

THE STABILITY OF LIP PATTERN CHARACTERISTICS OVER TIME

R.C. Coward

Private Dental Practitioner, UK

ABSTRACT

This paper studied the lip prints of 85 subjects over a seven-month period. The patterns of the vermillion 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.

(*J Forensic Odontostomatol* 2007;25:40-56)

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 Tsuchihashi² documented three cases in which they used lip prints to further criminal investigations. Thomas and Van Wyk³ identified human remains by matching the rugae pattern of his palate with that imprinted in his spare upper denture. Kasprzak⁴ used lip prints to identify and subsequently convict numerous criminals in Poland. Kennedy⁵ 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 scientifically⁷, 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 Snyder⁸ and by Santos in 1962.⁹ In 1970 Suzuki and Tsuchihashi² 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. Tsuchihashi¹⁰ expanded the database to include 1364 individuals and, as in 1970, determined that no two patterns were identical. Both papers of Suzuki and Tsuchihashi² and Tsuchihashi¹⁰ 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 downfall 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.

Tsuchihashi¹⁰ 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 Tsuchihashi² and Tsuchihashi¹⁰ 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 Kasprzak⁴ 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. Tsuchihashi¹⁰ 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 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 Tsuchihashi² 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 sagittal 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

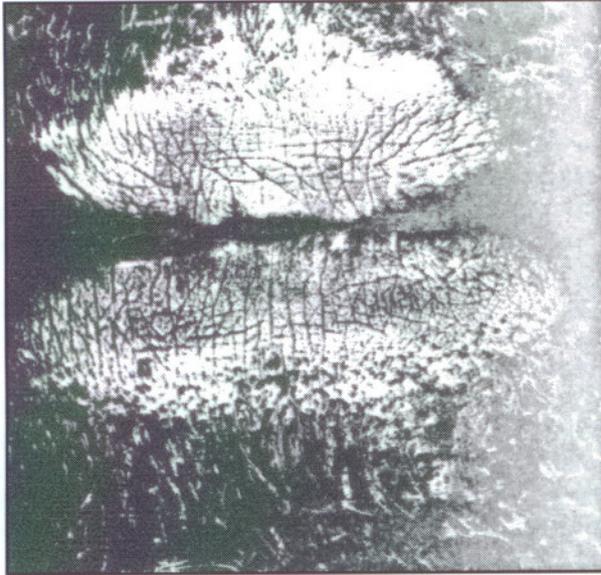


Fig.1: These lips are narrow in width, especially the upper, but full in height. The overall shape is ovoid and lacking in features. Facial hair is prominent.

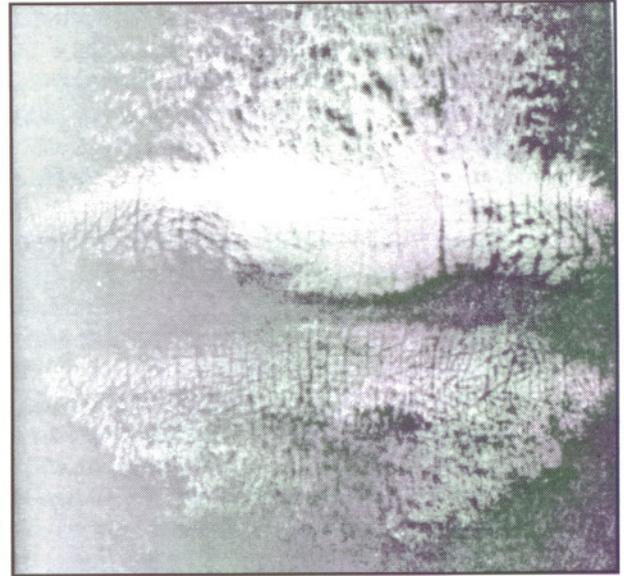


Fig.2: These lips are noticeably wider in comparison to Fig.1. However, they are thinner in absolute terms and relative to their width.



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

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

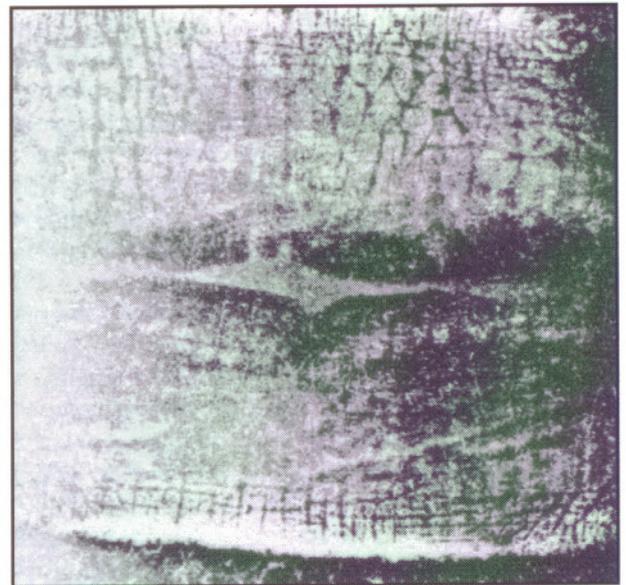


Fig.3b: These prints are of such a large size exceeding the dimension of the slide, that the prominence is in no doubt

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. Burstone¹³ 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

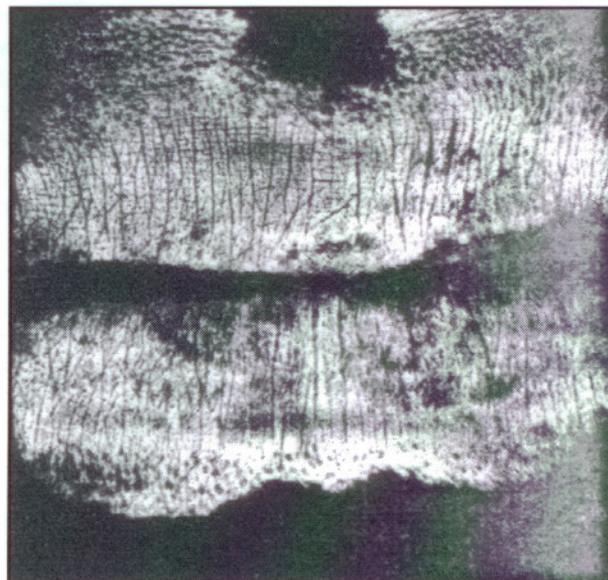


Fig.4b: A markedly deeper fossa which lacks obvious vertical ridges and appears distinct from the upper border of the lip

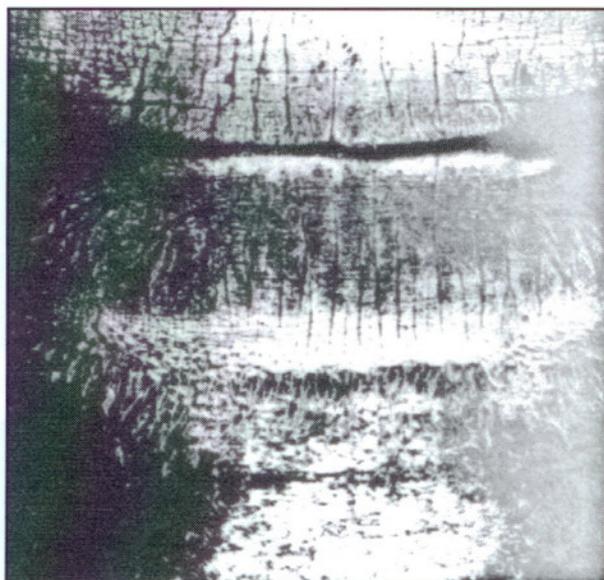


Fig.5: Notice female facial hair pattern - lower lip

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 Tsuchihashi² 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.

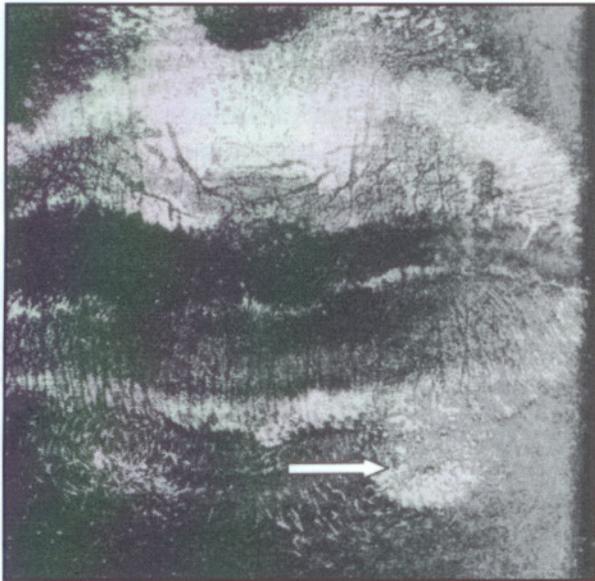


Fig. 6a: Mole on lower lip

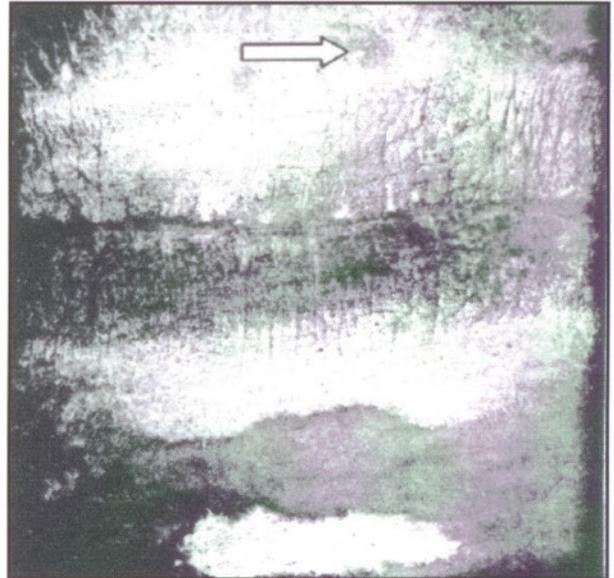


Fig. 6b: Transient lesions on upper lip



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

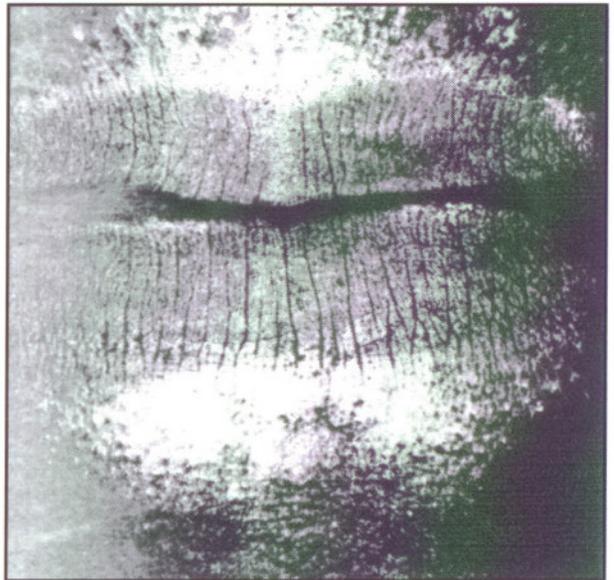


Fig. 7b: Linear pattern on both lips

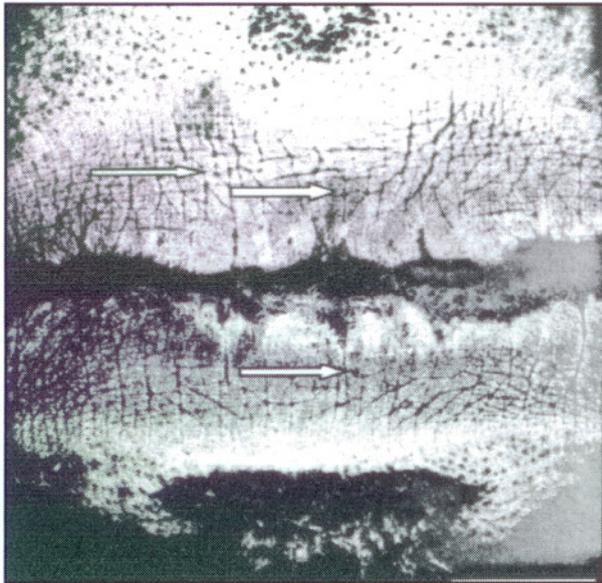


Fig.8a: An image showing predominated by "star" details. The shape of the sub-labial region is also distinctive

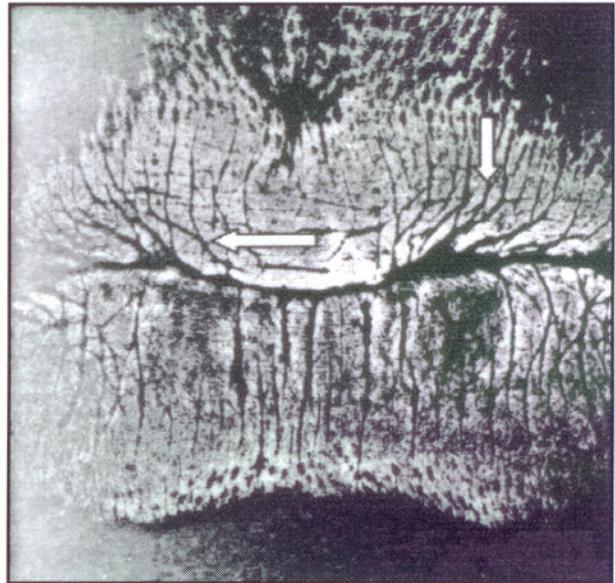


Fig.8b: The upper lip shows a heavy concentration of "Y" details. The lower has numerous "Parallel lines"

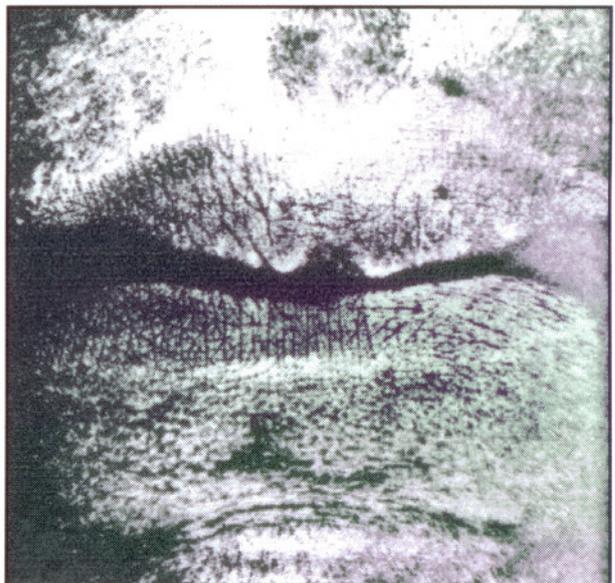


Fig.9: Two images showing conformity of contact pattern over the several months

- 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

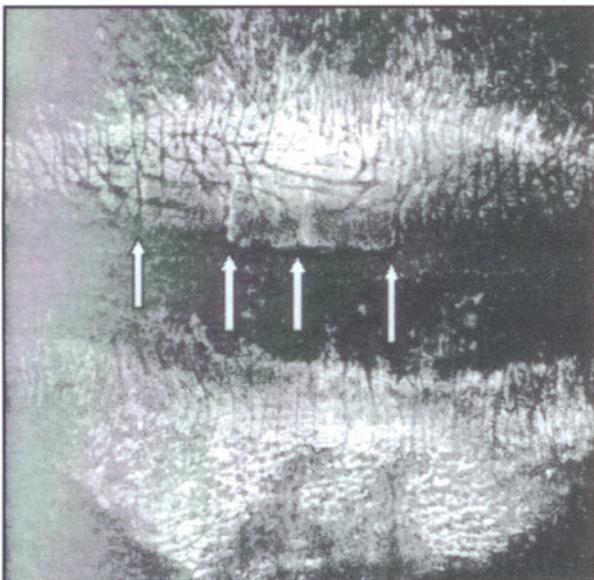


Fig. 11: Notches in lower border of upper lip

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 (Murdock¹⁷), lip prints (Kasprzak⁴ and Hirth *et al.*^{12,13}), and many fingerprinting departments¹⁸ 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. It 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 popⁿ 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

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

Month	25 th percentile	Mean	75 th 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 Popⁿ

% 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 Popⁿ matching per month

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

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 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 Popⁿ, 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 were 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-Schneider¹¹ 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,
- 29.4% of subjects showed one print with a region of altered contact.
 - 37.6% showed multiple prints
 - 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:

- 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 were 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	%	*variable subjects	%
always continuous	16.8	distinct/continuous	7.2
always distinct	8.4	absent/continuous	25.3
always absent	18.0	absent/distinct	15.6
variable*	56.6	all types	8.4

*Variable subjects subdivided according to combination of images

Table 14: Reliability of philtrum print

philtrum reliability	%	*exclusion of vague images	%
always visible	30.5	always visible	44.8
always absent	1.2	always absent	6.9
always vague	0.0	variable	48.3
variable*	68.2		

*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 recategorised.

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

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 vermillion 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.

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

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 C II. 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 C I, 40% for C II and 10% for C III.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 C I and only 4% C II.

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 C I, C II and C III 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:

- 90% of female subjects showed visible facial hair, which was extremely consistent over successive prints.
- 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 five 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 Tsuchihashi², Tsuchihashi¹⁰ and Endris and Poetsch-Schneider¹¹. 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 its 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-Schneider¹¹. 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 retrace 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.

ACKNOWLEDGEMENTS

The author wishes to extend his gratitude for the help provided by Professor David Whittaker and staff at The University of Wales College of Medicine.

REFERENCES

1. R v Leon Mayhew (1998) EWCA Crim 702.
2. Suzuki K, Tsuchihashi Y. New attempt of personal identification by means of lip print. *Ind Dent J* 1970;1:8-9.
3. Thomas CJ, van Wyk CW. The palatal rugae in an identification. *J Forensic Odonto-Stomatology* 1988; 6: 21-7.
4. Kasprzak J. Possibilities of cheiloscopy. *Forensic Sci Int* 1990;46:145-51.
5. Kennedy RB. Uniqueness of bare feet and its use as a possible means of identification. *Forensic Sci Int* 1996;82:81-7.
6. Henry E, Fingerprint Branch, Scotland Yard 1901. www.homeoffice.gov.
7. Standish M, Campbell H, Rhine S. Special techniques in outline of forensic dentistry. Eds: Cottone J, Standish M. UMI;1981:135.
8. Snyder Le M. Homicide investigations. Thomas, Springfield, Ill.1950:65.
9. Santos, Queiloscopy. A supplementary stomatological means of identification. *Int Microform J Legal Medicine* 1967.
10. Tsuchihashi Y. Studies on personal identification by means of lip prints. *Forensic Sci Int* 1974;3:233-48.
11. Endris R, Poetsch-Schneider L. Value of lip lines and nail striations for identification. *Arch Krim* 1985;175:13-20.
12. Hirth L, Gottsche H, Goedde HW. Variability and genetics of lip grooves. *Z Morph Anth* 1974;65:362-6.
13. Hirth L, Gottsche H, Goedde HW. Lip prints-variability and genetics. *Humangenetik* 1975;30:47-62.
14. Burstone CJ. The integumental profile. *Am J Orthodontics* 1958;44:1-25.
15. Weinstein S, Drew EJ, Tin Pau Ho, Bowley W. A comparison of physical properties of lips among white and black adults. *Israel J Dental Science* 1988;2:51-61.
16. Rawson RD, Ommen RK, Kinard G, Johnson J, Yfantis A. Statistical evidence for the individuality of the human dentition. *J Forensic Sci* 1984;29:245-53.
17. Murdock JE. Development of empirical testing of numerical criteria for the identification of striated toolmarks. *Forensic Science Communications* 1999: "Presentations to Int. Symp. on setting quality standards for forensic science."
18. Processing of fingerprint evidence after introduction of NAFIS. 2004:www.homeoffice.gov.uk

Address for correspondence:

Dr RC Coward
106 Sandringham Way
Frimley
Surrey GU16 9YF
UK
Email: exodus@fsmail.net