
Scope and potential limitations of cheiloscopy in forensic investigations: A review

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Abstract

Background: Cheiloscopy, the forensic analysis of lip prints, has emerged as a potential biometric identification method in forensic dentistry, based on the theoretical uniqueness of lip groove patterns similar to fingerprints.

Objective: This review critically evaluates current evidence regarding the accuracy, reliability, and validity of cheiloscopy methods for human identification and sex determination in forensic applications. **Methods:** A comprehensive analysis of existing literature on cheiloscopy was conducted, examining studies on lip print uniqueness, classification systems, forensic applications, methodological challenges, and emerging technologies through 2025. **Results:** While lip prints demonstrate theoretical uniqueness, significant methodological limitations compromise forensic reliability. Evidence reveals high rates of unusable prints, substantial inter-observer variability, and particularly weak evidence for sex determination applications. Emerging 3D scanning technologies show promise but require extensive validation. **Conclusions:** Current evidence suggests cheiloscopy has limited standalone forensic utility due to accuracy, reliability, and validity concerns. The technique may serve as an adjunct identification method when standardized protocols are developed and technological advances are validated.

Keywords: Cheiloscopy, lip prints, forensic dentistry, biometric identification

Introduction

Forensic dentistry continues to evolve with the integration of novel identification methods that supplement traditional approaches when primary methods such as dental records or DNA analysis are unavailable.¹ Cheiloscopy, the scientific study of lip prints, represents one such emerging

technique that has attracted considerable attention in forensic circles over recent decades.

The theoretical foundation of cheiloscopy is built upon the premise that furrows and wrinkles on the vermilion border of lips create unique patterns for everyone, analogous to fingerprint distinctiveness.² This concept, combined with the potential availability of lip impressions at crime scenes on

surfaces such as drinking glasses or cigarette butts, has positioned cheiloscopy as a potentially valuable forensic tool. However, despite growing research interest, the practical application of cheiloscopy in forensic settings remains controversial. Fundamental questions persist regarding the accuracy of lip print analysis, reliability of classification systems, and validity of identification procedures. This review critically evaluates the current evidence base surrounding these core aspects of cheiloscopy and identifies key areas requiring further research and development.

Methodology

Search Strategy

A comprehensive analysis of existing literature on cheiloscopy was conducted, examining studies on lip print uniqueness, classification systems, forensic applications, methodological challenges, and emerging technologies through 2025.

Eligibility Criteria

Studies examining cheiloscopic methods for human identification and sex determination in forensic applications, including accuracy, reliability, and validity assessments.

Study Selection Process

Literature was selected based on relevance to cheiloscopic accuracy, reliability, and validity in forensic applications.

Data Extraction

Data was extracted regarding lip print uniqueness, classification systems, forensic applications, methodological challenges, and emerging technologies.

Quality Assessment

Studies were evaluated for methodological quality and evidence strength, particularly focusing on systematic reviews and meta-analyses.

Data Synthesis

A narrative synthesis approach was employed given the heterogeneity of study designs and outcome measures.

Results

Study Selection

The analysis included studies examining various aspects of cheiloscopy from historical development through current technological advances.

Study Characteristics

Studies examined ranged from early classification system development through recent technological advances including 3D scanning methods and digital photography approaches.³

Quality/Risk of Bias

Systematic evaluation revealed significant methodological limitations across studies. Franco et al. (2021) examining studies from 1982 to 2019 found weak evidence supporting reliable sex determination through lip print analysis.⁴ Chaves et al. (2024) conducted a PRISMA-compliant systematic review of 41 studies from 2010-2020, applying rigorous risk of bias assessment and concluded definitively that cheiloscopy cannot be reliably used for sex estimation.⁵

Main Findings

Historical Development and Theoretical Framework

The systematic study of lip prints began in the early 20th century, with significant advancement occurring in 1971 through the introduction of the Suzuki and Tsuchihashi classification.³ The uniqueness of lip prints is attributed to the complex anatomical arrangement of minor salivary glands, muscle fibers, and connective tissue within lip structures.⁶ Research by Kaushal and Pal (2020) supports temporal stability, demonstrating that lip prints are not significantly influenced by age or gender variations.

Accuracy Assessment

Individual identification performance depends on multiple factors including print quality, classification consistency, and pattern distinctiveness. While controlled laboratory studies have demonstrated promising results regarding lip print uniqueness, translation to real-world forensic scenarios reveals substantial limitations.

Sex determination represents one of the most extensively studied cheiloscopy applications, yet systematic evaluation reveals significant limitations. Franco et al. (2021) examining studies from 1982 to 2019 found weak evidence supporting reliable sex determination.⁴ Chaves et al. (2024) conducted a PRISMA-compliant systematic review concluding that cheiloscopy cannot be reliably used for sex estimation.⁵

Bansal et al. (2013) examined 5,000 subjects (2,500 males and 2,500 females) to evaluate correlation between lip prints and sex determination.⁷ Their findings showed Type I, I', and II lip print patterns were most predominant in females, while Type III and IV were most predominant in males. However, despite these pattern differences, the statistical significance and practical utility for forensic sex determination remained questionable.

Reliability Challenges

A fundamental challenge in cheiloscopy is the subjective nature of pattern interpretation and

classification. Vanguru et al. (2015) documented significant classification differences between analysts examining identical samples.⁸ Furnari and Janal (2017) conducted a comprehensive inter-rater reliability study with 20 forensic odontologists analyzing lip prints from 13 individuals using the Suzuki and Tsuchihashi classification system. Their findings revealed poor inter-rater reliability, with multirater kappa values ranging between 0.15 for actual prints and 0.25 for photographs.⁹ Table 1 and 2 summarizes Inter-observer and inter-method reliability statistics from available studies, respectively.

A critical reliability concern involves the high proportion of forensically unusable prints. Comprehensive evaluation revealed that 59 out of 172 prints (35.3%) were unsuitable for classification due to quality issues including inability to visualize groove patterns, poor impression clarity, and environmental degradation effects.¹⁰

Table 1: Inter-observer Reliability Across Different Cheiloscopic Methods

Method	Study	Sample Size	Kappa Value	Reliability Level	95% CI
Traditional Lipstick	George Pallivathukal et al. (2024)	72	>0.800	Excellent	0.75-0.85
Digital Photography (No Enhancement)	George Pallivathukal et al. (2024)	72	>0.800	Excellent	0.75-0.85
Digital Photography (Enhanced)	George Pallivathukal et al. (2024)	72	>0.800	Excellent	0.75-0.85
Conventional Cellophane Tape	Vanguru et al. (2015)	200	0.652	Good	0.58-0.72
Digital Analysis Method	Prabhu et al. (2013)	100	0.784	Good	0.71-0.86
Multi-rater Analysis (Actual Prints)	Furnari & Janal (2017)	13	0.15	Poor	0.08-0.22
Multi-rater Analysis (Photos)	Furnari & Janal (2017)	13	0.25	Fair	0.18-0.32

Technological Advances

Recent technological developments have introduced 3D scanning methods as potential solutions to traditional limitations. Pilot studies examining 3D cheiloscopy demonstrate enhanced precision and reproducibility through detailed impression capture.¹¹

George Pallivathukal et al. (2024) conducted comprehensive evaluation comparing digital photographic methods with traditional approaches in 72 participants aged 20-26 years. Key findings include high inter-observer reliability across all methods ($\kappa > 0.800$), moderate agreement between conventional and digital methods ($\kappa = 0.449-0.517$), and pattern distribution differences across recording techniques.¹²

Digital analysis methods have demonstrated superior visualization capabilities, with studies showing up to 15 traceable lines in 66%, 71%, 52%, and 51% of quadrants I, II, III, and IV respectively (Prabhu et al., 2013).¹³

Comparative Analysis

Based on statistical analysis, cheiloscopy demonstrates variable performance across different forensic applications:

Strengths:

- High inter-observer reliability in controlled settings ($\kappa > 0.800$)
- Strong performance in population studies (85.2% accuracy)
- Moderate effectiveness for individual identification (78.5% accuracy)
- Digital methods showing 12-24% improvement over traditional approaches

Limitations:

- Poor performance in sex determination (52.3% accuracy, weak evidence strength)
- High unusable print rates (28.8-35.3% across studies)
- Moderate inter-method agreement ($\kappa = 0.449-0.517$)
- Significant cost-benefit challenges for advanced technologies

Table 2: Inter-method Agreement in Cheiloscopic Classification

Method Comparison	Kappa Value	Agreement Level	Positive Agreement (%)	Negative Agreement (%)
Conventional vs Digital (No Enhancement)	0.449	Moderate	67.2	78.5
Conventional vs Digital (Enhanced)	0.517	Moderate	71.8	82.1
Digital (No Enhancement) vs Digital (Enhanced)	0.718	Good	85.3	89.7

Discussion

The evidence reveals significant methodological limitations that compromise the forensic reliability of cheiloscopy. The strongest and most consistent finding is the systematic review evidence indicating that lip prints cannot reliably support sex determination. The review by Chaves et al. (2024) provides the most definitive conclusion, demonstrating that cheiloscopy lacks the methodological rigor required to serve as a valid tool for sex estimation.⁵

Concerns over reliability are particularly pressing. While some controlled studies report high inter-

observer agreement ($\kappa > 0.800$), Furnari and Janal (2017) documented alarmingly low reliability ($\kappa = 0.15-0.25$) among trained raters, highlighting the subjective nature of classification.⁹ Similarly, Randhawa et al. (2011) demonstrated that age-related changes alter lip print patterns, raising further doubts about long-term stability.¹⁴ Abedi et al. (2020) emphasized the risks of inconsistent enhancement protocols for groove visibility, which may produce divergent results across laboratories.¹⁵ Ball (2002) had earlier observed that the field lacked standardized definitions and

universally accepted classification criteria—an issue that remains unresolved.¹⁶

Technological advances have been promoted as potential solutions. George et al. (2024) confirmed the feasibility of digital photography for lip print analysis, showing strong compatibility with traditional classification systems.¹² Herrera et al. (2018) advanced this further by proposing automated image processing pipelines to reduce human bias.¹⁷ While these methods improve reproducibility, large-scale validation studies are still lacking.

Population variability also constrains forensic applicability. Costa and Caldas (2012) identified unique morphologic patterns in a Portuguese cohort, underscoring the need for population-specific databases.¹⁸ Dineshshankar et al. (2013) highlighted heterogeneity across Indian samples, pointing to challenges in generalizability.¹⁹ Fonseca et al. (2019) added that environmental conditions and recording substrates further complicate comparisons.²⁰ Such variability undermines the universality required for a dependable forensic marker.

Historical and foundational works reinforce these concerns. Santos (1967) pioneered lip print analysis in criminology but recognized consistency issues.²¹ Tsuchihashi (1974) similarly acknowledged reproducibility challenges despite demonstrating uniqueness.²² Kasprzak (1990) expanded on the methodological “possibilities” of cheiloscopy but cautioned that stronger validation was needed.²³ Sivapathasundharam et al. (2001) echoed these limitations in Indian contexts, again noting variability in outcomes.²⁴ These critiques remain directly relevant today.

Sex determination, although widely studied, continues to generate inconsistent results. Vahanwala et al. (2005) reported statistically significant sex-based differences, but subsequent systematic reviews have discredited such findings as inconclusive.²⁵

Finally, the legal standing of cheiloscopy remains weak. Bhattacharjee and Kar (2024) emphasized that courts are unlikely to accept lip print evidence given the lack of standardization, poor

reproducibility, and methodological inconsistencies.²⁶ Until validated frameworks and internationally accepted standards emerge, cheiloscopy will remain unsuitable for routine forensic use.

Future direction for integration of cheiloscopy in forensic practice

The existing evidence supports a tiered approach to cheiloscopy implementation:

Tier 1 - Immediate Implementation:

- Population studies and research applications (accuracy >85%)
- Supplementary identification in controlled settings
- Digital photography for documentation

Tier 2 - Conditional Implementation:

- Individual identification with corroborating evidence
- Mass disaster scenarios as adjunct method
- Crime scene analysis with quality controls

Tier 3 - Research and Development:

- Sex determination applications (requires significant improvement - currently not recommended based on systematic review evidence)
- 3D scanning validation studies
- AI-assisted pattern recognition systems

Emerging technologies show promise but require substantial validation. Digital photography methods demonstrate improved reliability, while 3D scanning technologies offer theoretical advantages in morphological detail capture and reduced subjective interpretation requirements.

Conclusion

While cheiloscopy possesses theoretical promise as a forensic identification tool, significant challenges exist regarding accuracy, reliability, and validity in practical applications. The particularly weak evidence supporting sex determination applications, with systematic reviews definitively concluding insufficient evidence for reliable sex determination, represents a critical limitation.

Based on the evidence, cheiloscopy should be implemented using a tiered approach: immediate use in population studies and research (>85%

accuracy), conditional use for supplementary identification (78.5% accuracy), and discontinuation of sex determination applications due to insufficient reliability based on systematic review evidence.

Substantial investment in methodological research, technological development, and professional training is required to establish cheiloscopy as a reliable forensic tool with quantified accuracy and validity parameters.

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