failed to leave consistent results, which was surprising for such an anatomic landmark. Variation in chin prints could be due to:

a) changes in the angle of recording.
b) changes in the pressure used to contact the lips.
c) alteration in the vertical position of the slide on contact or changes in recording area clipping off the chin print.
d) posturing of the lower jaw or lips during print recording.

When taking a print for future comparison with an evidential print, correct angulation and multiple prints should possibly overcome the first three.

PHILTRUM: As a means of individualising a print, its presence or absence leaves much to be desired. However the shape, dimensions and junction with upper vermilion border all provide additional useful data.

The major use of the philtrum image is orientation of the lip print.

PROFILES: Figures indicate that the relative prominence of upper and lower lip, as appears on the lip prints, is consistently recorded.

Unfortunately the accuracy of the perceived profile when compared with the actual soft tissue profile is not good. When the results of all the series were pooled, only 22% of subject's profiles were always correct.

FACIAL HAIR: This was very well recorded on the contact prints. The distribution and density showed clearly, the length less so. What was an interesting finding was the highly repetitive detection rate of 90% for women whilst only 31% of men showed hair and this was overwhelmingly a single occurrence. As well as providing a possible insight into sexing prints the distribution patterns of the follicles were variable and possibly suitable for discrimination, although further work is needed. The relative length of the hair or absence may provide a time frame when comparing two prints, and be of use in elimination of a suspect. A clean-shaven print at a crime scene is distinguishable from a fully bearded suspect arrested hours later.

CONCLUSION

The primary aim of this paper was to establish if the characteristics of the lip print are sufficiently stable over time to be of relevance to the forensic scientist attempting to identify a set of prints.

Study of the range of matching features of this study group concluded that an acceptable number confirming individuality was eight. In all subjects showing less than this number the cause appeared to be poor image clarity. In all cases when both the initial and subsequent prints were suitably clear it was possible to find in excess of eight points of similarity. This proved impossible with prints from differing subjects.

Using this number eight, successive prints of 85 individuals over an eight-month period were studied. In only two cases was it impossible to confirm a match at least once over the trial period. Both these appeared to be the result of chronically poor quality prints. Presumably use of an alternative method of data recording would have overcome even this small group. Each month on average 88.9% of the pool matched their comparison print, over 50% matched each and every month. Over the period of time this group was studied, the lip details were sufficiently stable in the vast majority of cases to allow recognition of the individual's pattern. In the few cases where this determination proved difficult the problem was the clarity of the contact print and not a change in anatomy.

As a practical application in a crime scene the physical durability of deposited lip prints is unlikely to exceed the time scale of a few months, but some evidence began to appear suggesting a much longer duration for the pattern itself. It proved possible in 14 cases to match the lip patterns of subjects taken during an initial trial in January 1999 with prints taken in November 1999 and June 2000, a period of 17 months. The small size of this group was due to difficulties relating to cyanoacrylate enhancement used in this earlier trial and represents 100% matching of those producing a clear print.

The second area of study was to explore the features of the lip print to determine which were useful in determining identity. Foremost amongst these was the pattern line details. This has been shown to be individual by past workers and in this study appeared to be stable over time. It is the feature most readily visible and comparable, containing an enormous bulk of detail. Together with the overall size and shape, these features provide sufficient data to achieve a comparison with most prints.

It is only when the quality of print fades that the other features are needed. When the details of the vermilion zone are indistinct, surrounding features can be utilised to provide additional information. None of the other features studied e.g. anatomic features, profile, contact line and print surface was sufficiently constant to be of use by itself. However, in combination with other such features they become increasingly important. They contribute to the layers of data that can be derived from a print and to a limited extent outline the physical features of the subject.

These peripheral details become very significant if the scenario produces multiple evidential prints. Some of these characteristics, such as the coarseness of the pattern or the presence of the chin print occur frequently in a single print but this decreases dramatically with repeated prints. Similarly pressure patterns appeared in most prints but their representation in several prints became highly indicative of an underlying dental cause.

Other features, such as visible pathologies were so rare that their presence in several prints would assume great statistical significance. Facial hair was an important indicator of time as well as a strong aid in sexing the subject.

The features that appeared to provide little accurate data included the presence of a philtrum, although it was extremely useful as an orientation landmark. Also included was the estimation of the profile. Although relatively consistent, this was not accurate enough to help visualise the subject as lip posturing and soft tissue deformation disguised the real anatomy except in extreme cases.

In summary the greatest aids to accurate analysis were clear, high quality prints that enabled easy study of the fine vermilion pattern, and multiple prints, both evidential and comparative. These allowed all the peripheral features to be studied and utilised in building up an image of the subject and a body of comparable features.

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AN ATYPICAL AIR BAG INJURY?

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ABSTRACT

The air bag is a passive safety device capable of saving many human lives each year. However, in a certain number of cases, it is itself the source of injuries to the occupants of a motor vehicle, mostly of cutaneous burns. The case describes peculiar abrasions to the enamel of the teeth scraped by the air bag, in particular atypic lesions involving the upper arch showing buccal rings of demineralization associated with roughness of the enamel that progressively assume a trend of fine parallel oblique striae from bottom to top and from left to right, as literature describes for cutaneous burns due to air bag insult.

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Key words: air bag, tooth injuries, friction burns

INTRODUCTION

The air bag is a passive safety device consisting of a cushion of nylon fabric and rubber that inflates and positions itself between the passengers and the internal parts of a motor vehicle's body when its sensors detect sudden longitudinal deceleration similar to that which occurs when a vehicle traveling at 20-30 km/h[1,2] collides with a barrier. The basic version, for the driver, anticipates that a folded bag inside the steering wheel, with a volume of 40 or 70 litres, will inflate in the span of 30-50 milliseconds (when the passenger's body has already come forward about 20 cm) and deflate within 2 seconds. The speed obtained during inflation varies from 160 km/h[3] to 330 km/h,[1] with the production of a sound wave that can reach 150-170 decibels[2], a value that, however, does not exceed the rupturing threshold of the tympanic membrane.[4]

The present work describes an unusual expression and localization of typical air bag injuries, friction burns, which are customarily found on the face. In this particular case, tooth enamel was affected, an occurrence that, as far as we know, has never been reported in the literature.

ADVERSE EFFECTS OF AIR BAG DEPLOYMENT

The introduction of the air bag into standard automobiles, first represented in Europe by the Mercedes Class S in 1982,[5] contributed to saving a considerable number of the lives of those involved in potentially lethal accidents. An approximation of this device's effectiveness in the United States is roughly 14,000 deaths prevented during the period between 1987 and 2003.[6]

Nevertheless, over the course of time, injuries to motor vehicle occupants began to be recorded, brought about precisely by the opening mechanism and operation of the air bags.[2] The literature reports the occurrence of cutaneous abrasions in 68.6% of the cases of subjects that display air bag injuries, either alone or in association with other injuries. Contusions involving the cervical column and temporomandibular joint (TMJ),[7] appear in 37.8% and cutaneous lacerations were observed in 18.2% of cases (a pressure of 7 atmospheres being sufficient to lacerate intact skin[2]). Burns constitute about 8% of air bag injuries, although less independent statistics maintain it as a slightly lower rate: the incidence verified by the automobile manufacturer Daimler-Chrysler is equal to 5%.[3]

Descriptions of fracturing injuries (3.2%) to the sternum, clavicle, ribs and bones of the face,[8] which include nasal and orbitozygomatic fractures, have also been reported. A force of 10-35 kg and 90-200 kg respectively was judged sufficient to produce these last two injuries.[1] Damage to the auditory apparatus and eyes is also frequently noted. Barotraumas with a residual permanent loss of hearing and peripheral vertigo have commonly been described,[8] as well as a range of ocular injuries, the most notable being subluxation of the lens, vitreous hemorrhage, traumatic iritis,[8] and retinal detachment in 1.8% of cases.[2] Also mentioned are serious visceral thoracic traumas, represented by pericardiodiaphragmatic ruptures[9] and pulmonary traumas,[9] as well as respiratory disorders in asthmatic subjects.[8]

CUTANEOUS BURNS

Of the above-described type of injury associated with air bag deployment, it seems worthwhile to examine burn injuries more closely. These most frequently affect the skin superficially, but second-degree burns are sometimes found. The aetiopathogenetic mechanism that causes them is multifactorial (chemical, thermal and physical) and can be understood through knowledge of the device's operational dynamics.

The inflation of the bag is due to the release of a gas, nitrogen, which is produced when an electric impulse triggers the pyrotechnic charge of a cartridge of 70 grams of sodium azide (the propellant) resulting in an exothermic reaction.[2] Along with the nitrogen (96%), carbon dioxide (3%) is released, as well as a mixture of gases and particulate compounds (1%), including carbon monoxide, nitric oxide, ammonia, benzene, toluene, ethylbenzene, xylene and hydrocarbons (methane, ethane, ethylene, etc). Moreover, an exceedingly basic and corrosive aerosol is generated in small quantities, made up of sodium hydroxide, sodium carbonate and metal oxides.

Burns, then, are attributable to three causes relating to the nature of the injury:

- caustic chemical burns, caused by the particulate material (in a manner that has still not been entirely explained) and by the pH of the mixture of the substances produced;
- thermal burns, produced both directly by the high temperature of the gases released and indirectly by the melting of synthetic clothing (especially polyester);
- friction burns (also the source of abrasions to the cornea and eyelids).

At the cutaneous level, permanent pigmentations produced by irritant dermatitis are frequently manifested, provoked by the combination of gases, abrasive dusts and talc discharged under great pressure. The injured consequently complain of itching, burning and stinging. The thorax, arms and face can present erythema, oedema and purpura. As far as is now known, it does not seem that these dermatides admit an allergic origin.

Chemical burns occur in the moment in which the dispersion of a white dust[9] settles and comes into contact with a liquid like sweat, producing an alkaline solution that has a burning effect. If the pulverulent residue penetrates into the eye and is dissolved by the tears, the solution can cause alkaline keratitis. The treatment to follow in such cases is a thorough washing with saline solution, to be repeated if necessary after having checked the eye's pH level, since it may rise again during the 30 minutes following the irrigation of the eye.[2] For superficial cutaneous chemical burns, treatment by the application of topical corticosteroids is sufficient.

The arms and thorax are the sites most affected by burns of the thermal kind. Superficial burns usually appear pink or pale red with the formation of painful blisters, while the deep burns are mostly whitish, asymptomatic and lacking blisters.[8]

Friction burns have instead the characteristic appearance of "numerous, fine, parallel superficial erosions on an erythematous base"[8] that are localized, usually on the face, chin and neck.[2] They are produced when the bag, unfolding during the opening process, rubs against the skin with an effect similar to a slap received "edgewise".

CASE REPORT

A 25-year-old male, while driving his own motor vehicle with his seatbelt fastened, was involved in a frontal collision owing to another automobile's incursion into his lane. Following the crash, the air bag deployed, hitting the driver and preventing his impact against the windshield. Subsequent to the accident, he was transported to a nearby emergency room where he was examined and treated. The emergency room records reported during the general exam: "... craniocervical and facial trauma ... post-traumatic epistaxis ... haematoma on the lips. Wounds (superficial) to the left nasal vestibule and the upper gingivolabial fornix. Does not require sutures".

In particular, the presence of a lacerated and contused wound on the upper left gingivolabial fornix and of abrasions on the buccal side of the enamel of 12, 11, 21, 22, 23, 24, 25 was noted. An orthopantomograph (OPG) was also taken, showing absence of periapical-radicular lesions at that time.

Seven months later the subject came under our observation while making a medicolegal visit in order to evaluate the damage resulting from this incident. At this time, the presence of lesions on the enamel of some maxillary teeth was noted (Figs. 1 and 2). The case history, thoroughly investigated, did not reveal any relevant element in this regard. In particular, the following explanations were refuted: a history of anorexia with induced vomiting or gastroesophageal reflux (furthermore, the palatal surfaces of the maxillary teeth did not present a smooth shiny look and tissue loss, both typical of

Fig.1: *The roughness of the enamel*

Fig.2: *The abrasive lesions of the teeth*

such conditions); eating habits including the excessive consumption of acidic foods like lemons or citrus juices; former traumas to the oral and maxillofacial zones. Moreover, there was no history of orthodontic treatment or other dental restorative treatment to 12 - 25. Unfortunately, previous dental treatment records were not available.

Our examination furnished the following findings:

- From 12 to 25: buccal rings of demineralization associated with roughness of the enamel that progressively from the first to the second maxillary hemiarch assume a trend of fine parallel oblique striae from bottom to top and from left to right. Nil of note on the palatal surfaces.
- 11: fracture of the incisal enamel.
- 21: fracture of the mesial edge limited to the enamel.
- Between 11 and 41: overjet of 1 mm; overbite of 2 mm.
- The mucosa of the upper left vestibular fornix and the attached gingiva were normotrophic, without cicatricial adhesions. Absence of functional deficiencies in homolateral movement of the upper lip.
- Electrical vitality test using a Kerr Vitality Scanner* of the pulpal sensitivity of 12 through 25 showed values within the norm (in the following medical inquiry, an increased sensitivity to thermal stimuli was reported by 12 through 25).
- No pathological findings for the lower teeth.

MEDICOLEGAL CONSIDERATIONS

The reported case concerns peculiar dental lesions of the enamel, resulting from an accident in which the air bag deployed. The injuries reported by the driver consisted of craniocervical and contusive facial trauma, with post-traumatic epistaxis, hematoma on the lips and superficial wounds to the nasal vestibule and the upper gingivolabial fornix, not requiring sutures. Abrasion of the buccal enamel of 12 - 25 was observed in the emergency room. Seven months later, during the medicolegal exam to evaluate injuries, clinical observations emphasized the persistence of abrasive lesions on the enamel of the teeth cited above. However, doubt persisted about whether they could be ascribed to the car crash in question and therefore also about the possibility and degree of reimbursement for the aftereffects suffered by the patient.

Since no reference to any such air bag-related injury could be found in the literature, these clinical observations became the object of a medicolegal study, utilizing the classic principles of causation. The topography of the lesions corresponded to what was recorded in the emergency room about distress to the vestibular mucosa of the maxillary dental arch. Endogenous causes were excluded, since the remaining teeth do not present with an appearance that could be traced to a developmental disturbance such as amelogenesis imperfecta. The lesions do not present the smooth appearance resulting from low impact mechanical insult, such as due to the brushing of the teeth with baking soda.[10] Nor do the palatal surfaces of the injured teeth show alterations that could be ascribed to the localized action of gasses or liquids of gastric origin. The inferior opposing teeth also appear without buccal demineralization resulting from potential atypical eating habits, through prolonged contact with acidic foods (for example, slices of a citrus fruit held in the left fornix), suggesting that they have been somehow protected from the injury by the lower *labium*.

The air bag deployment with high-pressure contact has been shown to cause injury: the roughness of

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the enamel was possibly produced by the abrasive mechanical action of the air bag's synthetic fabric rubbing against the teeth, producing thermal energy through friction. This energy acted together with the high temperature of the released gasses and the aggressive chemical action of the aerosol in which the subject found himself immersed. In effect, the premolars presented typical lesions, "numerous, fine, parallel erosions", absolutely analogous to those that are found described in the literature in the case of friction burns on the skin, whose appearance could be defined almost pathognomonic of the air bag abrasion. Moreover, no pure blunt trauma could produce such a pattern of lesion.

It has been suggested that the dynamics of air bag deployment follow situational dynamics, with injuries being more frequent among people of short stature (158-162 cm), in which the driver is positioned at a distance of around 25 cm or less from the wheel.[1] This is because the lower portion of the air bag, given the lack of space available, is "compressed" between the thorax and the steering wheel, and is forced to expand in a primarily vertical direction, from bottom to top, so that the person's face is hit not from the front, but "edgewise", resulting in the production of the cutaneous abrasions and lacerations. Such wounds were also correlated with the shape of the air bag when it is inflated. The subject in this instance was marginally taller than this height range. It has also been reported that bags that display a concavity at the center produce facial lesions less easily, since they have a range of action in expansion toward the subject of around 25 to 33 cm, in contrast to those bags that do not display a concavity, where the values are respectively of around 38 to 50 cm.[1]

In our opinion the combination of mechanical, chemical and thermal energy simultaneously contributed to the production of the peculiar parallel erosion of the enamel due to the deployment of the airbag and consequent impact on the exposed superior teeth, even we do not definitely know the way such effect can be produced by a brief and sudden contact with the dental surface. Further study is needed to confirm the aetiology and give a clear explanation of the mechanism of production of the injury.

In this instance the causal relation between the incident and the established effects on the tooth enamel was considered sufficiently proven, not only by the immediately suggestive appearance of the parallel and seriate erosions, but especially by the clinical history and its bibliographic correlations, notwithstanding that no case report has been found that indicates the recurrence of such lesions among those described by the literature as connected to air bag deployment. From the perspective of compensation, the application of porcelain veneers to 12 through 22 and of composite vestibular fillings in 23, 24 and 25, and their periodic renewal as required, was considered sufficient to completely correct the damage.

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"CHOUMP" ENAMEL TATTOOS

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ABSTRACT

Identification of both living and deceased individuals may be made by recognition of physical characteristics or comparison with data from medical or dental records. Data with low frequency of occurrence are prised by identification specialists. Two cases are presented of highly individual enamel tattoos.
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Key words: enamel tattoo, identification, forensic odontology

INTRODUCTION

Body art or tattoos are a common practice world over, with colour pigments impregnated into soft tissue to obtain a permanent staining of the skin. [1-4] Tooth art has also been described, with pictured veneers or jewellery inserted into anterior teeth.[5,6]

CASE HISTORY

We report a type of a tattoo on a hard tissue, tooth enamel, a practice in parts of Indian states of Rajasthan and Uttar Pradesh, locally known as "choump". In this practice tooth enamel of the labial surface of upper central incisors are engraved with circular patterns using a hand drill and are later filled with gold. Two patterns of such tattoos one (Fig 1) and three (Fig 2) circular engravings on a single tooth are documented. We have heard of other patterns being practiced, but have not been able to document them. Reasons given for these tattoos included that it was a fashion in their village to get such tattoos, some were of the belief that this will be the only gold they will carry with them after their death to their heavenly abode and some said they were used for identifying members of a given nomadic clan.

CONCLUSION

It is widely recognised that teeth displaying highly individual features are used by forensic odontologists to enable identification of individuals.[7,8] A single feature may hold sufficient weight to allow confirmation of identity.[9] However, for scientific verification there must be a record of that feature for comparison. Dentists must be encouraged to detail tooth modifications, including tooth art, accurately; preferably with a photographic record

Fig.1: *single gold spot tattoo on each of the upper central incisors*

Fig.2: *three gold spot tattoo on each of the upper central incisors*

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PROCEDURES FOR THE COLLECTION OF DENTAL RECORDS FOR PERSON IDENTIFICATION

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ABSTRACT

Dental treatment records offer a valuable resource for establishing the identification of deceased persons by means of dental comparison as required for forensic purposes. The creation, maintenance, storage and custody of such records is a legal and ethical duty of each dental practitioner. Dentists in Australia are also bound by federal and state legislation to protect their patients' confidentiality at all times. They are also required by law to note and report evidence of child abuse observed in the course of their treatment.

When dental records are required for forensic purposes certain procedures should be followed for their release and collection. This paper discusses these procedures, and illustrates by reference to an actual case the possible consequences of deviating from established protocols.
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Key words: Identification, dental records, forensic odontology, child abuse

INTRODUCTION

The important role of dental treatment records for use in the determination of the identity of both living and deceased persons has been recognised and accepted internationally for many years.[1,2] This has resulted in the development in various countries and administrations of procedures to be followed for the retrieval and collection of patient records from the dentists who have created them when needed by the authorities responsible for establishing identity in individual cases. Furthermore, over more recent years in some countries, dentists, along with other professionals, are legally obliged to record and report to police any evidence or suspicion of child abuse observed in the course of their practice.[3-6]

It is of fundamental importance that all procedures proposed for collecting records required for forensic purposes comply with the relevant laws of the State in which they are maintained. It is also important to understand that dentists in practice do not create and retain their patients' records for the sole purpose of forensic identification. Indeed, dental records fulfil two functions: - to chart the teeth present and details of their treatment in the best interests of their patients; and then, of considerable significance to the business success of the dentist, to record details of the fees charged. These records remain the property of the dentist, not the patient. Thus the forensic odontologist, in effect, exploits the existence of dental records as sequelae of dental practice.

The use of these records for forensic purposes, however, must always comply with the relevant legal and ethical obligations of all parties involved in a particular matter. First, there is the matter of professional confidentially which is binding upon dentists and their patient records. This raises issues about the release and collection of records that are required for forensic purposes, and is of particular concern to all dentists as well as the administrators of state dental services who are at risk of facing charges of breach of professional confidentiality. In Australia, a dentist can be protected against such charges if a warrant for the release of records is issued by the State Coroner. The warrant is served upon the dentist by a police officer who takes possession of the records and provides the dentist with a receipt for them.

In 1990, pursuant to the Australian Federal Privacy Act[7] and South Australian Local Government Act[8], the South Australian Dental Service (SADS) adopted a policy to preserve the confidentiality of dental records held in school dental clinics. Under this policy, all school dental clinic staff were forbidden to release dental records to any person without the specific

personal authority of the Chief Executive Officer of SADS, who would arrange for collection and release of records to the Forensic Odontology Unit (directed by the Coroner to undertake the identification of the deceased). A case in the files of the Forensic Odontology Unit, The University of Adelaide, demonstrates how serious issues may arise by failure to observe a similar protocol.

CASE HISTORY

A missing child, believed drowned in the River Murray, was reported to local police. The child's father, on the advice of a police officer, sought the child's dental records from the local School Dental Clinic. These were refused in accordance with departmental policy, and the Chief Executive Officer was informed. Subsequently the child's body was located in the river. In due course, the Coroner's Office issued an order for confirmation of the identification of the child by means of dental comparison to be undertaken by the Forensic Odontology Unit. The school dental clinic records essential for this procedure were promptly obtained by the CEO who reported that the Senior Dental Officer at the school clinic had recorded a note that his examination had revealed injuries consistent with a pattern of child abuse. This information was then reported to the Coroner's Officer and an alarm was raised with the police officer who had previously investigated evidence of the abuse of a sibling by the child's father.

CONCLUSION

It is sobering to reflect that if staff at the School Dental Clinic had acceded to the request of the child's father and surrendered the records to him, the father could have been alerted by the note about the abuse implicating him, and destroyed the records, thus seriously frustrating the identification. This case illustrates the importance of carefully considering the possible consequences of deviating from established protocols for the collection of records, and it also indicates the importance of ensuring that all police officers are adequately educated about procedures to be followed for their collection.

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The International Association of Craniofacial Identification

13th Biennial Scientific Meeting

Dear Colleague, please accept this invitation to attend the 13th Biennial Meeting of the International Association of Craniofacial Identification (IACI), from July 14-18, 2008, hosted by the University of Dundee, Scotland.

IACI was founded in 1992 in order to bring together in an international setting all those involved in research and practical applications in the field of cranio-facial identification. The University of Dundee, Centre of Anatomy and Human Identification, is honoured to be organizing and hosting this congress.

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I would like to take this opportunity to thank the members of the Scientific Committee, of the Organizing Committee and all those who are contributing, with their dedicated work, to the success of the meeting.

I look forward to welcoming you in Dundee next July.

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