

# Hand Determination of Whorl Patterns Using Axis Slant

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**Abstract:** This study examines the use of whorl slant in hand determination through whorl axis analysis. Two certified latent print examiners determined the whorl axis for 550 whorls. They found a higher percentage of right slant whorls in the right hand (92.7% and 93.8%) and a higher percentage of left slant whorls in the left hand (91.0% and 91.2%). A small percentage of whorls absent of any axis were reported in both hands. Interestingly, a higher percentage of right slant whorls were present in the left index finger, and a higher percentage of left slant whorls were present in the right index finger. Applying the chi-square test to overall whorl slant data from each hand demonstrated that using the whorl axis to determine hand orientation is statistically significant.

## Introduction

Hand determination of a single latent fingerprint can reduce the amount of time a latent print examiner spends conducting comparisons. One example of hand determination most commonly used by latent print examiners is based on frequency data that applies to left and right slant loops. It is known that the frequency of radial loops, loops that flow in the direction of the radial bone, are approximately 4.0% of loops, whereas ulnar loops, loops that flow in the direction of the ulna bone, are approximately 96.0% of loops [1]. This means that if a latent print examiner has a latent fingerprint that is a left slant

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loop, it should be interpreted as an ulnar loop, because they are more frequent. This would mean that the left slant loop latent fingerprint would most likely be from the left hand. A latent fingerprint with a right slant loop would most likely be from the right hand. Additionally, it is more common to find a radial loop in the index fingers [2]. Therefore, a latent print examiner understands that if the left slant latent print is not found in the left hand, he or she should examine the right index finger next or vice versa. Latent print examiners who understand the frequency of right and left slant loops become more efficient in their casework, identifying latent prints in less time by decreasing their search time.

Much like loops, whorls also have a right or left slant, which has often been overlooked by examiners. Cummins and Midlo have explained that central pocket loop whorls, like loops, can be classified as ulnar or radial [3]. Cowger [4] explained that whorl patterns, like loops, generally exhibit a slant. He described right slanting whorls as being more prevalent in the right hand and left slanting whorls as being more prevalent in the left hand; however, no data was cited. It is also noted that it is common to find radial slanting whorls in the index fingers, meaning a left slant whorl in the right index finger and a right slant whorl in the left index finger. More recently, Kapoor and Badiye reported data for latent fingerprint hand determination that was based on the slant of the central portion of the whorl pattern. They determined that 79.2% of right slant whorls were found in the right hand and 73.6% of left slant whorls were found in the left hand [5].

This study explores the usage of whorl slant and proposes a latent fingerprint hand determination method by analyzing the axis of the whorl. The whorl axis is defined as the imaginary line from top to bottom of a whorl that passes through the central pattern area in which the pattern could be rotated (Figure 1). In this method, the whorl can be thought of as a globe. The whorl axis may be left or right in slant. If the axis points down and to the left, it is a left slant whorl, and if it points down and to the right, it is a right slant whorl. Furthermore, this study determines the percentage of right and left slant whorls in each finger to determine whether the whorl axis is a useful tool for hand determination.



*Figure 1*

*An illustration of the whorl axis (drawn in red). It is drawn down and to the right, indicating a right slant whorl.*

## **Materials and Methods**

Fingerprint cards ( $n = 202$ ) of Caucasian males were obtained from the record files of the Columbus County Sheriff's Office in Whiteville, North Carolina. All samples were taken from a standard fingerprint card containing 10 inked fingerprint impressions that were collected from February 1931 through August 1960.

The fingerprints were classified according to arch, loop, and whorl [6]. It should be noted that not every fingerprint was analyzed, either because of poor quality of the recording of the fingerprint or an amputation of an individual finger. These recorded fingerprints were marked as not available (NA) when classifying each fingerprint card. Two latent print examiners, certified by the International Association for Identification (IAI), independently classified the fingerprint cards. The fingerprint cards were classified to determine the pattern frequency for the sampled population as well as each finger of the sampled population.

After all of the fingerprint cards were classified, each whorl pattern was further analyzed to determine the whorl axis. The same two IAI-certified latent print examiners independently drew the whorl axis on a copy of the fingerprint card. The whorl axis was then recorded as right, left, or absent. If the drawn axis pointed down and to the left (Figure 2), it was recorded as a left slant whorl; if it pointed down and to the right (Figure 3), it was recorded as a right slant whorl. If the axis was straight down the pattern or the pattern that was recorded was an accidental whorl,

which is devoid of an axis, it was recorded as absent (Figure 4). The results for both examiners were captured, and the whorl axis percentage for each finger as well as hand was calculated. Statistical analysis of the overall whorl axis data for each hand was performed using a chi-square test, at a  $p < 0.01$ .

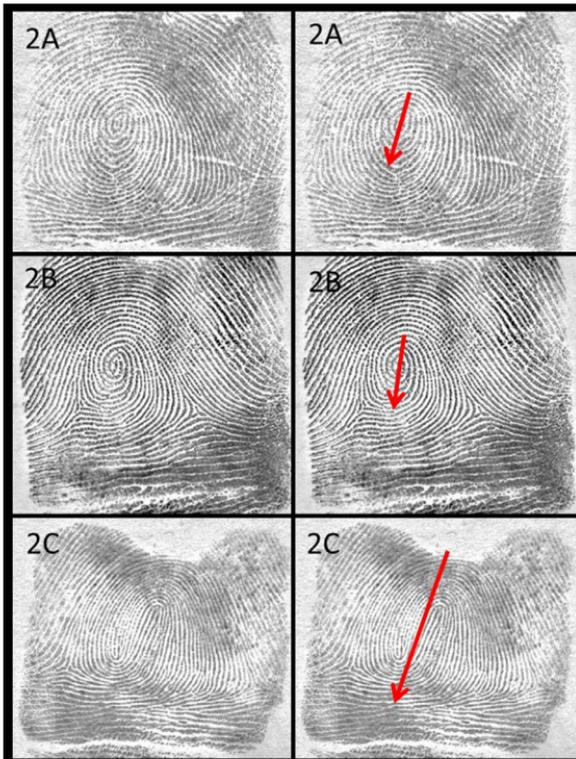


Figure 2

*Illustration of the left slant whorl axis for a plain whorl (A), central pocket loop whorl (B), and double loop whorl (C). The whorl axis is drawn on the right image in red.*

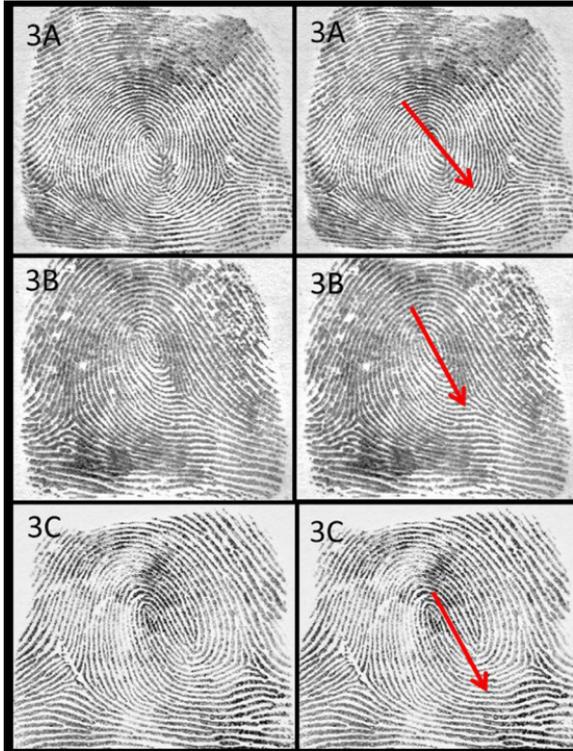


Figure 3

*Illustration of the right slant whorl axis for a plain whorl (A), central pocket loop whorl (B), and a double loop whorl (C). The whorl axis is drawn on the right image in red.*



Figure 4

*Examples of the two whorl pattern types that can possess an absent whorl axis. The pattern on the left is a plain whorl with a whorl axis that is traced straight down. The pattern on the right is an accidental whorl, which does not have a traceable axis.*

## Results

Table 1 reports the pattern frequency for 2,020 fingerprints taken from 202 Caucasian males for each finger as well as pooled for all fingers. Finger values corresponding to right and left hands are denoted as 1 to 10. The thumbs were numbered 1 and 6, the index fingers 2 and 7, the middle fingers 3 and 8, the ring fingers 4 and 9, and the little fingers 5 and 10. The loop pattern type was the most prevalent type that was observed, followed by the whorl pattern type and arch pattern type, with an overall occurrence frequency of 64.7%, 27.2% and 7.0%, respectively. A closer analysis of the 550 reported whorl patterns found that the highest whorl pattern occurrence was in the thumbs and ring fingers.

Pattern Distribution									
Hand	Digit	# Loops		# Whorls		# Arches		#NA	
Right	1	112	55.4%	85	42.1%	4	2.0%	1	0.5%
	2	113	55.9%	53	26.2%	33	16.3%	3	1.5%
	3	140	69.3%	42	20.8%	18	8.9%	2	1.0%
	4	99	49.0%	91	45.0%	8	4.0%	4	2.0%
Left	5	166	82.2%	30	14.9%	3	1.5%	3	1.5%
	6	116	57.4%	77	38.1%	8	4.0%	1	0.5%
	7	111	55.0%	59	29.2%	3	14.9%	2	1.0%
	8	147	72.8%	26	12.9%	27	13.4%	2	1.0%
	9	132	65.3%	61	30.2%	9	4.5%	0	0.0%
	10	170	84.2%	26	12.9%	2	1.0%	4	2.0%
<b>Total</b>		<b>1306</b>	<b>64.7%</b>	<b>550</b>	<b>27.2%</b>	<b>142</b>	<b>7.0%</b>	<b>22</b>	<b>1.1%</b>

NA means the quality of the recorded fingerprint was too poor for analysis or an amputation of an individual finger was present.

*Table 1*

*Overall pattern type frequency for 202 Caucasian males as well as pattern type finger by finger.*

The results of whorl axis analysis for 550 whorl patterns are reported in Tables 2 and 3, examiner A and examiner B, respectively. The overall results found a higher percentage of right slant whorls in the right hand, 92.7 and 93.8%, and a higher percentage of left slant whorls in the left hand, 91.0 and 91.2%. A lower percentage was reported for right slant whorls in the left hand, 6.2 and 7.3%, and a lower percentage of left slant whorls in the right hand, 8.8 and 9.0%. Whorls absent of any axis were reported in both hands.

A closer examination of the individual finger data from both examiners (Tables 2 and 3) found that the highest percentage of right slant whorls in the left hand were on the index finger, 90.5% and 100.0%. The highest percentage of left slant whorls in the right hand were on the index finger, 81.0% and 85.0%. No right slant whorls were found in the left ring or left little fingers. Furthermore, no left slant whorls were found in the right little finger.

Whorl Axis Distribution Examiner A								
Hand	Digit	Right		Left		Absent		N
Right	1	82	30.0%	1	0.4%	2	4.1%	85
	2	29	10.6%	17	7.5%	7	14.3%	53
	3	33	12.1%	1	0.4%	8	16.3%	42
	4	83	30.4%	1	0.4%	7	14.3%	91
	5	29	10.6%	0	0.0%	1	2.0%	30
	<b>Total</b>	<b>256</b>	<b>93.8%</b>	<b>20</b>	<b>8.8%</b>	<b>25</b>	<b>51.0%</b>	<b>301</b>
Left	6	0	0.0%	75	32.9%	2	4.1%	77
	7	17	6.2%	30	13.2%	12	24.5%	59
	8	0	0.0%	24	10.5%	2	4.1%	26
	9	0	0.0%	54	23.7%	7	14.3%	61
	10	0	0.0%	25	11.0%	1	2.0%	26
	<b>Total</b>	<b>17</b>	<b>6.2%</b>	<b>208</b>	<b>91.2%</b>	<b>24</b>	<b>49.0%</b>	<b>249</b>
<b>Total</b>		<b>273</b>	<b>49.6%</b>	<b>228</b>	<b>41.5%</b>	<b>49</b>	<b>8.9%</b>	<b>550</b>

Right = right slant; Left = left slant; Absent = no slant or accidental whorl pattern type.

Table 2

Whorl axis distribution for IAI-certified latent print Examiner A.

Whorl Axis Distribution Examiner B								
Hand	Digit	Right		Left		Absent		N
Right	1	81	28.3%	1	0.4%	3	10.0%	85
	2	29	10.1%	17	7.3%	7	23.3%	53
	3	38	13.3%	2	0.9%	2	6.7%	42
	4	87	30.4%	1	0.4%	3	10.0%	91
	5	30	10.5%	0	0.0%	0	0.0%	30
	<b>Total</b>	<b>265</b>	<b>92.7%</b>	<b>21</b>	<b>9.0%</b>	<b>15</b>	<b>50.0%</b>	<b>301</b>
Left	6	1	0.3%	75	32.1%	1	3.3%	77
	7	19	6.6%	29	12.4%	11	36.7%	59
	8	1	0.3%	23	9.8%	2	6.7%	26
	9	0	0.0%	60	25.6%	1	3.3%	61
	10	0	0.0%	26	11.1%	0	0.0%	26
	<b>Total</b>	<b>21</b>	<b>7.3%</b>	<b>213</b>	<b>91.0%</b>	<b>15</b>	<b>50.0%</b>	<b>249</b>
<b>Total</b>		<b>286</b>	<b>52.0%</b>	<b>234</b>	<b>42.5%</b>	<b>30</b>	<b>5.5%</b>	<b>550</b>

Right = right slant; Left = left slant; Absent = no slant or accidental whorl pattern type.

Table 3

Whorl axis distribution for IAI-certified latent print Examiner B.

Interestingly, the percentages of right slant whorls found in the right hand and left index finger were calculated at 99.3% and 100%. Furthermore, the percentages of left slant whorls found in the left hand and right index finger were 98.3% and 98.7%.

Applying the chi-square test to overall whorl slant data from each hand demonstrated that using the whorl axis to determine hand orientation is statically significant ( $p < 0.00001$ ),  $x^2 = 362.6$  for Examiner A and  $x^2 = 364.0$  for Examiner B.

## Discussion

Pattern frequency data has been used by latent print examiners to conduct comparisons more efficiently, often assisting in determining from which hand the latent fingerprint originated. The use of pattern frequency is most commonly seen among examiners when they are conducting comparisons for loops. The slant of the loop is used to determine the hand from which it originated. The current study demonstrates that using the slant of a whorl, based on its axis, is also a useful and effective tool for hand determination.

The pattern frequency for whorls in this study was reported as 27.2% (Table 1). This pattern frequency fell within the previously reported data by Cummins and Mildo, Holt, and Cowger, 25.4%, 26.1%, and 30.4%, respectively [2, 3, 7]. The pattern frequency for loops and arches also fell within the range reported by Cummins and Midlo, Holt, and Cowger. Additionally, Cowger reported a higher whorl pattern frequency in the thumbs and ring fingers, which is in agreement with the current study.

Recently, Kapoor and Badiye reported that 79.2% of right slant whorls were found in the right hand and 73.6% of left slant whorls were found in the left hand. This study reported higher percentages than Kapoor and Badiye. It reported that 92.7% and 93.8% of right slant whorls were found in the right hand and 91.0% and 91.2% of left slant whorls were found in the left hand. The differences reported between the two studies may be due to the technique used to determine the slant of the whorl. In the method proposed by Kapoor and Badiye, a rectangle is drawn through the central area of the pattern and uses the tilt of the top of the rectangle to determine the slant or hand, whereas the current study draws a line from top to bottom through the center most ridges of the pattern area, and the bottom direction determines the whorl slant or hand. It should also be noted that although both studies reported whorls absent of an axis,

Kapoor and Badiye had a higher percentage of absent whorls. Both studies found that hand determination using whorl slant is statistically significant when applying the chi-square test.

Furthermore, this study reported higher percentages of the opposite slant whorl in the opposing hand index finger. Interestingly, when the whorl slant data of the opposing index finger was combined with the right or left hand whorl slant, data percentages reached 99.3% and 100.0% for right slant whorls and 98.3% and 98.7% for left slant whorls. Similarly, data presented by Cowger found that 99% of right slant loops are found in the right hand and left index finger and 98.8% of left slant loops are found in the left hand and right index finger [8]. This data demonstrates that right and left slant whorls behave in the same matter as right and left slant loops

## **Conclusion**

This study demonstrates that using the whorl axis to determine the slant of a whorl is a useful tool for determining the hand from which a fingerprint originated. No longer should latent print examiners think of the slant of only a loop; they should also think of the slant of a whorl when analyzing latent prints. This study reported that much like the slant of a loop, a right-slanted whorl is most likely associated with the right hand and a left-slanted whorl is most likely associated with the left hand. Like loops, exceptions were found with the index fingers that showed an increased amount of the opposing slanted whorls. Using whorl slant as a tool for conducting comparisons will make latent print examiners more efficient in their case work by reducing search time and increasing the speed and confidence of their analyses.

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