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Lip print evaluation of Indian and Malaysian-Chinese subjects by manual and digital methods: a correlational study with gender and ethnicity

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Abstract

Background: Cheiloscopy is a reliable method of personal identification which may augment the established methods like dactylography, DNA (deoxyribonucleic acid) profiling, and dental records.

Aim: This study aimed to determine the correlation of lip prints with ethnicity and gender of individuals in an attempt to bridge the gap between conventional manual methods and digital methods of cheiloscopy.

Methods: Lip prints of 300 gender-matched subjects of Indian and Malaysian-Chinese descents were collected and analyzed using the Suzuki K and Tsuchihashi Y classification system. The lip sizes were measured and lip print patterns were analyzed. The analysis was carried out using manual and computer-aided methods. A customized software for lip print analysis and validate it with the manual lip print analysis was developed.

Results: Independent sample *t* test showed a statistically significant difference between the width and length of the lips between males and females of the total population ($p < 0.001$). Pearson's chi-square test showed no statistically significant difference between the Indian males and females in the width of the lower lip ($p = 0.074$). In the Malaysian-Chinese population, there was a statistically significant difference between males and females in the length of the upper lip ($p = 0.032$) and lower lip ($p = 0.035$). The type V grooves were predominant in the total study population (51.3%) followed by type III pattern (38.7%). The new customized software could not provide reliable results.

Conclusions: Lip sizes differed significantly among the Indian and Malaysian-Chinese subjects. There was no significant gender dimorphism in the distribution of lip print patterns. The results from manual and computer-aided methods were comparable.

Keywords: Lips, Analysis, Forensic dentistry, Personal identification system, Sex determination analysis, Ethnic groups, Software tool

Background

Personal identification of an individual is of paramount importance in any forensic investigation. The process of human identification can be very challenging even though each individual possesses many unique and distinctive traits, anatomic or behavioral, which can prove helpful in individualizing. Identification of a deceased or a live person can be crucial due

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to social, legal, or forensic reasons. This can provide tangible proof of death, identification of criminal/victim, mass disasters, and cases of identity fraud (Rao, 2010).

The role of dental records and palatal rugoscopy has been widely discussed in the literature, and much attention is now being diverted to the evaluation of the role of lip prints in the distinctive identity of a victim or a criminal (Bansal et al., 2014; Sharma et al., 2018). Cheiloscopy, also known as queiloscopy, is defined as the study of the grooves or furrows present on the vermillion zone of human lips. These grooves and irregularities on the external lip are unique to an individual, as their pattern never undergoes permanent alteration. Although lip print identification and analysis can be performed more easily with visible lip prints produced by lipstick bearing lips, latent (invisible) lip prints can also serve as equally strong evidence. The greatest advantage is that the criminals are relatively unaware of their significance as trace evidence and overlook their presence at a crime scene thus failing to destroy them. Additionally, the lip prints may also provide an insight into the type of the event, the number and gender of people involved, and the pathological status of lips if any (Suzuki & Tsuchihashi, 1970; Rastogi & Parida, 2012; Tsuchihashi, 1974).

The last two decades have seen the publication of numerous studies evaluating the role of cheiloscopy in forensic identification. However, a literature review of the worldwide dynamics between the law and cheiloscopy reveals that there still exists a great degree of insufficiency in population and gender-specific data with regard to lip print patterns leading to several instances of rejection of cheiloscopy based evidence by the judiciary (Herrera & S, Serra M da C., 2013).

Manual analysis involves the visual analysis of the lip print patterns using a magnifying lens. This has been utilized by many studies, as compared to computer-aided analysis, but a large amount of subjectivity and errors may occur with the manual method. The advent of digital technology in assisting lip print analysis renders an easy and faster alternative providing reproducible results with a higher amount of objectivity. Very few studies to date have utilized this inter-professional approach for providing a more reliable analytical technique (Herrera & S, Serra M da C., 2013).

The present study is an attempt to determine the gender- and ethnicity-based dimorphism in the lip prints of Indian and Malaysian-Chinese descents. We also intended to bridge the gap between conventional, manual analytical methods and modern digital technologies in lip print evaluation.

Methods

This observational cross-sectional study was conducted in the Department of Oral Medicine and Radiology in collaboration with the Department of Computer Science and Engineering over a period of one and a half years. Approval from the Institutional Ethics Committee (IEC no: 588/2014) was obtained before the commencement of the study. The subject group comprised of students from Medical and Dental College. Written Informed consent was obtained from the subjects who were willing to participate in the study. Sample size calculation was performed using the G-power software.

In order to assess the ethnicity-based dimorphism in the lip prints, the study population was stratified under the following two groups:

- Group 1: 150 Indian subjects (75 males and 75 females)
- Group 2: 150 Malaysian-Chinese subjects (75 males and 75 females)

Students of Indian and Malaysian-Chinese descent (Malaysian citizens of Chinese ethnicity) who volunteered to participate in the study were included. The ethnic background of the study participants was confirmed by interviewing them. Subjects with any lip anomalies, known allergy to lipsticks, subjects with mixed ethnic origin, or any active lesions on the lips (herpes labialis, cheilitis, visible wounds/scabs) were excluded from the study.

Lip prints of both the upper lip and the lower lip were obtained with the lips being relaxed and slightly separated from each other. This procedure of lip print collection was similar to the method employed by Sivapathasundharam et al. (Sundharam et al., 2001). Recording of the lip prints was repeated if the quality of the lip print procured in the first attempt was unsatisfactory (due to movement of operator/subject, uneven distribution of lipstick, smudging of the print).

A dark shade color (Miss Claire^{R} Aqua rouge lipstick in shade no. 336) was chosen for clear visualization of the intricate lip groove patterns during manual lip print analysis. The lipstick application brushes were washed and thoroughly cleansed using detergent and were then sterilized in the UV sterilizer after every use. Also, the lipstick bullets were wiped with tissue paper after each use to prevent cross-contamination (Fig. 1).

The participants were required to record their names, gender, age, ethnicities in the lip print collection data sheet at the time of lip print recording. Lip print patterns of each subject were collected and stored in a designated folder and was handled by one of the co-investigators to ensure confidentiality and safe-keeping. They were

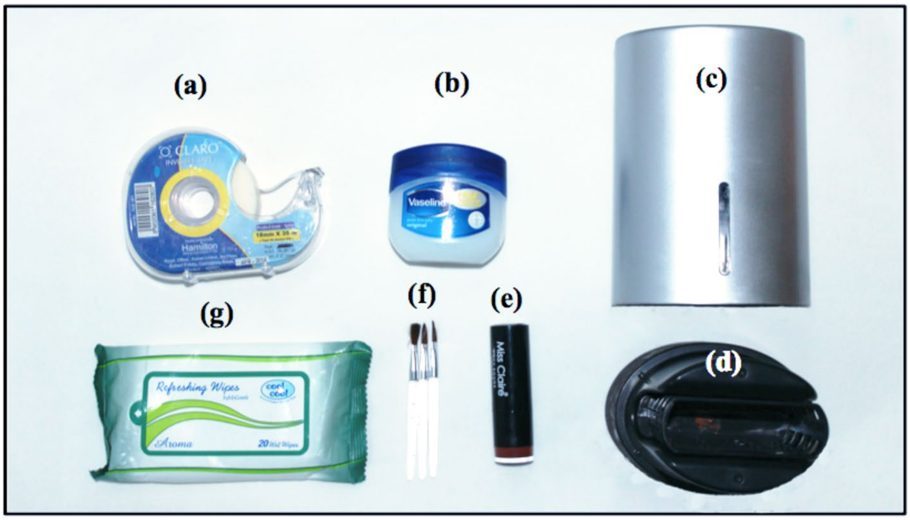


Fig. 1 Lip print acquisition kit—materials used in recording of lip prints: (**a**) cellophane-tape with cutter, (**b**) vaseline (**c**), (**d**) UV sterilizer, (**e**) lipstick [Miss Claire[R] Aqua Rouge Lipstick in shade no. 336] (**f**) lipstick application brushes, and (**g**) wet tissues

randomly assigned subject codes, and their name, ethnicity, and gender were not disclosed to the principal investigator to facilitate anonymization. The method of lip print collection is depicted in Fig. 2.

Digitization of lip prints

The acquired lip prints were also scanned at a resolution of 400 PPI (Pixels per inch) and digitized. The digitized lip prints were saved as JPEG files and assigned names according to their subject codes. Digitization provided furthermore permanency to these records.

Method of analysis of lip prints

The lip prints were divided into six equal portions, namely P1–P6 (Fig. 3). The same method has also been advocated by Sivapathasundharam et al.(Sundharam et al., 2001).

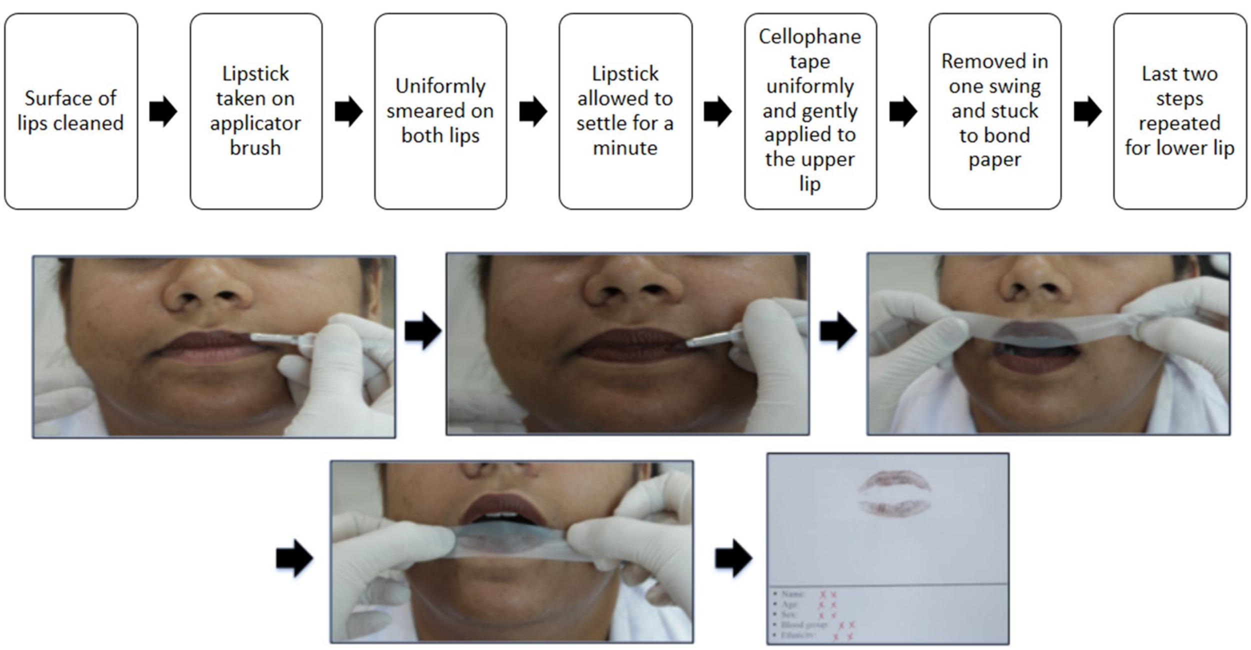


Fig. 2 Figure depicting steps in acquisition of lip prints from the study subjects

Fig. 3 Division of upper and lower lip prints in six equal portions for manual analysis (P1: upper right portion, P2: upper middle portion, P3: upper left portion, P4: lower left portion, P5: lower middle portion, P6: lower right portion) and depiction of measurement of lip size

Lip prints were then analyzed for grove patterns using the following methods:

- Method A: Manual analysis of acquired lip prints
- Method B: Manual analysis of digitized lip prints

They were classified according to the Suzuki K and Tsuchihashi Y (Suzuki & Tsuchihashi, 1970) system, which is the most widely employed (Fig. 4). Only those lines that bifurcated once in the shape of a "Y" were considered as type II, whereas lines showing trifurcation and multiple branching appearance were considered as type V. Lines showing multiple interconnections and those difficult to categorize as types I–IV were directly categorized as type V.

Method A: Manual analysis of acquired lip prints

Firstly, using a measuring scale, the length of both lips was measured between the outermost visible points on the lip print at the angle of the mouth. Then, the thickness of both lips was measured in the midline. Finally, all six portions were observed using a magnifying glass for the most common grooves present in them. In case more than one type of groove was observed in some portions of the lips, the most commonly occurring type was considered, and in case of equal distribution, both the types were recorded.

Method B: Manual analysis of digitized lip prints

In this method, the digitized lip print images were inverted into gray-scale using the GIMP (GNU Image Manipulation Program) software (Fig. 5). The image sizes were adjusted (magnified) to facilitate ease of analysis, according to the observer's requirements. Each portion was then analyzed by the principal investigator for the most commonly occurring pattern, in a manner similar to method A.

Intra- and inter-observer agreement

For intra- and inter-observer agreement analysis, the manual method was used. Ten percent of the collected

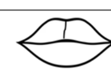
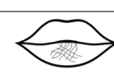
Type of Groove	Name	Illustration
I	Complete vertical grooves	
I'	Partial thickness vertical grooves	
II	Branched or forked grooves	
III	Intersected grooves	
IV	Reticular grooves	
V	Miscellaneous grooves	

Fig. 4 Schematic diagram of lip print pattern

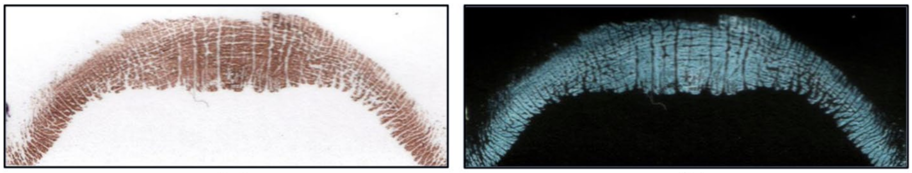


Fig. 5 (**a**) Digitized lip print. (**b**) Digitized lip print inverted into gray-scale

lip prints (30 lip print samples) were manually analyzed again by the principal investigator after 2 weeks of the first session of analysis. Also, the same 30 lip print samples were further analyzed by a second examiner, trained in the lip print analysis.

Development of customized computer software for lip print analysis

A customized software was developed with the technical expertise from the Department of Computer Science and Engineering using the data programming language MATLAB (Matrix Laboratory). This software utilized the Suzuki K and Tsuchihashi Y classification system of the grooves to analyze the lip print patterns. This product was developed as an attempt towards simplifying and objectifying an otherwise tedious process of manual analysis of lip prints. It aimed at matching/superseding manual analysis in its efficiency, with added advantages of speed and objectivity.

When the digitized lip print was imported into this software, it yielded the most common pattern in the upper lip, the lower lip, and both lips combined. The results from this method were compared with those obtained from the manual methods of analysis, the latter serving as the gold standard, in an effort to validate the use of the software.

Statistical analysis

Data entry was done using a Microsoft Excel spreadsheet and analysis carried out using SPSS version 18.0. A p-value of 0.05 or less was considered statistically significant. A comparison of mean values of lip lengths and widths with ethnicity and gender was done using the independent sample t test. Also, multiple logistic regressions were performed to formulate an equation in order to predict ethnicity and gender from the significant lip length and width values. Correlation of the lip print patterns with ethnicity and gender was done using Fisher's exact test and with intra-group gender using Pearson's chi-square test. The efficacy of both manual and computerized methods was compared using the kappa coefficient. Also, kappa co-efficient for inter- and intra-observer agreement was calculated.

Results

There were 300 gender-matched students of Indian and Malaysian-Chinese descents who participated in the study. The age range of the subjects was 17 to 32 years. The distribution of the lip prints into various types observed in this study population is depicted in Table 1.

Lip size and gender

The length and width of the lips differed significantly among the male and female subjects among the overall population. There were no significant differences in the lengths and widths of the upper and lower lips among the Indian males and females, with the sole exception being the width of the lower lip, which was significantly greater in the Indian males than the females ($p = 0.074$). Among the Malaysian-Chinese males and females, a statistically

Table 1 Distribution of lip grooves in various parts of lips in total population

Part of lips	Lip groove types (Suzuki and Tsuchihashi) *n* (%)						
	I	I'	II	III	IV	V	Mix[a]
P1	0 (0.0)	6 (2)	4 (1.3)	147 (49)	14 (4.7)	129 (43)	0 (0.0)
P2	1 (0.3)	2 (0.7)	1 (0.3)	110 (36.7)	42 (14)	143 (47.7)	1 (0.3)
P3	1 (0.3)	5 (1.7)	0 (0.0)	163 (54.3)	19 (6.3)	112 (37.3)	0 (0.0)
P4	0 (0.0)	1 (0.3)	0 (0.0)	125 (41.7)	0 (0.0)	172 (57.3)	2 (0.7)
P5	0 0.0)	0 (0.0)	0 (0.0)	51 (17)	15 (5)	232 (77.3)	2 (0.6)
P6	0 (0.0)	1 (0.3)	1 (0.3)	106 (35.3)	0 (0.0)	191 (63.7)	1 (0.3)
Total	0 (0.0)	0 (0.0)	1 (0.3)	116 (38.7)	6 (2)	154 (51.3)	23 (7.6)

[a] Combination of more than one type of groove

Table 2 Gender-based variation in mean sizes of the lips among the study population ($n = 300$; Indian: 75 males and 75 females, Malaysian-Chinese: 75 males and 75 females)

Group						
	Length—upper lip		*p*-value*	Length—lower lip		*p*-value*
	Mean	SD		Mean	SD	
Indian male	5.28	0.51	0.167	5.63	0.67	0.167
Indian female	4.96	0.43		5.26	0.49	
	Width—upper lip		*p*-value*	Width—lower lip		*p*-value*
	Mean	SD		Mean	SD	
Indian male	0.98	0.17	0.2	1.13	0.18	0.074
Indian female	0.89	0.14		0.99	0.15	
	Length—upper lip		*p*-value*	Length—lower lip		*p*-value*
	Mean	SD		Mean	SD	
Malaysian-Chinese male	5.52	0.52	0.032	5.67	0.57	0.035
Malaysian-Chinese female	5.08	0.41		5.16	0.42	
	Width—upper lip		*p*-value*	Width—lower lip		*p*-value*
	Mean	SD		Mean	SD	
Malaysian-Chinese male	1.15	0.19	0.320	1.30	0.20	0.743
Malaysian-Chinese female	1.08	0.16		1.16	0.18	
Gender						
	Length—upper lip		*p*–value*	Length—lower lip		*p*-value*
	Mean	SD		Mean	SD	
Male	5.40	0.53	< 0.001	5.66	0.63	< 0.001
Female	5.03	0.43		5.21	0.46	
	Width—upper lip		p-value*	Width—lower lip		p-value*
	Mean	SD		Mean	SD	
Male	1.07	0.20	< 0.001	1.22	0.21	< 0.001
Female	0.99	0.18		1.08	0.19	

*Independent sample *t* test; $p \leq 0.05$ is considered significant

significant difference was noted in the length of the lips. The same, however, was not true in the case of their widths (Table 2).

Lip size and ethnicity

Only the length of the upper lip differed significantly among Indian and Malaysian-Chinese subjects. The width of both lips differed significantly among the Indian and Malaysian-Chinese subjects. The length and width of the lips differed significantly among the male and female subjects among the overall study population. There were no significant differences in the lengths and widths of the upper and lower lips among the Indian males and females (Tables 2 and 3).

Multiple logistic regressions for ethnicity and gender determination using lip measurements

A statistically significant difference was observed among the lengths and widths of both the upper and lower lips in the different genders and ethnic groups (except the

Table 3 Mean sizes of the lips among the Indian and Malaysian-Chinese population

Race	Length—upper lip		*p*-value*	Length—lower lip		*p*-value*
	Mean	SD		Mean	SD	
Indian	5.12	0.50	0.002 SIG	5.45	0.62	0.668 NS
Malaysian-Chinese	5.31	0.52		5.42	0.56	
Race	Width—upper lip		*p*-value*	Width—lower lip		*p*-value*
	Mean	SD		Mean	SD	
Indian	0.94	0.17	< 0.001 SIG	1.06	0.19	< 0.001 SIG
Malaysian-Chinese	1.12	0.18		1.23	0.21	

*Independent sample *t* test

Table 4 List of previous cheiloscopic research comparing the patterns among Indian and Malaysian-Chinese populations

S. no	Authors	Year	Country	Population studied	Age range	Sample size and gender	Way of lip print evaluation
1.	Neo et al.	2012	Malaysia	Indian, Malay and Malaysian-Chinese	20-26	134: I—5m/5f, MC—18m/18f, M—44m/44f	–
2.	Rao B et al.	2014	India	Indians, Malay and Malaysian-Chinese	18–23	183: I—30m/31f, C—29m/32f, 32m/31f	Mid portion of the lower lip
3.	Present study	2021	India	Indian and Malaysian-Chinese	18–23	300: I-75m/75f	In quadrants

I Indian, *M* Malaysians, *MC* Malaysian-Chinese, *m* male, *f* female

length of the lower lip and ethnicity, where there was no statistically significant correlation). Multiple logistic regression was performed to predict gender and ethnicity using the significant lip length and width values, which yielded the following equations:

- Ethnicity: $-9.922 + LU(0.3) + WU(4.861) + WL(2.953)$
- Gender (total population): $14.07 + LU(-0.706) + LL(-1.143) + WU(-0.408) + WL(-3.327)$
- Gender (Indians): $11.125 + WL(-5.464)$
- Gender of (Malaysian-Chinese): $17.33 + LL(-1.188) + LU(-1.229)$

(LU, length of the upper lip; LL, length of the lower lip; WU, width of the upper lip; WL, width of the lower lip)

The cut off value being 0.5, where any result greater than 0.5 suggested that the lip print belonged to a Malaysian-Chinese /Indian female and a value less than 0.5 suggested that the lip print belonged to an Indian/Malaysian-Chinese male.

Intra- and inter-observer agreement for manual lip print analysis

Ten percent of the collected lip prints were analyzed again by the principal investigator, 2 weeks after the first session of analysis. Also, the same samples were further analyzed by a second examiner (a dental surgeon who was trained for the lip print analysis). The kappa coefficient for inter-observer agreement was 0.73 (substantial agreement) and for intra-observer agreement, it was 0.83 (near-perfect agreement).

Agreement between conventional and digitized lip print analysis

The results from the two tests were then compared to determine if one method was more superior to the other. The kappa coefficient was computed to measure the agreement between methods 1 and 2, which turned out to be 1, suggestive of perfect agreement in the results from the two methods.

Lip print analysis by customized software

The digitized lip prints were also analyzed by the customized software to detect the most common types of lip grooves in the upper lip, the lower lip, and both lips. However, this customized software erroneously detected type I' grooves in large proportions (92.3%) which is contrary to the findings from the manual analysis. Resultantly, this software could not be validated.

Discussion

The present study evaluated the lip sizes along with the lip groove patterns of the study population and attempted to correlate them with ethnicity and gender. Multiple logistic regressions were performed taking all significant lip measurements into account and equations derived to predict the genders and ethnicities of subjects, but their legitimacy remains to be tested.

Gender, ethnicity, and age form the foundation on which the science of forensic identification is based and we attempted to augment the former by aiming to determine the correlation between lip prints and ethnicity and gender. We included 300 gender-matched students of Indian and Malaysian-Chinese descents with equal distribution. Similar studies performed in Indian and Chinese subjects are depicted in Table 4.

Even though few studies have been conducted with a larger sample size, they were conducted among the Indian population and other ethnicities were not included (Bansal et al., 2014; Dhall et al., 2012; Kaul et al., 2017). The present study is one of a select few, wherein lip prints of people of Indian and Malaysian-Chinese ethnic origins were analyzed to determine any significant ethnic/environmental influences on the lip prints of an individual. To the best of our knowledge, this is the largest ever study comparing the ethnicity-based differences in the lip size and prints between the Indian and Malaysian-Chinese subjects. However, a recent study by Hamzah N H et al. evaluated the lip prints for gender determination confined to the Malaysian Chinese population using the lipstick-cellophane tape technique in 412 individuals (Hamzah et al., 2020). We could find only very few similar studies which had attempted to collect such population-specific data, but they included a smaller sample size (Xu et al., 2012; Bharath et al., 2014).

The sizes of the lips differed significantly among the Indian and Malaysian-Chinese populations, with the lips of the Malaysian-Chinese population being larger, except in the case of the length of the lower lips, which was greater in the Indians. Similar studies which evaluated the size of lips among the two ethnicities were not available in the literature; our results could not be compared.

When the total study population was taken into account, the lengths and widths of lips of the males were significantly larger than those of the females. This was in agreement with the findings of Neo et al., who studied Indian, Malay, and Malaysian-Chinese subjects and found that the lip length and width of the lower lip could be utilized for sex determination. However, they did not correlate the size of lips among the Indian and Malaysian-Chinese subjects (Xu et al., 2012).

The same trend was observed among the Indian males and Indian females, but only the width of the lower lip differed significantly. These findings were partly in agreement with those of Kautilya VD et al. who found that in the Indian population, the thickness of both lips was significantly larger in males as compared to that in females (Vijay Kautilya et al., 2013). There was a difference of about 3 mm in the lip thickness between both the upper and lower lips separately, among males and females. These findings are in accordance with the findings by Sharma V et al. (Sharma et al., 2014).

For the lip print pattern analysis, we adopted the popular Suzuki and Tsuchihashi classification system of grooves, which was applied by majority of the available cheiloscopic researches. However, few studies have employed either a modification of this classification (Dhall et al., 2012; Bharath et al., 2014; Kolli et al., 2013) or devised a new classification system (Kapoor & Badiye, 2017). Lip prints are most frequently available as partial/fragmented patterns in a crime scenario. The central portions of the lower lips are reported to be most frequently discovered at crime scenes. Hence, we adopted the sextant system to evaluate the lip print pattern, similar to the studies done by Kautilya VD et al. and Verma P et al. (Vijay Kautilya et al., 2013; Verma et al., 2015).

In our Indian subjects, type V grooves were noted predominantly either when both lips were considered together or when each part of the lips, the upper lip and the lower lip, was considered separately. Among the Malaysian-Chinese subjects, type V grooves were predominantly seen when both lips were considered together, in the lower lip as well as in all parts of the lower lip. Type III grooves were predominant in the upper lip and all portions of the upper lip evaluated separately. On the contrary, Rao B who studied Indian, Malay, and Chinese populations noted that the type IV pattern was most common among the Chinese and Malay subjects (36.1% and 38.1%, respectively). Among Indians, type II groove was most common (50.8%) (Bharath et al., 2014). Our findings were also in contrast to the findings of Neo et al. where type I grooves were seen most commonly among Indian and Chinese subjects (Xu et al., 2012).

The lip print pattern was also evaluated for gender dimorphism and we found that type V grooves were noted predominantly in males when both the lips were considered together, in the lower lip and in P2, P4, P5, and P6. Type III grooves were predominantly noted in the upper lip, P1 and P3. These findings were also in contrast with those of Neo et al. who found that type III was the most predominant pattern in all the male subjects while type I and I' grooves were most predominant among the female subjects (Xu et al., 2012).

Numerous studies are available in the literature comparing the gender dimorphism of lip print patterns among the Indian population. We found that type III grooves predominated in Indian males when both lips were considered together, in the upper lip as well as in the lip portions P1, P3 and P4, whereas type V grooves were predominantly present in the rest of the portions. In the Indian females, type V grooves were seen predominating in all the areas. Our findings are in agreement with those of Prabhu RV et al., who found that type V grooves were the most predominant patterns noted in the Indian population, irrespective of the gender (Prabhu et al., 2012). These findings were partly in agreement with those of Sharma V et al. who found that the most common lip patterns among Indian males were type III and type IV. In contrast, they noted that type I and I' grooves predominated in the Indian females (Sharma et al., 2014).

However, our findings were completely in contrast with those of Kautilya VD et al. where the most common pattern found in females was type I, as compared to type III in males (Vijay Kautilya et al., 2013). Similar findings were also noted in studies of Sharma et al. (Sharma et al., 2014) and Narang et al, while studies by Padmavathi BN et al. and Patel et al. found the type II pattern to be the most common among females (Padmavathi et al., 2013; Patel et al., 2010).

The reason for the contrasting results of the present study could possibly be due to the strict standards of lip groove pattern identification which were employed in the present study; the typical type I and I' grooves were scarce, and branched grooves, though numerous, usually exhibited multiple branching. This resulted in categorization of such grooves and other ambiguous grooves as type V which could likely explain the preponderance for type V grooves across our study population.

In the recent past, we have observed a shift from conventional manual methods to computerized methods being employed in various cheiloscopic studies (Prabhu et al., 2012; Padmavathi et al., 2013; Jeergal et al., 2016; Augustine et al., 2008; Gugulothu et al., 2015). We also incorporated conventional manual and contemporary digital methods of lip print analysis in our study and their results were compared. The manual method of lip print analysis using a magnifying glass was followed in a majority of studies (Sharma et al., 2014; Patel et al., 2010; Gondivkar et al., 2009; Narang et al., 2011). For the computer-aided analysis, we digitized the collected lip print sample by scanning at 400-dpi resolution.

Further, we attempted to develop a computerized software using MATLAB data programming language. In our experience, this customized software detected type I' grooves in large proportions (92.3%) from the collected lip print sample, contrary to the findings from the manual analysis, which was considered as the gold standard for comparison. Thus, it could be concluded that the voids in groove detection by the software need to be addressed further and require more sophisticated coding and expertise in order to be accepted as a valid lip print analytical tool and successfully replace manual methods of lip print analysis. During the present attempt, we also realized that other, more economical, freely available data programming languages could also be used in the design of such software, which would ensure an easier integration of the same in the law enforcement agencies, especially those of the developing countries.

Conclusions

There was no significant dimorphism in the distribution of the lip prints patterns, across the various groups and sub-groups of the study. There was a significant difference in the lengths and widths of the lips among the two genders (total population) and ethnicities (with the exception of the length of the lower lip and ethnicity). It was observed from the present study population that ethnicity can be guessed based on the length and width of the upper lip and width of the lower lip, whereas the length and width of the upper and lower lips can be used for gender prediction. Further studies involving a larger sample size from diverse ethnic backgrounds can serve as a data pool which will be a valuable tool for personal identification.

Abbreviations

DNA: Deoxyribonucleic acid; IEC: Institutional Ethics Committee; GIMP: GNU Image Manipulation Program; JPEG: Joint Photographic Expert Group; PPI: Pixels per inch; MATLAB: Matrix Laboratory; SPSS: Statistical Package for the Social Sciences; LU: Length of the upper lip; LL: Length of the lower lip; WU: Width of the upper lip; WL: Width of the lower lip.

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None.

Authors' contributions

AC, RV, and KMP: conceived and designed this study. AC, MK, and DB: interpreted the data. AC, RV, and MK: drafted the manuscript, and revised the manuscript for important intellectual content. PA: interpreted the data and provided statistical testing expertise and advice and revised the manuscript for important intellectual content. AC, VR, MK, and PA: aided in the interpretation of the data and revised the manuscript for important intellectual content. All of the authors reviewed, discussed, and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

All procedures for data collection were treated with confidentiality according to the Helsinki declarations of biomedical ethics. The researchers requested the informed consent of the participants after explanation of the study objectives and importance. Participants were informed about the procedure and participation was voluntary. The study was approved by the Institutional Ethics Committee (IEC no: 588/2014).

Consent for publication

Informed consent was obtained from all the participants of the study.

Competing interests

The authors declared that they have no competing interests.

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