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ORIGINAL ARTICLE

A study of distribution, sex differences and stability of lip print patterns in an Indian population

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Abstract Lip prints are very useful in forensic investigations. The objective of this study is to determine predominant lip print pattern found among a central Indian population, to evaluate whether any sex difference exists and to study the permanence of the pattern over a 6 month duration. This study included 200 healthy adult subjects comprising of 100 males and 100 females in the age group of 18–25 years. A convenient and easier method of data collection i.e., digital photography was used instead of the traditional lipstick methods. Lip prints were then divided into four quadrants and recognized as per Suzuki and Tsuchihashi's classification.

Type I (30.63%) was found to be most predominant overall in the Marathi population. Type I (29.75%) and Type III (35.75%) were found most prevalent in males and females respectively. Applying the Chi-Square test, statistically significant differences ($p < 0.05$) were observed between male and female lip print patterns in each of the quadrants individually and all quadrants taken together. The lip print patterns remained stable over a period of six-months. Being stable and with significant sex differences, lip prints can be effectively used as an important tool in forensic investigations for individualization as well as identification of sex of the donor, thus, narrowing down the scope of investigation to almost half.

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1. Introduction

In various civil, criminal and mass disaster cases, positive identification of a person can be very difficult. Out of the many existing techniques implied for the purpose, comparison of fingerprints, DNA and dental records are probably the most common techniques used in this context. However, 'human lip recognition' also known as cheiloscopy, is one of the most interesting emerging fields which find its roots in criminal and forensic practices (Caldas et al., 2007; Sharma et al., 2009; Reddy and Reddy, 2011). Previous studies have shown to establish the fact that lip prints can positively distinguish individuals and hence have potential use in human identification

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(Venkatesh and David, 2011; Prabhu et al., 2012, 2013; Dwivedi et al., 2013).

The term "Cheiloscopy" is derived from the Greek words *cheilos* meaning 'lips' and *e skopein* meaning 'to see' and is defined as the study of the characteristic patterns of the wrinkles and grooves present on the labial mucosa (sulci laborium), called as lip prints (Sivapathasundharam et al., 2001; Molano et al., 2002; Rajendran and Sivapathasundharam, 2006; Shafer et al., 2009). R. Fischer was among the first to take notice of the biological phenomenon of systems of furrows on the red part of human lips in the year 1902 (Thomas and Van Wyk, 1988; Kasprzak, 1990, 2000). Use of lip prints in personal identification and criminalization was first recommended in France by Edmond Locard as early as 1932 (Warren, 1976; Thomas and Van Wyk, 1988). Le Moyne Snyder was the first to introduce a case in which lip prints helped the crime investigators in an unusual way (Suzuki and Tsuchihashi, 1970a,b; Williams, 1991; Ball, 2002). Santos, Suzuki and Tsuchihashi were among the first to classify the various patterns present on the human lips (Suzuki and Tsuchihashi, 1970a,b; Tsuchihashi, 1974; Williams, 1991).

The importance of cheiloscopy is linked to the fact that the lip prints are unique to one person, except in monozygotic twins (Neville et al., 2002), like fingerprints and palatal rugae, the lip grooves are permanent throughout life (Tsuchihashi, 1974). It is possible to identify lip patterns as early as the 6th week of uterine life (Caldas et al., 2007; Koneru et al., 2013).

The oily and moist secretions from sebaceous and salivary glands located at the vermillion border and subsequent moisturization from the tongue enables the formation of a latent lip print whenever there is contact (Ball, 2002) and is likely to be encountered and should be suspected to be present on the scene of the crime of burglary, sexual assault, house tress-pass, homicide, rape, etc. Depending upon the scenario of/at the crime scene, lip prints may be found on various physical evidences at the crime scene, such as shirt, handkerchief, tissue paper/wipes, cups, photographs, letters, glass, window panes, cutlery, fruit skin/peel, cigarette butts, clothing, and even biological materials such as skin (Kavitha et al., 2009; Vats et al., 2012).

Lip prints are very useful in forensic investigations and are considered to be important forms of transfer evidence, and are analogous to fingerprints (Tsuchihashi, 1974). Apart from identification and evidential use, lip prints may also be used in detection work, being the source of tactical and criminalistic information. Being unknowingly left at the scene of the crime, lip prints can directly and effectively be helpful in placing the suspect on the scene (Satyanarayana et al., 2011). A lip print at the scene of crime can be a basis for conclusions as to the character of the event, the number of the people involved, sexes, cosmetics used, habits, occupational traits, and the pathological changes of lips themselves (Vahanwala and Parekh, 2000). If a complete match or identification is not possible, proper examination of lip prints may help in establishing other relative facts like sex identification of the donor, hence reducing the burden of the forensic examiner to half.

The objective of this study is to determine predominant lip print pattern found among a central Indian population, to evaluate whether any sex difference exists and to study the permanence of the same over a 6 month duration.

2. Methodology

2.1. Sample

The study comprised of 200 healthy individuals (100 males and 100 females), in the age group of 18–25 years and belonged to Marathi population of the Nagpur region of the Maharashtra state, India. Informed consent was obtained from all the subjects.

2.2. Inclusion criteria

Only healthy subjects, free from any oral pathologies, inflammation, abnormalities or deformities such as cleft lip, cut marks, surgical scars or lesions of the lip were included in the study.

2.3. Recording the lip prints

Recording of the data is an extremely important step for the success of this study; still digital photography was used, as the mobile nature of the human lips can affect the accuracy of the lip print impressions even with slight variations in the strength or the direction of the pressure applied (Tsuchihashi, 1974). The subjects were made to stand erect with the head positioned in Frankfurt plane. From a fixed distance, lips of volunteers in 'natural condition' (without the application of lipstick, lip fillers, lip gloss or any other cosmetic product) were photographed twice using a digital camera (Nikon D3100-14.2 MP-AF-S NIKKOR 18–55 mm lens kit). This method is relatively easier and involved nil physical contact with the volunteers in terms of application of lip gloss or lipstick as previously used and suggested by others, which can be quite laborious and unhygienic (if the same lipstick is used for all the subjects).

2.4. Classification used

In this study, we followed (Fig. 1) the classification of patterns of the lines on the lips proposed by Suzuki and Tsuchihashi (Suzuki and Tsuchihashi, 1971; Tsuchihashi, 1974).

- Type I: Long vertical (Clear-cut vertical grooves that run across the lips).
- Type I′: Short vertical (Partial length groove of type I).
- Type II: Branched grooves (Branching Y-shaped pattern).
- Type III: Intersected grooves (Criss-cross/'x' pattern grooves).
- Type IV: Reticular pattern (Grooves that forms rectangular shape).
- Type V: Mixed/Indefinite (Grooves that do not fall into any of the above categories, combination of two or more patterns and/or cannot be differentiated morphologically/undetermined).

2.5. Examination of the prints

After transferring the photographs of the lips on a computer, lip prints (Fig. 2) were divided into four quadrants namely

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Lip Print	Type
	Type I Long Vertical
	Type I' Short Vertical
	Type II Branched
	Type III Intersecting
	Type IV Reticulate
	Type V Indefinite/Mixed

Figure 1 Photographs showing all the patterns of the lip prints followed/observed in this study.

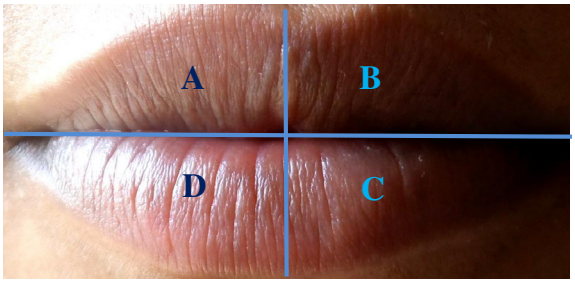

Figure 2 Lip print divided clockwise in four quadrants namely A, B, C and D.

A, B, C, D moving clockwise, starting from the left side of the upper lip to the left side of the lower lip. Quadrants were manually classified twice by both authors independently, so as to assess the inter- and intra-rater reliability of the observations.

The same criteria of inclusion and exclusion; procedure for recording the prints; classification and same method of examination were repeated for the same individuals after 6 months. The older photographs were compared with the recent ones by the same observers.

2.6. Statistical analysis

The obtained results were statistically analyzed using the Chi-Square test, wherein a value of $p < 0.05$ was considered as significant. Kappa (K) value was also calculated to check the inter-observer and intra-observer agreement strength.

3. Result and discussion

The division of lip prints into four quadrants was in accordance to Tsuchihashi (1974), Gondivkar et al. (2009), Saraswathi et al. (2009), ElDomiaty et al. (2010), Satyanarayana et al. (2011), Gupta et al. (2011), Venkatesh and David (2011), Prabhu et al. (2012), Koneru et al. (2013) and Prabhu et al. (2013).

In the present study, overall, Type I (long vertical) was the most frequently observed pattern (Table 1) in the examined subjects of the Marathi population of the Nagpur region of the Maharashtra state in India. The result is in accordance to results of the studies conducted by Koneru et al. (2013) on Kerala and Manipur population and by Vahanwala and Parekh (2000) on the Mumbai population, who also found the Type I pattern to be most predominant, while Type I′ was observed to be the least common type.

Type I (long vertical) and Type III (intersecting) lip print patterns were found to be most commonly found in males and females respectively. In male lip prints, the order of appearance of patterns were Type I > Type V > Type II > Type III > Type IV > Type I′ (least common). In female lip prints, the order of appearance of patterns were Type III > Type I > Type II > Type IV > Type V > Type I′ (least common) shown in Table 2 and Fig. 3.

Quadrant wise distributions of lip print patterns are shown in Table 3. Some interesting points to be noted as they appear here are that the upper lips of males and females have about the same frequency of Type V prints, while the lower lips are vastly different (66 Type V lower lip patterns in males; 2 in females). Thus, the difference in the frequency of Type V between males and females is coming almost entirely from the lower lip, and is a much stronger sex difference than found when combining upper and lower lip frequencies. Other upper/lower lip differences are seen in Type II patterns (no sex differences here), and type I and type IV, females only.

Table 1 Percentage distribution of lip patterns in the Marathi population.

Lip pattern types	All quadrants (A + B + C + D) Percentage
Long vertical (Type I)	30.63%
Short vertical (Type I′)	1.88%
Branched (Type II)	16.50%
Intersecting (Type III)	25.38%
Reticulate (Type IV)	8.63%
Mixed/Indefinite (Type V)	17%
Total	100

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Table 2 Distribution of patterns among male and females.

Pattern	Distribution of patterns			
	Male		Female	
	n	%	*n*	%
Long vertical (Type I)	119	29.75	126	31.50
Short vertical (Type I′)	14	3.5	1	0.25
Branched (Type II)	75	18.75	57	14.25
Intersecting (Type III)	62	15.5	141	35.75
Reticulate (Type IV)	27	6.75	42	10.5
Mixed/Indefinite (Type V)	103	25.75	33	8.25
Total	400	100	400	100

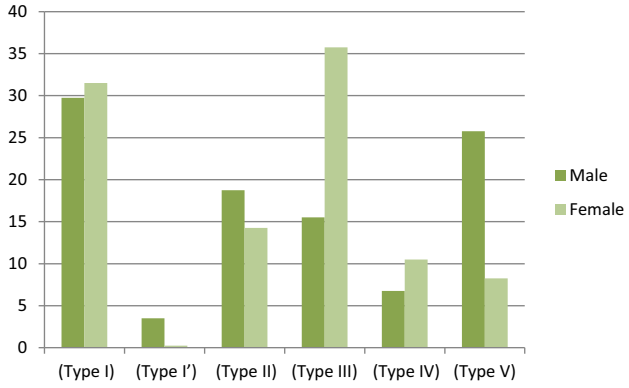

Figure 3 Percentage distribution of lip print patterns in the studied group.

Statistical analysis, applying the Chi-Square test, shows significant difference ($p < 0.05$) between lip print patterns in males and females in all quadrants individually as well as combined (Table 4). The result is in accordance with the results obtained by Kumar et al. (2012) in the Pondicherry population, Vats et al. (2012), Dwivedi et al. (2013) and Koneru et al. (2013) in Kerala and Manipuri populations, but is in contrast to the results obtained by Sivapathasundharam et al. (2001), Saraswathi et al. (2009), Sandhu et al. (2012), Prabhu et al. (2013) and Verghese et al. (2010) who did not find any statistically significant differences.

Statistically insignificant ($p > 0.05$) inter-observer and intra-observer variability was observed in assessing the morphologic pattern of the lips in all the four quadrants by both authors. The calculated Kappa (K) values showed that the strength of agreement between both the observers was 'good' to 'very good'.

Considered an environmental factor, peeling off the superficial layers of the skin of the lips was not seen in the present study, which is in contrast to the study by ElDomiaty et al. (2010) who observed it as a common feature of the lips in their study and explained it as a probable result of the dry weather in the study area, which dried the lips and made the people accustomed to bite away the dried skin. However, they also noted that, this did not mask the pattern of the lip print as it appeared after taking the print many times. This phenomenon could help a great deal in identification of subjects as the lip pattern does not change due to differences in climate or any illness present around the mouth (Tsuchihashi, 1974).

No two lip prints showed the exactly same pattern in our study, which is in accordance to the detailed study by Tsuchihashi (1974) on 1364 Japanese subjects (757 males and 607 females) where no lip print showed the same pattern in

Table 3 Quadrant wise distribution of patterns in lip prints of males and females.

Pattern type	Male				Female			
	A	B	C	D	A	B	C	D
Long vertical (Type I)	20	23	43	33	12	15	49	50
Short vertical (Type I′)	5	4	2	3	0	0	0	1
Branched (Type II)	34	34	2	5	28	25	2	2
Intersecting (Type III)	12	16	15	19	27	28	45	41
Reticulate (Type IV)	9	6	8	4	18	16	3	5
Mixed/Indefinite (Type V)	20	17	30	36	15	16	1	1
Total	100	100	100	100	100	100	100	100

A, B, C, D = Quadrant.

Table 4 Statistical analysis result (applying the Chi-Square test).

Statistical analysis Lip print patterns: males Vs females					
	Quadrant A*	Quadrant B*	Quadrant C*	Quadrant D*	All quadrants*
χ^2	17.1	14.9	46.8	47.1	84.0
df	5	5	5	5	5
Probability	0.004	0.011	0.000	0.000	0.000

χ^2 = Value of Chi-Square, df = Degree of freedom.
* Significant at $p < 0.05$.

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the investigation. He also observed that although the lip print patterns of the uniovular twins are in duplicate, in detail no two of them were exactly identical.

The lip prints of the studied individuals in our study remained unchanged even after 6 months, which is practically useful in a criminal search where the unchanged pattern even for short period (6 month) would be helpful (Tsuchihashi, 1974). These findings are in accordance with the results of (Tsuchihashi, 1974) who studied the lip prints of the same individuals every month for three years to see whether the lip prints are permanent or not. None showed any change throughout this period. Similar results in terms of permanence were demonstrated in a very recent study by ElDomiaty et al., 2014 who investigated the stability of lip-print patterns in, Saudi females, over time to validate their secure use in civil and criminal investigations by analyzing and comparing the prints of the same subjects taken 3 years earlier. They also urged the need for similar studies on a larger sample size of both sexes to confirm the rate of stable lip-print patterns and to investigate the sex differences, so as to validate lip prints as a powerful forensic tool.

4. Conclusion

The study revealed that lip print Type I (30.63%) and Type I′ (1.88%) were the most and least predominant (respectively) among the Marathi population of the Nagpur region of the Maharashtra state in India. In males Type I (29.75%) and in females Type III (35.75%) were found to be most prevalent and Type I′ least seen in both sexes. The statistically significant difference ($p < 0.05$) obtained in all the quadrants individually and taken together suggests the potential of usage in sex discrimination. The lip print patterns were also found to be stable over a period of 6 months. Further studies on similar grounds considering different populations should be done in order to create a comprehensive database so that the hidden potential of lip prints as an important source of information can be utilized optimally.

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