*Mapana – Journal of Sciences*
2024, Vol. 23, No. 4, 83-97
ISSN 0975-3303 | https://doi.org/10.12723/mjs.71.5

# Novel Approach for Personal Identification using Dorsal Knuckle Crease Patterns: A Pilot Study

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**Abstract**

Despite the availability of various identification methods, such as fingerprints, ridge density, palm prints, and vein patterns, forensic identification remains a complex challenge. While substantial research has been conducted on the palmar surface of the hand, there has been limited focus on the dorsal surface for identification purposes. The dorsal surface, like fingerprints, contains minutiae and skin crease patterns believed to be permanent. The crease patterns present on the dorsal side of the proximal interphalangeal joints are known as knuckle crease patterns. This research aimed to classify and examine the characteristics of dorsal finger knuckle crease patterns and to explore their potential for determining sex. A total of 800 finger image samples were collected from 80 subjects. The knuckle crease patterns were categorised into six distinct types: Horizontal, Vertical, Oblique, Semi-lunar, Mixed, and Cross patterns. Additionally, the study investigated sex determination based on the distance between creases, revealing that males tend to have a greater average distance between ridges than females. This difference was statistically confirmed using a t-test with a 95% confidence level. The findings indicate that finger knuckle crease patterns are unique, individual, and classifiable, making them a valuable tool for identification and potentially aiding forensic investigations.

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**Keywords:** Dactyloscopy, Anthropometry, Minutiae, Knuckle crease, Proximal interphalangeal.

## Background

The task of Identification is still a challenging endeavour in forensic investigation despite of various methods at our disposal, including dactyloscopy (Bhuvaneshwari et al., 2023), anthropometry (Krishan, 2007), iris prints (Sankhyan, 2016), ear prints (Meijerman et al., 2005), lip prints (Mishra et al., 2009), footprints (Kennedy, 1996), nose prints (Nandy, 2007), palatoprints (Limson & Julian, 2004), etc. The significance of identification stretches beyond forensic context to encompass civil applications such as security check-ins, banking, smart cards, various licenses, and personal IDs. In the present time though, various biometric traits have been studied and are in use, fingerprints are still considered as one of the best biometric or identification traits (Yang et al., 2019; Kaushal & Kaushal, 2011). Extensive studies have been done on the palmer surface of the hand, exploring features like fingerprints (Yang et. al, 2019), ridge density (Nayak et al., 2010; Chavan & Kumar, 2023), palm prints Han et al., 2003; Jain & Feng, 2009), vein patterns (Jain & Kumar, 2019), etc. Conversely, very limited studies are available on the dorsal surface of the hand for identification purposes. Like fingerprints, the dorsal surface of the hands also consists of minutiae and skin crease patterns, which are considered to be permanent in nature throughout life (Charles, 1997; Chattopadhyay & Sukul, 2012). It is assumed that these skin crease patterns present on the proximal interphalangeal joints remain unaltered throughout life. Though the skin becomes loose with the progressing age, the creases present remain unaltered. The distribution of collagen fibres in the fingers determines the tension lines and wrinkle lines in the fingers. (Warwick & William, 1973). When the fingers are flexed, they tend to run parallel to the crease that appears (Moore & Dalley, 2005). Most of the studies done on Finger knuckle prints focus on the biometric and technical application of Finger knuckle pattern (FKP), which includes the construction of a device for FKP recording, designing new software and formulating new algorithms for feature extraction, recognition, identification and matching of Knuckle Prints (Charles, 1997; Woodard & Flynn, 2005; Kumar & Ravikanth, 2009; Kumar & Zhou, 2009; Zhang & Zhang, 2009;

Nanni & Lumini, 2009; Badrinath et al., 2011; Swati & Ravishankar, 2013; Kumar, 2014; Vidhyapriya & Rose, 2019; Trabelsi et al., 2020). All of these studies are computerised and software-based.

Only two researchers have been found to do a manual study of knuckle prints focusing on the characteristics of knuckle prints (Chattopadhyay & Sukul, 2012; John, 2021,) and only one study has been reported so far where the classification of knuckle prints is being studied.

In the present study, an attempt is made to study the classification and characteristics of dorsal finger knuckle crease patterns and to identify the sex by studying the features of the knuckle crease pattern.


Figure 1: Phalanges of Finger

## Methods

### Sampling Strategies

Healthy consenting individuals between the age group 18 to 35 were included in the study. Individuals having any kind of skin disease, fracture of the hand or fingers, amputation, deformity, scars, or any injury over the fingers were excluded from the study.

A stratified random sampling method was used for the collection of samples. The total sample size used was 800 finger knuckle crease pattern samples collected from all 10 fingers of 80 individuals (40 males and 40 females). Demographic and other relevant details of the individual were also taken along with the consent.

### Sample collection

The samples were collected by photographing the dorsal knuckle crease patterns against a white background. The subjects were asked to place their fingers, without any strain, over a flat white surface already marked with a scale. The dorsal aspect of the finger was then photographed using a Redmi Note 7 pro mobile camera with 45 megapixels. The height of the camera was fixed for taking all the photographs. Two sets of photographs were taken for each finger, i.e., a total of 1600 photographs were taken.

**Sample analysis**

Photographs captured by the mobile camera were transferred to a computer using a data cable. Then images were converted to greyscale, cropped, and resized in Microsoft Office 16 (Microsoft Office picture tools).

Each finger comprises 3 phalanges, referred to as proximal, middle, and distal phalange, while the thumb has only 2 phalanges, i.e. proximal and distal phalanges. Figure 1 depicts the Phalanges of fingers. A human finger consists of three joints namely the Distal interphalangeal joint, Proximal interphalangeal joint and Metacarpophalangeal joint. In the case of the thumb, only the interphalangeal joint and metacarpophalangeal joint are present. The skin creases present on the Proximal inter-phalangeal joint of the dorsal surface of the fingers and the interphalangeal joint present on the dorsal surface of the thumb were studied. The proximal interphalangeal joint of fingers and the interphalangeal joint of the thumb were divided into three segments – Proximal, Middle and Distal segments, for study (Chattopadhyay and Sukul, 2012). Thus, a total of 80 * 10 * 3 = 2400 segments were analysed.

**Classification**

Images were analysed in a computer using appropriate magnification for classification. Three dominant crease patterns present on the proximal interphalangeal joint were first identified and then considered for classification.

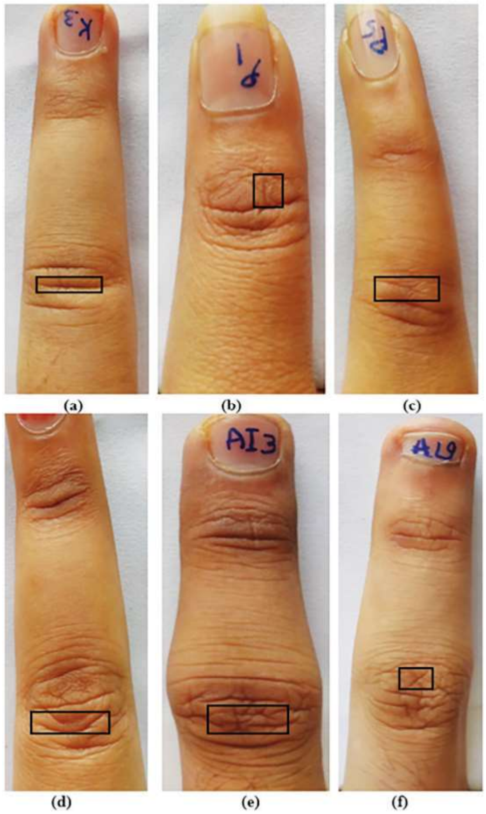


Figure 2: Different types of crease patterns. (a) Horizontal Crease, (b) Vertical Crease, (c) Oblique Crease, (d) Semi lunar Crease, (e) Mixed Crease and (f) Cross Crease Pattern.

Classification of the segments was done manually, according to Chattopadhyay and Sukul (2012). Different types of crease patterns are Horizontal (H), Vertical (V), Oblique (O), Semi-lunar (S) and mixed (M) crease patterns and different types of branching patterns are body proximal (BP), body distal

(BD), body proximal and distal (BPD), terminal radial (TR), terminal ulnar (TU), terminal radial & ulnar (TRU), and Combined (C). (Chattopadhyay and Sukul, 2012). Different types of crease patterns are depicted in Figure 2.

**Measurement of distance between the segments**

Printouts of the normalised image of the photographs were taken. The region of interest was obtained. With the help of Themisto TH-

M61 digital Vernier calliper, the distance between the creases was measured from both the right and left end of the crease.

## Data analysis

Left and right endings of the segment were identified and marked. The proximal, middle and distal segments of proximal interphalangeal joints were marked as a, b, and c at the left ending and a′, b′ and c′ at the right ending. Classification of the segments was done, and the distance between the segments was measured on both sides by a digital Vernier calliper. The readings obtained were further statistically analysed.

## Statistical analysis

The data was entered into the Microsoft Excel worksheet, and all the statistical analyses were performed in Microsoft Office 16. The chi-square test was applied to examine the relationship between sex and STEM patterns, and an unpaired t-test was employed to compare the means of data (inter distance between creases) of males and females to estimate whether the two sets of data are statistically significantly different from each other.

## Results

A total of 800 finger knuckles were studied, of which 400 belong to males and 400 to females. Overall, 800*3 = 2400 crease segments were identified and classified. Horizontal pattern was found to be the most common pattern in the sample analysed. The results agree with the findings of only such study (Chattopadhyay & Sukul, 2012). The least common pattern identified in this study was the Vertical pattern, whereas in the study done by Chattopadhyay & Sukul (2012), the least common pattern was Semi-lunar. The distribution of different types of crease patterns (Males + Females) in the studied population is shown in Table 1. Overall, the highest percentage of the pattern was found to be Horizontal (63.5%), followed by semi-lunar (18.3%), oblique (9.0%), mixed (7.3%), cross (1.5%) and vertical (0.4%). Tables 2 to 6 depict the frequency of different types of Crease patterns with their sub-types based on branching patterns.

The chi-square test revealed significant associations between sex and STEM pattern distributions. A statistically significant difference was observed in the overall distribution of STEM patterns ($p < 0.05$). When applied to individual STEM patterns considering different branching patterns, the chi-square test revealed significant associations between sex and STEM pattern distributions in the horizontal ($p < 0.05$), oblique ($p < 0.05$), and semi-lunar STEM patterns ($p < 0.05$). However, no statistically significant difference was found for cross-STEM patterns ($p = 0.279$).

| Sex | STEM Patterns | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Horizontal | | Vertical | | Oblique | | Semi lunar | | Cross | | Mixed | | Total | |
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| **Male** | 742 | 61.8 | 6 | 0.5 | 110 | 9.2 | 253 | 21.1 | 19 | 1.6 | 70 | 5.8 | 1200 | 100 |
| **Female** | 782 | 65.2 | 4 | 0.3 | 105 | 8.8 | 187 | 15.6 | 17 | 1.4 | 105 | 8.8 | 1200 | 100 |
| **Total** | 1524 | 63.5 | 10 | 0.4 | 215 | 9.0 | 440 | 18.3 | 36 | 1.5 | 175 | 7.3 | 2400 | 100 |

Table 1: Distribution of various types of crease patterns. $\chi^2 = 18.58$, Df = 5, p-value 0.0023

| Sex | Horizontal STEM Patterns | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | H | HBP | HBD | HBPD | HTR | HTU | HTRU | HC | Total |
| **Male** | 60 | 39 | 15 | 103 | 60 | 72 | 96 | 297 | 742 |
| **Female** | 38 | 32 | 4 | 107 | 21 | 29 | 108 | 443 | 782 |
| **Total** | 98 | 71 | 19 | 210 | 81 | 101 | 204 | 740 | 1524 |

Table 2: Frequency of different types of Horizontal crease patterns. $\chi^2 = 77.673$, Df = 7, p-value 0.

| Sex | Vertical STEM Patterns | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | V | VBP | VBD | VBPD | VTR | VTU | VTRU | VC | Total |
| **Male** | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 2 | 6 |
| **Female** | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 4 |
| **Total** | 2 | 2 | 0 | 2 | 0 | 0 | 2 | 2 | 10 |

Table 3: Frequency of different types of Vertical crease patterns. The chi-square test could not be performed because some expected frequencies were zero.

| Sex | Oblique STEM Patterns | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | O | OBP | OBD | OBPD | OTR | OTU | OTRU | OC | Total |
| **Male** | 5 | 11 | 4 | 19 | 12 | 3 | 23 | 33 | 110 |
| **Female** | 4 | 3 | 5 | 19 | 2 | 7 | 8 | 57 | 105 |
| **Total** | 9 | 14 | 9 | 38 | 14 | 10 | 31 | 90 | 215 |

Table 4: Frequency of different types of Oblique crease patterns. $\chi^2 = 27.093$, Df = 7, p-value 0.0003.

| Sex | Semi-lunar STEM Patterns | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S | SBP | SBD | SBPD | STR | STU | STRU | SC | Total |
| **Male** | 30 | 13 | 11 | 20 | 24 | 40 | 60 | 55 | 253 |
| **Female** | 6 | 5 | 10 | 20 | 6 | 8 | 78 | 54 | 187 |
| **Total** | 36 | 18 | 21 | 40 | 30 | 48 | 138 | 109 | 440 |

Table 5: Frequency of different types of Semi-lunar crease patterns. |$^{2}$ = 45.21, Df = 7, p-value= 1.24*10$^{-}$

| Sex | Cross STEM Patterns | | | |
|---|---|---|---|---|
| | XC | XR | XU | Total |
| **Male** | 14 | 5 | 0 | 19 |
| **Female** | 12 | 3 | 2 | 17 |
| **Total** | 26 | 8 | 2 | 36 |

*Table 6: Frequency of different types of Cross crease patterns. |$^{2}$ = 2.55, Df = 3, p-value 0.279*

## Descriptive Statistics of the Distances Between Crease Patterns

The maximum distance observed in the case of males between the creases in all the four parameters studied (ab, bc, a′b′, b′c′) was 10.26 in ab, and the minimum distance was found to be 1.19 in a′b′.

Meanwhile, in the case of females, the maximum and minimum distance observed were 7.98 in ab and 0.10 in b′c′. Significant differences were observed between male and female groups for all distances (p-values less than 0.05). A finger-wise descriptive analysis of the distance between creases was also performed.

An unpaired t-test was used to find the relation between the two values of means of the combined distance of creases abc(t-abc) of males and females. Value was calculated against a degree of freedom n-2 with $p<0.0001$. It was found that for the total sample, the difference was extremely statistically significant with a 95% confidence interval. The two-tailed p-value was less than 0.0001.

## Confidence interval:

The mean of male minus female = 1.60470.

95% confidence interval of this difference: From 1.366005 to 1.843395.

Intermediate values used in the calculation:

t = 13.2084, df = 798, standard error of difference = 0.121. Table 8 depicts the values of mean, SD, SEM, and N in an unpaired t-test. It was observed in the descriptive statistics study that the distance between the crease patterns in the case of males is comparatively larger than in females in all the parameters studied. The results obtained are comparable to only such study (John, 2021) where the author reported that in the case of males, the spacing between the ridge lines (named as crease in the present study) is higher as compared to females.

| **Group** | **MALE** | **FEMALE** |
|---|---|---|
| **Mean** | 7.0779 | 5.4732 |
| **SD** | 1.9516 | 1.4475 |
| **SEM** | 0.0976 | 0.0724 |
| **N** | 400 | 400 |

*Table 7: Unpaired T- test*

## Discussion

The present study was designed with the objective of studying the classification of knuckle crease patterns on dorsal aspects of a finger, to find whether they are individual and unique characteristics of each individual, and to determine the sex by studying features of knuckle crease patterns. The uniqueness of knuckle crease patterns has been highlighted in previous studies as a reliable biometric marker for forensic applications (Chattopadhyay & Sukul, 2012; Kumar, 2014). 800 samples of knuckle crease patterns were collected, and 2400 crease segments were analysed and classified. A new crease pattern was identified during this study, which was named Cross Pattern (X).

Knuckle crease patterns of each individual were manually classified and matched, considering various existing and novel parameters. Inter- and intra-individual matches of finger knuckle crease patterns were also performed, and it was observed that no two knuckle patterns were the same. Statistical analysis using the chi-square test showed a significant association between sex and the type of STEM pattern, suggesting that the distribution of specific patterns differs markedly between males and females. This aligns with findings that dermatoglyphic traits can exhibit sex-specific variations useful in forensic contexts (Acree, 1999; Gondvikar et al., 2009).

Other than classification, the distance between the 3 creases was measured from the two endings of the creases, i.e., right and left endings. It was observed that no two knuckle patterns were found to have all 4 measurements similar. Sex determination through the distance between the creases was also studied, and it was found that the average distance between the creases in the case of males is higher than that of females. It was statistically proven by the t-test with a 95% confidence level.

## Conclusions

The findings of the study would be significant from a forensic point of view. Finger knuckle crease patterns were found to be individual, unique, and classifiable in nature. By identifying the classification of FKP and by using parameters like inter-distance between the creases and combined distance (t-abc), estimation of the sex of an individual can be done, which helps the investigator in narrowing down the pool of suspects. FKP can be used as a biometric trait for the verification of individuals in various security check-ins, attendance systems, electronic fund transfer devices, etc.

The core outcome of the research study are:

- Finger knuckle patterns are unique and individualistic in nature, i.e., no two Finger knuckle patterns were found to be identical.
- Systematic classification of finger knuckle patterns can be done. i.e., FKP are classifiable.
- A new classification pattern was identified.
- There is a significant association between sex and the type of STEM pattern. The distribution of STEM patterns differs significantly between males and females.
- It is possible to determine the sex from the dorsal finger knuckle patterns, Using the combined distance between the creases (t-abc) and using the inter distance between the a, b and c.
- The forensic significance of Knuckle crease patterns is given while adding new parameters to the already existing ones.

This research pioneers the exploration of finger knuckle crease patterns (FKPs), highlighting their individuality, classification, and forensic utility. A significant contribution is the identification of the previously unrecognised *Cross pattern*, enriching the scope of FKP studies. Detailed manual analysis ensured high precision and reliability, while statistical assessments confirmed the potential of FKPs in distinguishing sex, showcasing their robustness in forensic science. By emphasising their applicability in real-world investigations, this study underscores the transformative role of FKPs in advancing identification methods.

## Limitations of the Research

The findings of this study are based on a sample size of 800 images from 80 individuals and may not be universally applicable to diverse populations. Additionally, the impact of external factors such as humidity, pressure, or prolonged environmental exposure was not assessed, which could influence the results. Furthermore, using a mobile camera for data collection introduces variability compared to high-end biometric imaging systems, potentially affecting the consistency and accuracy of the images.

## Future scope and recommendations

More extensive studies with larger sample sizes are recommended to verify the findings of the present work. Various parameters like the effect of climate, long-term exposure to water, change in the angle of a finger, the effect of pressure, etc. on the FKP must be considered in future studies. Similar studies in different populations of the world are recommended to verify and strengthen the general applicability of these parameters.

## Declarations

### Ethics approval and consent to participate

Ethical approval is not required. Informed consent was obtained from the participants, and other demographics were obtained after the protocols and rights were explained to them.

### Consent for publication

Both authors have consented to submit this work to the Mapana Journal of Sciences for publication consideration.

All authors have agreed to the submission to the journal and declare that the manuscript is not currently under submission to any other journal.

### Availability of data and materials

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

### Competing Interests

The authors declare that they have no competing interests.

### Funding

Not applicable.

### Author's contributions

Author1 conceptualised the main idea and research structure, did data collection, analysis, and interpretation, and wrote the original manuscript. Author2 supervised the project and oversaw overall direction and planning. Both authors read and approved the final manuscript.

### Acknowledgements

The authors would like to extend their profound gratitude to all the individuals whose knuckle images were used in this study; without your participation, this study would not have been possible.

### List of Abbreviations

FKP Finger Knuckle Patterns

H - Horizontal

V - Vertical

O - Oblique

S - Semi lunar

M - Mixed

C - Cross

BP - Body Proximal

BD - Body Distal

BPD - Body Proximal & Distal

TR - Terminal Radial

TU - Terminal Ulnar

TRU - Terminal Radial Ulnar

C - Combined

## References

[1]. Acree, M. A. (1999). Is there a gender difference in fingerprint ridge density? *Forensic Science International, 102*(1), 35–44.

[2]. Badrinath, G.S., Nigam, A., Gupta, P. (2011). An Efficient Finger-knuckle-print based recognition system fusing SIFT and SURF matching scores. Information and communication security ISBN 978-3- -642-25242-6,374-387.

[3]. Bhuvaneshwari, S., Chand, S., Chaudhari, D., Manohar, B., Buyan, L., & Srinivasan, S. (2023). Dactoscopy in human identification: A retrospective study in Bhubaneswar city. *Journal of Pharmacy and Bioallied Sciences, 15*(Suppl 1), S326–S329. https://doi.org/10.4103/jpbs.jpbs_526_22

[4]. Charles C. (1997). Knuckle profile identity verification system. US Patent 5594806. Google Patent

[5]. Chattopadhyay, S., & Sukul, B. (2012). Identification from dorsal finger pattern: A new approach. Medicine, Science and the Law, 52(1), 17–21.

[6]. Chavan, V., & Kumar, R. (2023). Exploring the potential of ridge density as a measure of sex identification. *11*, 2020.

[7]. Gondvikar, S. M., Indurkar, A., Degwekar, S., & Bhowate, R. (2009). Cheiloscopy for sex determination. *Journal of Forensic Dental Sciences, 1*(2), 56–60.

[8]. Han, C., Cheng, H., Lin, C., & Fan, K. (2003). Personal authentication using palmprint features. *Pattern Recognition, 36*(2), 371–381.

[9]. Jain, A. K., & Feng, J. (2009). Latent palmprint matching. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 31*(6), 1032–1047.

[10]. Jain, T., & Kumar, R. (2019). A study of vein recognition system. *Acta Informatica Malaysia, 3*, 13–15.10.26480/aim.01.2019.13.15

[11]. John, A. (2021). Comparative study of finger knuckle prints-pilot study. Journal of Forensic Research, 12(9), 4–7.

[12]. Kaushal, N., & Kaushal, P. (2011). Human identification and fingerprints: A review. *Journal of Biometrics & Biostatistics, 2*(4), Article 123. https://doi.org/10.4172/2155-6180.1000123

[13]. Kennedy, R. A. (1996). Uniqueness of bare feet and its use as a possible means in identification. *Forensic Science International, 82*(1), 81–87.

[14]. Krishan, K. (2007). Anthropometry in forensic medicine and forensic science: "Forensic anthropometry." *Internet Journal of Forensic Sciences, 2*(1). DOI:10.5580/1dce

[15]. Kumar, A., & Ravikanth, C. (2009). Personal Authentication Using Finger Knuckle Surface. IEEE Transactions on Information Forensics and Security, 4, 98-110.

[16]. Kumar, A., & Zhou, Y. (2009). Personal identification using finger knuckle orientation features. Electronics Letters, 45, 1023.

[17]. Kumar, A. (2014). Importance of being unique from finger dorsal patterns: Exploring minor finger knuckle patterns in verifying human identities. IEEE Transactions on Information Forensics and Security, 9(8), 1288–1298.

[18]. Limson, K. S., & Julian, R. (2004). Computerized recording of the palatal rugae pattern and an evaluation of its application in forensic identification. Journal of Forensic Odonto-Stomatology, 22(1), 1–4.

[19]. Meijerman, L., Thean, A., & Maat, G. (2005). Earprints in forensic investigations. *Forensic Science, Medicine, and Pathology, 1*(4), 247–256. https://doi.org/10.1385/FSMP:1:4:247

[20]. Mishra, G., Ranganathan, K., & Saraswathi, T. R. (2009). Study of lip prints. *Journal of Forensic Dental Sciences, 1*(1), 28–31. https://doi.org/10.4103/0974-2948.50885

[21]. Moore, K.L., Dalley. (2005). Clinical Oriented Anatomy. 5th edn. USA: Lippincott Williams and Wilkins.

[22]. Nandy, A. (2007). Principles of forensic medicine (2nd ed.). Kolkata, India: New Central Book Agency.

[23]. Nanni, L., & Lumini, A. (2009). A multi-matcher system based on knuckle-based features. Neural Computing and Applications, 18, 87-91.

[24]. Nayak, V. C., Rastogi, P., Kanchan, T., Lobo, S. W., Yoganarasimha, K., Nayak, S., Rao, N. G., Kumar, G. P., Shetty, B. S. K., & Menezes, R. G. (2010). Sex differences from fingerprint ridge density in the Indian population. *Journal of Forensic and Legal Medicine, 17*(2),84–86. https://doi.org/10.1016/j. jflm.2009.09.002

[25]. Sankhyan, D. (2016). Iris patterns as a biometric tool for forensic identifications: A review. *Brazilian Journal of Forensic Sciences, Medical Law and Bioethics, 5*(2), 205–217.

[26]. Swati, M. R., and Ravishankar, M., (2013). Finger Knuckle Print recognition based on Gabor feature and KPCA+LDA. International Conference on Emerging Trends in Communication, Control, Signal Processing and Computing Applications (C2SPCA), Bangalore, India, 1-5.

[27]. Trabelsi, Selma & Samai, Djamel & Meraoumia, Abdallah & Bensid, Khaled & Benlamoudi, Azeddine & Dornaika, Fadi & taleb-ahmed, Abdelmalik. (2020). Finger-Knuckle-Print Recognition Using Deep Convolutional Neural Network. 163-168. 10.1109/CCSSP49278.2020.9151531.

[28]. Vidhyapriya, R., & S, L. R. (2019). Personal Authentication Mechanism Based on Finger Knuckle Print. Journal of Medical Systems, 43(8), 232.

[29]. Warwick R, Williams P.L. (1973). Gray's Anatomy. 35th edn. Edinburg: Longman.

[30]. Woodard, D., & Flynn, P.J. (2005). Finger surface as a biometric identifier. Comput. Vis. Image Underst., 100, 357-384.

[31]. Yang, W., Wang, S., Hu, J., Zheng, G., & Valli, C. (2019). Security and accuracy of fingerprint-based biometrics: A review. *Symmetry, 11*(2),141. https://doi.org/10.3 390/sym11020141

[32]. Zhang, L., Zhang, D. (2009). Finger-Knuckle Print: A New Biometric Identifier, Image Processing ICIP, IEEE International Conference, 1981-84.