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Forensic value of lip patterns in a population of Kohat, Pakistan

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ABSTRACT

Background: Cheiloscopy has been proposed as a supplementary forensic identification tool; however, its reliability remains debated.

Objective: To evaluate lip pattern distribution, sexual dimorphism, and inter-rater reliability in a Kohat population.

Methods: A cross-sectional study was conducted on 119 participants. Lip prints were collected using the lipstick-cellophane method and classified (Suzuki & Tsuchihashi). Chi-square test assessed gender association, and Cohen's Kappa evaluated inter-rater reliability (95% CI).

Results: Type II pattern was most prevalent (48.66%), followed by Type IV (16.74%). A significant association between gender and upper lip patterns was observed ($p < 0.05$), with Type I more frequent in males and Type IV in females. No significant difference was found in lower lip ($p > 0.05$). Inter-rater reliability was low ($\kappa = 0.096–0.180$; 95% CI indicating slight agreement). Gender prediction accuracy ranged from 60.0% to 66.96%

Conclusion: Although lip patterns show population-specific trends and limited sexual dimorphism, low reproducibility limits their standalone forensic utility. Cheiloscopy should be used as a corroborative tool.

KEY WORDS

Lip prints; Cheiloscopy; Forensic identification; Sexual dimorphism

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Introduction

Forensic odontology plays a pivotal role in identifying individuals in mass disasters, criminal investigations, and cases where traditional biometric data, such as fingerprints, are unavailable or compromised [1]. Among the various techniques available, cheiloscopy the study of the elevations and depressions on the external surface of the lip has garnered attention as a potential tool for human identification. The term "cheiloscopy" is derived from the Greek words cheilos (lips) and skopein (to see) [2].

The biological basis of cheiloscopy rests on the theory that the grooves and wrinkles on the labial mucosa (sulci labiorum) form during the sixth week of intrauterine life and remain permanent and unique to each individual, much like dermatoglyphics [3]. The distinctiveness of these patterns was first described by anthropologist R. Fischer in 1902. Still, it was not until the extensive work of Suzuki and Tsuchihashi in the 1970s that a standardized classification system was established, which remains the gold standard in forensic research today [4,5].

Despite the theoretical promise of cheiloscopy, its practical application in forensic casework depends heavily on two factors: the stability of the print acquisition method and the reliability of interpretation. While fingerprints have automated, objective matching systems, lip print analysis remains manual and largely subjective. Previous studies conducted in South Asia, particularly in India and Pakistan, have reported varying prevalence of lip patterns, suggesting that ethnicity and geographic origin may influence phenotype [6,7].

The population of Kohat, located in the Khyber Pakhtunkhwa (KPK) province of Pakistan, represents a distinct demographic with specific genetic and environmental characteristics. While studies have been conducted in Abbottabad and Punjab, there is a paucity of forensic data particular to the Kohat region. Furthermore, few studies have rigorously tested the inter-rater reliability of these classifications, often assuming that trained observers will see the same pattern. This study aims to fill this gap by analyzing the forensic value of lip patterns in the Kohat population, explicitly focusing on pattern prevalence, sexual dimorphism, and the reproducibility of the analysis [7,8].

Hypothesis

Null hypothesis (H_0)

There is no significant association between lip print patterns and gender, and inter-rater reliability is high.

Alternative hypothesis (H_1)

Lip print patterns show significant gender association, but inter-rater reliability is low.

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Materials and Methods

Study setting and ethical approval

The study was conducted at the Khyber Medical University - Institute of Dental Sciences (KMU-IDS), Kohat. Ethical clearance was obtained from the Institutional Review Board (IRB) of KMU-IDS under reference number KIDS-IRBB/ECC/25-09/30 on the 20th of December 2024 before the commencement of the study. Written informed consent was obtained from all participants after the purpose and non-invasive nature of the procedure were explained.

A total of 119 subjects (n=119) were selected from the student body of KMU-IDS. The sample size (n=119) was calculated using prevalence estimates from previous regional studies (~50%), with 95% confidence level and 9% margin of error. A non-probability convenience sampling method was used.

The sample included both males and females of the Northern Pakistani population, an equal distribution of both genders was assured. Inclusion criteria required individuals with healthy, competent lips free from pathology. Exclusion criteria included hypersensitivity to cosmetics, active herpetic lesions, congenital deformities (e.g., cleft lip), or recent trauma.

The method used for recording lip prints was the "Lipstick and Cellophane Tape" technique, in which the lips are first cleaned and dried. Then, a non-glossy, long-lasting dark lipstick is evenly applied to the vermilion borders. Next, a strip of high-quality, transparent cellophane tape is pressed onto the lipstick-coated labial surface with the lips in a relaxed position. The tape is then removed and stuck onto white bond paper.

The recorded lip prints were divided into four quadrants (Upper Right Q1, Upper Left Q2, Lower Left Q3, Lower Right Q4). Two independent reviewers analyzed the central portion (10mm) of each quadrant using a magnifying lens based on the Suzuki and Tsuchihashi classification [4]:

a) **Type I:** Clear-cut vertical grooves.

b) **Type I':** Partial-length vertical grooves.

c) **Type II:** Branched grooves.

d) **Type III:** Intersected grooves.

e) **Type IV:** Reticular (net-like) grooves.

f) **Type V:** Undetermined/Irregular.

Prior to analysis, both reviewers underwent calibration sessions using standardized lip print samples. Inter-observer agreement was pre-tested on 20 samples to ensure consistency.

Data were analyzed using SPSS. Frequency distribution determined the dominant pattern. Chi-Square tests assessed sexual dimorphism. Cohen's Kappa (κ) was calculated to measure Inter-Rater Reliability. Accuracy, Sensitivity, and Specificity for gender determination were calculated based on blind predictions.

Results

The study analyzed the lip prints of 119 individuals of which 60 were female and 55 were males from the Northern Pakistani population to assess the feasibility of cheiloscopy and to establish the frequency of specific lip patterns according to the Suzuki and Tsuchihashi classification system. The results (Table 1) indicated that the Type II (Branched) pattern is the predominant lip characteristic in this specific demographic, accounting for 48.66% of all quadrants analyzed, as shown in Figure 1. This dominance was consistent across both the upper and lower lips, appearing in approximately 46% of upper quadrants and 51% of lower quadrants. The second most common pattern observed was Type IV (Reticular), at 16.74%, while Type V (Undetermined) was the least frequently encountered, at 5.36% of the sample.

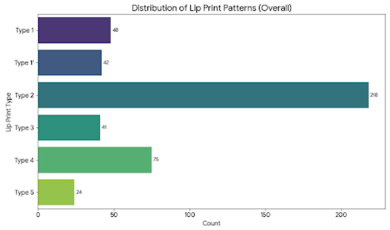


Figure 1. Distribution of lip pattern types.

Table 1. Distribution of lip patterns.

Lip Print Type	Count	Percentage (%)
Type 1	48	10.71%
Type 1'	42	9.38%
Type 2	218	48.66%
Type 3	41	9.15%
Type 4	75	16.74%
Type 5	24	5.36%

Despite identifying dominant patterns, the study revealed significant challenges regarding the analysis's reliability. Inter-rater reliability testing showed that cheiloscopy is highly subjective, with Cohen's Kappa values ranging between 0.096 and 0.180 across the four quadrants. This indicates only "slight agreement" between the two reviewers. While the observers generally agreed on the presence of the dominant Type II patterns, they frequently classified other subtypes differently, particularly when distinguishing between Type I and Type I' or Type III and Type IV. The raw agreement data highlighted that for any given quadrant, the reviewers selected the same lip print type only 25% to 30% of the time.

In terms of gender-based differences, the study found a statistically significant degree of sexual dimorphism, but it was limited to the upper lip. Chi-square analysis revealed a significant association between gender and print patterns in both the Upper Right and Upper Left quadrants. Specifically, Type I (Vertical) patterns appeared significantly more often in males, whereas Type IV (Reticular) patterns were significantly more frequent in females. Conversely, the lower lip showed no statistically significant difference in pattern distribution between the genders; a summary of the gender-based analysis can be seen in Figure 2 below.

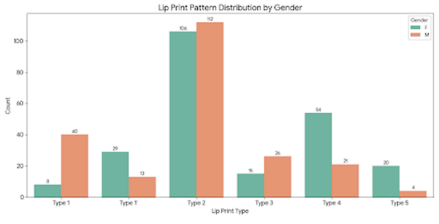


Figure 2. Gender based differences.

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When applying these patterns to gender determination, the method yielded an overall accuracy of 60% to 67%. Reviewer 1 achieved a higher overall accuracy of 66.96% and was particularly effective at identifying females, with a sensitivity of 72.9%. In contrast, Reviewer 2 had a lower overall accuracy of 60.00% but demonstrated slightly better ability to identify males, with a specificity of 65.5%. The agreement between the two reviewers regarding gender prediction was "fair" (Kappa = 0.364). Ultimately, while distinct trends exist such as vertical patterns in males and reticular patterns in females on the upper lip the low inter-rater reliability (Table 2) and moderate prediction accuracy suggest that cheiloscopy has limitations asa standalone method for gender determination in this population, as seen in Figure 3 below.

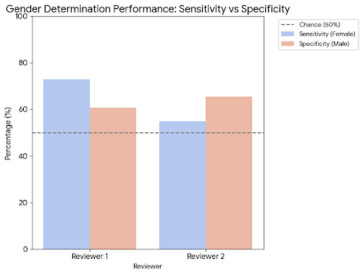


Figure 3. Gender determination accuracy comparison.

Table 2. Inter-rater reliability (Cohen's Kappa).

Quadrant	Kappa ()	Raw Agreement (%)	Interpretation
Upper Right	0.180	29.81%	Slight agreement
Upper Left	0.112	24.76%	Slight agreement
Lower Left	0.096	27.68%	Slight agreement
Lower Right	0.141	30.36%	Slight agreement

While Reviewer 1 achieved moderate accuracy in gender determination (67%), the low inter-rater reliability for specific lip print patterns suggests that the classification process is subjective. The difference in accuracy between the two reviewers (67% vs 60%) further highlights the variability in reading these prints.

Inter-rater reliability was assessed using Cohen's Kappa with 95% confidence intervals, and weighted kappa was calculated to account for partial agreement.

Discussion

The present study evaluated the distribution, sexual dimorphism, and reliability of lip prints in the Kohat population. The findings offer significant insights when compared to regional and international data, highlighting both the potential and the limitations of cheiloscopy in forensic science. In the current study, Type II (Branched) was the most predominant pattern (48.66%). This finding aligns with Tsuchihashi's original work in Japan, which identified Type II as the most common pattern [5]. Similarly, comparative studies in South India by Sivapathasundaram et al. [9] and Saraswathi et al. [10] also reported Type II as the predominant pattern. In the context of Pakistan, our results align with those of Simra et al., who studied a Pashtun population similar to Kohat and found Type II to be dominant [11].

However, this contrasts with findings from the Punjab province of Pakistan. Nadeem et al. [8] reported that Type I (Vertical) was the most frequent pattern in their sample from Lahore. Furthermore, Vahanwala et al. [12] in a study in Mumbai, India, found Type I to be dominant in the lower lip. This discrepancy strongly supports the hypothesis that lip print patterns exhibit ethnic and geographic variation [13]. The dominance of Type II in Kohat, distinct from the Type I dominance in Punjab, suggests a potential genetic drift or hereditary clustering specific to the Northern Pakistani population. This reinforces the necessity of establishing regional reference databases for forensic identification, as a universal standard for "common patterns" does not exist [14].

The establishment of biological sex is a primary objective in forensic anthropology and odontology. Our study demonstrated a statistically significant association between gender and lip patterns in the Upper Lip, with males exhibiting more Type I (Vertical) patterns and females exhibiting more Type IV (Reticular) patterns.

This finding presents an interesting contrast to existing literature. Classic studies by Suzuki and Tsuchihashi [4] suggested that Type I and II were more common in females, while Type III and IV were more common in males, essentially the inverse of our findings. Similarly, Sharma et al. [15] and Gondivkar et al. [16] in India reported Type I/I' dominance in females. However, our results are consistent with the work of Costa and Caldas [17] and recent studies in the Middle East [18], which have challenged the traditional gender assignments of lip patterns.

The fact that our study found significance only in the upper lip, while the lower lip showed no dimorphism, is also noteworthy. This contradicts the findings of Multani et al. [19], who suggested the lower lip provides a better canvas for gender determination due to its larger surface area. The variability in these findings across the globe [20,21] suggests that while sexual dimorphism in lip prints exists, it is not uniform across populations. Therefore, using lip prints as the sole indicator of gender in the Kohat population carries a risk of error, as evidenced by our moderate accuracy rates (60–67%).

Perhaps the most significant and concerning finding of this study is the low inter-rater reliability (Cohen's Kappa 0.096 – 0.180), indicating only "Slight Agreement." While forensic literature is replete with studies claiming high efficacy for cheiloscopy, very few rigorously report Kappa statistics for observer agreement.

Our low Kappa values align with the critical review by Utsuno et al. [22], who noted that the pressure applied during the recording process can distort the flexible soft tissues of the lip, altering the appearance of grooves (e.g., changing a Type I vertical groove into a Type II branched groove). Furthermore,

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more recent studies using digital scanners rather than the lipstick method [23,24] have argued that traditional manual analysis is inherently subjective. The inability of two trained reviewers in our study to consistently agree on the Suzuki classification (agreement on the exact type occurring only ~30% of the time) highlights a significant vulnerability in using this evidence in a court of law.

This subjectivity likely explains the variance in accuracy between Reviewer 1 (67%) and Reviewer 2 (60%). In a real-world forensic scenario, such a discrepancy is problematic. As noted by Pretty and Sweet [25] in their critique of bite mark analysis, forensic methods must demonstrate high reproducibility to meet the Daubert standard for scientific evidence. Our findings suggest that traditional cheiloscopy, in its current form, may not yet meet this rigorous standard without digital enhancement or automated pattern-recognition software [26,27].

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Additionally, the sample size of 119, while sufficient for a pilot analysis, is small compared to national databases. Comparing our results to large-scale studies in Poland by Kasprzak or in Saudi Arabia by El Domiaty highlights the need for a larger, multi-centre study across Khyber Pakhtunkhwa to validate these pattern frequencies [33].

Conclusion

This study demonstrates that Type II lip pattern predominates in the Kohat population, with limited sexual dimorphism confined to the upper lip. However, the low inter-rater reliability ($\kappa < 0.2$) highlights significant subjectivity in classification. Therefore, cheiloscopy should not be used as a standalone forensic tool but rather as supportive evidence alongside more reliable identification methods.

Limitation and Future Directions

Limitations

a) Small sample size

b) Use of manual recording method prone to distortion

c) Lack of digital analysis tools

d) Absence of weighted kappa analysis

Future directions

a) Integration of digital imaging and AI-based classification

b) Development of automated lip print recognition systems

c) Large-scale multicenter studies

Forensic significance

The findings highlight that while cheiloscopy has potential in forensic identification, its reliability must be enhanced through digital standardization and machine learning approaches to meet legal admissibility standards.

Disclosure Statement

No potential conflict of interest was reported by the author.

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