Technical Note

Angle of Impact Determination from Bullet Holes

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Abstract: This paper discusses using the shape of a bullet hole to determine the angle of impact of the bullet.

Introduction

When a nontumbling bullet has perforated solid, flat objects, an examiner can oftentimes discern the directionality of the bullet based on physical evidence such as bullet wipe of the lead-in mark, the pinch point, or the bow effect in paint [1]. Dr. Victor Balthazard was credited as having recognized the relationship that exists between the length and width of a resulting bloodstain and the angle at which the droplet impacts, because the shape of the bloodstain defines the angle of impact [2]. Haag also eluded to this same scientific principle applying to the angle of incidence or impact of bullets into virtually flat objects [3]. The circular cross-section of the nose of a cylindrical projectile approximates a spherical shape analogous to a blood droplet in flight as it impacts a surface, providing a very general notion of incident angle based on the roundness or out-of-roundness of a bullet hole. Therefore, it might be possible to determine the angle of impact from bullet holes by using the same trigonometric relationship between the major and minor axis of the observed bullet hole, as concluded by Balthazard for determining the angle of impact for a blood droplet.

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The goal of this study was to compare the known angle of impact of bullets fired into flat media (sheetrock, wood, and vehicle sheet metal) with the calculated angle of impact, as determined by Balthazard for bloodstains, to correlate the validity of the calculation for the angle of impact of bullets.

Materials

Firearm and Ammunition

Walther, P4, 9 mm (Carl Walther Gmbh, Ulm, Germany)

PMC, 115 grain, 9 mm, full copper-jacketed (PMC Ammunition, Houston, TX) (diameter = 0.355"/9.02 mm)

Sheetrock (water resistant)

Wood pressboard (5/8" thick)

Sheet metal (cargo van siding purchased from a local auto wrecker yard)

Method

The aforementioned ammunition was fired at a distance of one yard using a ransom rest and laser set at 10-degree increments from 10 to 90 degrees. Three bullet holes were produced in each target medium (drywall, pressboard, metal) for each of the 10-degree increments. Each resulting bullet hole was examined and measured by two examiners. Both used two methods: (1) an ellipse template [4] and (2) calipers to measure the widest portion of the bullet hole and then also using that widest point as the half-length point for measuring the elongated portion of the hole. Both examiners calculated the approximate strike angle using the width-to-length ratio [4]. The results of both examiners' measurements and calculated angles were then compared to the known angles (Tables 1–6).

Results

Wood Pressboard

Template-Based Method of Estimation

Thirty-nine of the 54 calculated angles of impact were within 10 degrees of the known impact angle. The variation of average determinations of impact angles ranged from a low of 2.9 degrees from the known impact angle of 80 degrees to a high of 11.2 degrees from the known impact angle at 40 degrees (Table 1).

There was a high level of consistency between Examiner A's and Examiner B's average determination of the angle of impact. The largest difference between the combined averages for the calculated angles per known impact angle between the two examiners was 9.6 degrees, and only 6 of the 27 bullet holes resulted in calculated angles with more than a 10-degree difference between the examiners.

Half-Length Method of Estimation

Forty-six of the 54 calculated angles were within approximately 10 degrees of the known impact angle. Specifically, the difference between the combined averages for the calculated angles ranged from a high of 10.6 degrees difference from the known impact angle of 70 degrees to an exact determination of 90 degrees at the known impact angle of 90 degrees (Table 2).

There was a high level of consistency between Examiner A's and Examiner B's average determination of the angle of impact. The largest difference between the combined averages for the calculated angles per known impact angle between the two examiners was 6.3 degrees, and only 2 of the 27 bullet holes resulted in calculated angles with more than a 10-degree difference between examiners.

Sheetrock

Template-Based Method of Estimation

Sixteen of 54 calculated angles of impact were more than 10 degrees off of the known angle. The difference between the combined averages for the calculated angles ranged from a low of 1.3 degrees from the known impact angle of 30 degrees to a high of 14.1 degrees from the known impact angle at 50 degrees (Table 3).

The level of consistency between Examiner A's and Examiner B's average determination of the angle of impact showed a range from a 0.3-degree difference to as high as a 12.6-degree difference. Furthermore, 11 of the 27 bullet holes (i.e., 40 %) resulted in calculated angles with more than a 10-degree difference between examiners.

Half-Length Method of Estimation

Forty-four of the 54 calculated angles of impact were within 10 degrees of the known impact angle. The difference between combined averages for the calculated angles ranged from two angles (both 20 degrees and 90 degrees) varying 1.6 degrees from the known impact angle to a high variance of 12.5 degrees from the known impact angle at 60 degrees (Table 4).

Except for one fairly large disparity of 12.9 degrees (when Examiner A calculated an average angle of impact of 68.1 degrees versus Examiner B's calculated average angle of impact of 55.2 degrees for the known impact angle of 50 degrees), there was a high level of precision between the examiners. This is further supported by the fact that only 3 of the 27 bullet holes resulted in calculated angles with more than a 10-degree difference between examiners.

Vehicle Sheet Metal

Template-Based Method of Estimation

All three of the bullets fired into the sheet metal target media at the known impact angle of 10 degrees did not penetrate the sheet metal because the impact angle of 10 degrees was ostensibly below the critical angle for penetration of the media. However, despite this fact, the resulting elliptical ricochet mark in the paint's surface still allowed one examiner to use the template to estimate the width and length, which resulted in an average calculation of 5.7 degrees.

Twenty of the 48 calculated angles of impact were within approximately 10 degrees of the known impact angle. The difference between the combined averages for the calculated angles ranged from a low of 2.1 degrees from the known impact angle of 20 degrees to a high of 21.8 degrees from the known impact angle at 50 degrees (Table 5).

Except for one large disparity of 28.1 degrees (when Examiner A calculated an average angle of impact of 61.9 degrees versus Examiner B's calculated average angle of impact at 90 degrees for the known impact angle of 70 degrees), there was a high level of precision between the examiners. The average calculated angles of impact for the remaining determinations between the two examiners were all within less than 5 degrees of each other (Table 5).

Half-Length Method of Estimation

Twenty-three of the 48 calculated angles of impact were within approximately 10 degrees of the known impact angle. The difference between the combined averages for the calculated angles ranged from a high of 23 degrees[1] from the known angle of 40 degrees to an exact determination at the known angle of 90 degrees (Table 6).

The variability of the calculated angles of impact ranged from a low of 12.4 degrees less than the known impact angle at 60 degrees to an overestimation of 2.2 degrees at the known impact angle of 80 degrees (Table 6).

There was a high level of consistency between Examiner A's and Examiner B's average determination of the angle of impact. All calculated angles were within 10 degrees, and the average of the calculated angle determinations between the two examiners were all within less than 2 degrees (Table 6).

[1] We originally attributed these wide variances of approximately 20 degrees off of the known impact angles to be due to the overall increased rigidity of the target media adjacent to our target areas. However, the test shots fired at the 30-degree impact angle were actually closest to the structural supports, even though the test shots only perforated the sheet metal and did not hit the supports. Haag indicated that typical vehicular sheet metal is 22 gauge and measures at a thickness of 0.031 to 0.032 inches [5]. The cargo van siding that we were able to obtain for the study was 0.037 to 0.055 inches in thickness (therefore 7 to 30% thicker), which may have had some effect on the observed results.

Impact Angle	Examiners A & B	Bullet Hole Width (Inches)	Bullet Hole Length (Inches)	Calculated Angle of Impact (Degrees)	Average of Examiners A & B	Difference Between Examiners A & B (Degrees)	Combined Average of Both Examiners	Difference of Combined Avg. from Known (Degrees)
10°	1A	0.352	3.430	5.9				
	1B	0.352	3.340	6.3	6.1			
	1C	0.360	3.260	6.3				
						0.4	6.3	-3.7 < known
	2A	0.387	3.431	6.5				
	2B	0.368	3.282	6.5	6.5			
	2C	0.374	3.240	6.6				
20°	1A	0.389	1.770	12.7				
	1B	0.371	1.580	13.6	13.2			
	1C	0.363	1.570	13.4				
						1.2	12.6	-7.4 < known
	2A	0.328	1.704	11.1				
	2B	0.324	1.606	11.6	12.0			
	2C	0.365	1.575	13.4				
30°	1A	0.417	1.230	19.8				
	1B	0.351	0.905	22.8	20.0			
	1C	0.356	1.190	17.4				
						2.7	21.3	-8.7 < known
	2A	0.353	0.935	22.2				
	2B	0.336	0.890	22.2	22.7			
	2C	0.348	0.865	23.7				
40°	1A	0.363	0.986	21.6				
	1B	0.343	0.888	22.7	24.0			
	1C	0.404	0.865	27.8				
						9.6	28.8	-11.2 < known
	2A	0.363	0.592	21.6				
	2B	0.344	0.553	38.5	33.6			
	2C	0.351	0.539	40.6				
50°	1A	0.352	0.650	32.5				
	1B	0.356	0.555	39.9	36.7			
	1C	0.408	0.669	37.6				
						8.7	40.4	-9.6 < known
	2A	0.341	0.473	46.1				
	2B	0.327	0.453	46.2	44.0			
	2C	0.308	0.481	39.8				
60°	1A	0.340	0.427	52.7				
	1B	0.340	0.441	50.4	52.2			
	1C	0.338	0.421	53.4				
						2.8	53.6	-6.4 < known
	2A	0.343	0.433	52.4				
	2B	0.344	0.390	61.9	55.0			
	2C	0.347	0.449	50.6				
70°	1A	0.354	0.372	72.0				
	1B	0.348	0.441	52.1	59.6			
	1C	0.348	0.426	54.8				
						8.3	63.8	-6.2 < known
	2A	0.333	0.362	66.9				
	2B	0.340	0.373	65.7	67.9			
	2C	0.348	0.368	71.0				
80°	1A	0.345	0.349	81.1				
	1B	0.343	0.354	75.7	77.7			
	1C	0.343	0.353	76.4				
						1.3	77.1	-2.9 < known
	2A	0.342	0.353	76.3				
	2B	0.346	0.356	76.4	76.4			
	2C	0.345	0.353	76.4				
90°	1A	0.349	0.350	81.9				
	1B	0.349	0.350	81.9	81.9			
	1C	0.349	0.350	81.9				
						3.6	80.1	-9.9 < known
	2A	0.341	0.348	78.5				
	2B	0.349	0.357	77.8	78.3			
	2C	0.354	0.361	78.7				

Table 1
Wood pressboard target media (template method).

Impact Angle	Examiners A & B	Bullet Hole Width (Inches)	Bullet Hole Length (Inches)	Calculated Angle of Impact (Degrees)	Average: Examiners A & B	Difference Between Examiners A & B (Degrees)	Combined Average of Examiners	Difference of Combined Avg. from Known (Degrees)
10°	1A	0.340	2.23	8.7				
	1B	0.352	2.12	9.6	9.4			
	1C	0.371	2.13	10.0				
						0.1	9.4	-0.6 < known
	2A	0.336	2.19	8.8				
	2B	0.340	2.11	9.2	9.3			
	2C	0.367	2.14	9.8				
20°	1A	0.363	1.024	20.7				
	1B	0.348	1.052	19.3	19.4			
	1C	0.348	1.11	18.3				
						0.8	19	-1.0 < known
	2A	0.339	1.056	18.7				
	2B	0.339	1.026	19.2	18.6			
	2C	0.349	1.134	17.9				
30°	1A	0.363	0.816	26.4				
	1B	0.357	0.838	25.2	27.5			
	1C	0.366	0.712	30.9				
						1.2	28.1	-1.9 < known
	2A	0.363	0.786	27.5				
	2B	0.351	0.722	29.0	28.7			
	2C	0.360	0.728	29.6				
40°	1A	0.357	0.486	47.3				
	1B	0.350	0.454	50.4	50.4			
	1C	0.415	0.516	53.5				
						3.1	48.9	+8.9 > known
	2A	0.350	0.508	43.5				
	2B	0.351	0.426	55.4	47.3			
	2C	0.373	0.546	43.0				
50°	1A	0.356	0.570	38.7				
	1B	0.388	0.492	52.1	45.5			
	1C	0.444	0.620	45.7				
						6.3	42.3	-7.7 < known
	2A	0.347	0.552	38.9				
	2B	0.386	0.512	48.9	39.2			
	2C	0.324	0.652	29.7				
60°	1A	0.348	0.426	54.8				
	1B	0.348	0.402	60.0	57.5			
	1C	0.348	0.412	57.7				
						1.8	56.6	-3.4 < known
	2A	0.375	0.424	62.1				
	2B	0.342	0.418	54.9	55.7			
	2C	0.344	0.448	50.1				
70°	1A	0.362	0.400	64.8				
	1B	0.345	0.434	52.7	60.3			
	1C	0.345	0.386	63.4				
						1.8	59.4	-10.6 < known
	2A	0.356	0.396	64.0				
	2B	0.352	0.460	50.0	58.5			
	2C	0.362	0.412	61.5				
80°	1A	0.360	0.358	90.0				
	1B	0.353	0.358	78.5	80.7			
	1C	0.345	0.358	73.7				
						1.6	79.9	-0.1 < known
	2A	0.351	0.320	90.0				
	2B	0.352	0.368	73.1	79.1			
	2C	0.354	0.368	74.2				
90°	1A	0.349	0.348	90.0				
	1B	0.349	0.348	90.0	90.0			
	1C	0.352	0.352	90.0				
						0.0	90.0	0.0
	2A	0.368	0.368	90.0				
	2B	0.355	0.355	90.0	90.0			
	2C	0.356	0.356	90.0				

Table 2
Wood pressboard target media (half-length method).

Impact Angle	Examiners A & B	Bullet Hole Width (Inches)	Bullet Hole Length (Inches)	Calculated Angle of Impact (Degrees)	Average: Examiners A & B	Difference Between Examiners A & B (Degrees)	Combined Average of Examiners	Difference of Combined Avg. from Known (Degrees)
10°	1A	0.328	3.810	4.9				
	1B	0.341	4.020	4.9	5.0			
	1C	0.340	3.830	5.1				
						2.5	6.2	-3.8 < known
	2A	0.467	3.079	8.7				
	2B	0.415	3.330	7.2	7.5			
	2C	0.354	3.077	6.6				
20°	1A	0.333	1.080	17.9				
	1B	0.335	0.933	21.0	17.1			
	1C	0.345	1.610	12.4				
						2.1	16.1	-3.9 < known
	2A	0.343	1.275	15.6				
	2B	0.347	1.329	15.1	15.0			
	2C	0.353	1.422	14.4				
30°	1A	0.350	0.549	39.6				
	1B	0.344	0.607	34.5	37.0			
	1C	0.351	0.584	36.9				
						11.4	31.3	+1.3 > known
	2A	0.351	0.790	26.4				
	2B	0.349	0.794	26.1	25.6			
	2C	0.340	0.830	24.2				
40°	1A	0.333	0.442	48.9				
	1B	0.354	0.417	58.1	51.2			
	1C	0.342	0.471	46.6				
						12.6	44.9	+4.9 > known
	2A	0.366	0.588	38.5				
	2B	0.347	0.584	36.5	38.6			
	2C	0.347	0.531	40.8				
50°	1A	0.335	0.404	56.0				
	1B	0.348	0.370	70.2	63.4			
	1C	0.353	0.393	63.9				
						1.5	64.1	+14.1 > known
	2A	0.374	0.425	61.6				
	2B	0.350	0.419	56.6	64.8			
	2C	0.377	0.388	76.3				
60°	1A	0.342	0.357	73.3				
	1B	0.334	0.351	72.2	71.5			
	1C	0.322	0.345	68.9				
						1.6	70.7	+10.7 > known
	2A	0.341	0.362	70.4				
	2B	0.330	0.374	61.9	69.9			
	2C	0.356	0.365	77.3				
70°	1A	0.353	0.355	83.7				
	1B	0.344	0.363	71.4	79.6			
	1C	0.346	0.348	83.7				
						2.3	80.8	+10.8 > known
	2A	0.350	0.353	82.5				
	2B	0.330	0.338	77.5	81.9			
	2C	0.352	0.353	85.7				
80°	1A	0.339	0.337	90.0				
	1B	0.339	0.335	90.0	85.3			
	1C	0.327	0.337	75.9				
						0.3	85.4	+5.4 > known
	2A	0.329	0.338	76.7				
	2B	0.339	0.334	90.0	85.6			
	2C	0.345	0.341	90.0				
90°	1A	0.338	0.337	90.0				
	1B	0.330	0.345	73.1	84.4			
	1C	0.336	0.334	90.0				
						6.2	81.3	-8.7 < known
	2A	0.345	0.343	90.0				
	2B	0.326	0.338	74.7	78.2			
	2C	0.328	0.349	70.0				

Table 3
Sheetrock target media (template method).

Impact Angle	Examiners A & B	Bullet Hole Width (Inches)	Bullet Hole Length (Inches)	Calculated Angle of Impact (Degrees)	Average: Examiners A & B	Difference Between Examiners A & B (Degrees)	Combined Average of Examiners	Difference of Combined Avg. from Known (Degrees)
10°	1A	0.329	1.470	12.9				
	1B	0.329	1.410	16.8	13.4			
	1C	0.329	1.780	10.6				
						0.9	13.0	+3 > known
	2A	0.331	1.470	13.0				
	2B	0.333	1.400	13.8	12.5			
	2C	0.352	1.770	10.6				
20°	1A	0.330	0.838	23.2				
	1B	0.330	0.880	22.0	21.9			
	1C	0.330	0.928	20.4				
						0.6	21.6	+1.6 > known
	2A	0.355	1.200	17.2				
	2B	0.350	0.872	23.6	21.3			
	2C	0.375	0.956	23.1				
30°	1A	0.337	0.550	37.7				
	1B	0.337	0.588	34.9	34.8			
	1C	0.337	0.638	31.9				
						1.0	35.3	+5.3 > known
	2A	0.364	0.558	40.7				
	2B	0.383	0.658	35.6	35.8			
	2C	0.367	0.710	31.1				
40°	1A	0.334	0.514	40.5				
	1B	0.349	0.464	48.7	44.5			
	1C	0.336	0.482	44.2				
						0.6	44.2	+4.2 > known
	2A	0.366	0.534	43.2				
	2B	0.370	0.496	48.2	43.9			
	2C	0.363	0.562	40.2				
50°	1A	0.330	0.354	68.7				
	1B	0.335	0.378	62.4	68.1			
	1C	0.349	0.364	73.3				
						12.9	61.7	+11.7 > known
	2A	0.352	0.410	59.2				
	2B	0.351	0.460	49.7	55.2			
	2C	0.344	0.412	56.6				
60°	1A	0.340	0.368	67.4				
	1B	0.337	0.350	74.2	69.7			
	1C	0.325	0.352	67.4				
						5.6	72.5	+12.5 > known
	2A	0.363	0.308	90.0				
	2B	0.354	0.366	75.2	75.3			
	2C	0.335	0.384	60.7				
70°	1A	0.349	0.358	76.9				
	1B	0.346	0.352	79.1	78.4			
	1C	0.346	0.352	79.1				
						4.8	80.8	+10.8 > known
	2A	0.356	0.357	85.6				
	2B	0.350	0.352	83.7	83.2			
	2C	0.352	0.357	80.4				
80°	1A	0.344	0.328	90.0				
	1B	0.339	0.338	90.0	90.0			
	1C	0.337	0.330	90.0				
						0.0	90.0	+10 > known
	2A	0.345	0.330	90.0				
	2B	0.339	0.330	90.0	90.0			
	2C	0.338	0.338	90.0				
90°	1A	0.338	0.338	90.0				
	1B	0.337	0.342	80.1	86.7			
	1C	0.349	0.342	90.0				
						3.3	88.4	-1.6 < known
	2A	0.338	0.338	90.0				
	2B	0.337	0.336	90.0	90.0			
	2C	0.349	0.342	90.0				

Table 4
Sheetrock target media (half-length method).

Impact Angle	Examiners A & B	Bullet Hole Width (Inches)	Bullet Hole Length (Inches)	Calculated Angle of Impact (Degrees)	Average: Examiners A & B	Difference Between Examiners A & B (Degrees)	Combined Average of Examiners	Difference of Combined Avg. from Known (Degrees)
10°	1A	DNP*	DNP*	DNP*	(< Critical Angle Required For Penetration)			
	1B	“	“	“	N/A			
	1C	“	“	“				
						N/A	N/A (5.7*)	N/A (-4.3 < known*)
	2A	“	“	“				
	2B	“	“	“	N/A			
	2C	“	“	“				
20°	1A	0.533	1.650	18.8				
	1B	0.533	1.570	19.8	19.0			
	1C	0.533	1.690	18.4				
						2.2	17.9	-2.1 < known
	2A	0.510	2.303	12.8				
	2B	0.530	2.271	13.5	16.8			
	2C	0.513	2.452	24.1				
30°	1A	0.505	1.630	18.0				
	1B	0.543	1.640	19.3	18.8			
	1C	0.530	1.630	19.0				
						0.6	19.1	-10.9 < known
	2A	0.516	1.580	19.1				
	2B	0.536	1.581	19.8	19.4			
	2C	0.531	1.607	19.3				
40°	1A	0.463	1.260	21.5				
	1B	0.463	1.280	21.6	21.7			
	1C	0.463	1.230	22.1				
						0.4	21.9	-18.1 < known
	2A	0.471	1.224	22.6				
	2B	0.467	1.246	22.0	22.1			
	2C	0.453	1.225	21.7				
50°	1A	0.459	1.010	27.0				
	1B	0.429	1.010	25.2	28.2			
	1C	0.428	0.795	32.5				
						0.0	28.2	-21.8 < known
	2A	0.440	0.993	26.3				
	2B	0.428	0.940	27.1	28.2			
	2C	0.398	0.767	31.3				
60°	1A	0.382	0.567	42.4				
	1B	0.417	0.561	48.0	46.1			
	1C	0.417	0.561	48.0				
						4.7	43.8	-16.2 < known
	2A	0.381	0.579	41.1				
	2B	0.390	0.580	42.3	41.4			
	2C	0.386	0.589	40.9				
70°	1A	0.384	0.430	63.3				
	1B	0.369	0.424	60.5	61.9			
	1C	0.372	0.422	61.9				
						28.1	76.0	+6.0 > known
	2A	0.441	0.361	90.0				
	2B	0.446	0.359	90.0	90.0			
	2C	0.443	0.353	90.0				
80°	1A	0.399	0.388	90.0				
	1B	0.388	0.388	90.0	90.0			
	1C	0.388	0.388	90.0				
						3.1	88.4	+8.4 > known
	2A	0.365	0.370	80.6				
	2B	0.377	0.366	90.0	86.9			
	2C	0.368	0.362	90.0				
90°	1A	0.389	0.368	90.0				
	1B	0.380	0.368	90.0	83.9			
	1C	0.357	0.376	71.6				
						1.8	84.8	-5.2 < known
	2A	0.362	0.363	85.7				
	2B	0.364	0.359	90.0	85.7			
	2C	0.362	0.366	81.5				

* DNP = Did not penetrate

Table 5
Sheet metal target media (template method).

Impact Angle	Examiners A & B	Bullet Hole Width (Inches)	Bullet Hole Length (Inches)	Calculated Angle of Impact In Degrees	Average: Examiners A & B	Difference Between Examiners A & B In Degrees	Combined Average of Examiners	Difference of Combined Avg. from Known (Degrees)
10˚	1A	DNP*	DNP*	DNP*	(< Critical Angle Required For Penetration)			
	1B	"	"	"	"	"	"	
	1C	"	"	"	"	"	"	
	2A	"	"	"	"	"	"	
	2B	"	"	"	"	"	"	
	2C	"	"	"	"	"	"	
20˚	1A	0.507	2.660	11.0				
	1B	0.536	2.620	11.8	11.2			
	1C	0.515	2.720	10.9				
						1.4	10.5	-9.5 < known
	2A	0.507	2.650	11.0				
	2B	0.335	2.600	7.4	9.8			
	2C	0.520	2.740	11.0				
30˚	1A	0.497	1.680	17.2				
	1B	0.534	1.760	17.6	17.5			
	1C	0.515	1.710	17.6				
						0.6	17.8	-12.2 < known
	2A	0.533	1.690	18.4				
	2B	0.534	1.760	17.6	18.1			
	2C	0.537	1.720	18.2				
40˚	1A	0.499	1.640	17.7				
	1B	0.535	1.850	16.8	16.8			
	1C	0.511	1.860	16.0				
						0.3	17.0	-23 < known
	2A	0.530	1.670	18.5				
	2B	0.534	1.870	16.6	17.1			
	2C	0.521	1.880	16.1				
50˚	1A	0.436	0.822	32.0				
	1B	0.433	0.832	31.3	32.1			
	1C	0.407	0.750	32.9				
						0.6	31.8	-18.2 < known
	2A	0.436	0.823	32.0				
	2B	0.433	0.833	31.3	31.5			
	2C	0.427	0.822	31.3				
60˚	1A	0.398	0.540	47.5				
	1B	0.402	0.540	47.7	47.7			
	1C	0.398	0.536	48.0				
						0.2	47.6	-12.4 < known
	2A	0.398	0.541	47.4				
	2B	0.399	0.540	47.6	47.5			
	2C	0.398	0.540	47.5				
70˚	1A	0.372	0.398	69.2				
	1B	0.370	0.402	66.9	67.1			
	1C	0.370	0.408	65.1				
						0.6	67.4	-2.6 < known
	2A	0.372	0.399	68.7				
	2B	0.373	0.402	68.1	67.7			
	2C	0.370	0.404	66.3				
80˚	1A	0.369	0.370	85.6				
	1B	0.370	0.372	84.3	82.6			
	1C	0.364	0.372	78.0				
						0.9	82.2	+2.2 > known
	2A	0.370	0.380	76.9				
	2B	0.369	0.372	82.7	81.7			
	2C	0.371	0.372	85.6				
90˚	1A	0.369	0.360	90.0				
	1B	0.371	0.362	90.0	90.0			
	1C	0.367	0.362	90.0				
						0.0	90.0	0.0
	2A	0.369	0.361	90.0				
	2B	0.370	0.362	90.0	90.0			
	2C	0.369	0.362	90.0				

* DNP = Did not penetrate

Table 6
Sheet metal target media (half-length method).

Discussion and Conclusion

As can be gleaned from these results, the angle of impact from bullet holes that are commonly observed in crime scenes can be approximated using the same trigonometric relationship between the major and minor axis of the observed bullet hole, as concluded by Balthazard for determining the angle of impact for a blood droplet. Because the methods are the same, whether for a blood droplet or a bullet hole, one might assume that the results would be the same. However, as a general rule, the accuracy of determination of the impact angle for bloodstains is within 5 degrees to 7 degrees [6], whereas, according to this study, the bullet holes that were examined tended to produce much more variable results. This may be because with a blood drop, the collapse and deposition of the blood drop as it impacts the target surface occurs in a very predictable fashion, based on the cohesive forces of the blood drop [7]. However, depending on the target media, the production of the bullet hole caused by the impact of the bullet may result in tearing and destruction of the target media because the original cross-sectioned spherical shape of the bullet may become deformed as the bullet distorts upon impact into the target.

It has been well established that for less elliptically shaped blood droplets (i.e., more circular in morphology), the error rate rises dramatically in determining impact angles for blood droplets that impact at angles greater than 60 degrees. This general maxim was also observed for the bullet holes examined in this study. In the half-length method with the sheetrock, both examiners reported calculated angles of impact of 90 degrees for the known impact angle of 80 degrees. Conversely, with the wood pressboard, both examiners reported average calculated angles of impact of approximately 80 degrees for the known impact angle of 90 degrees. Such increased error rates in more orthogonal bullet holes demand that examiners carefully consider making conclusions in directionality determination in bullet holes of angles greater than 60 degrees [3], because the test bullet holes produced between 70 degrees to 90 degrees were virtually indistinguishable from one another without the context of the known impact angle.

Gardner has indicated that the relationship of determining the impact angle for bloodstains and defects created by bullets is the same [8] and that using this method for calculating the angle of impact from bullet holes may be sufficiently accurate to provide important information as merely an estimate of the angle of impact. He furthermore cautions that the bullet holes do not provide a precise angle of impact and should not be misconstrued to do so. In general, circular shaped bullet holes indicate an angle of impact in the area of approximately 90 degrees, whereas elliptical shaped bullet holes indicate a more tangential impact angle [9]. Our study results concur with this conclusion because generally, except for the aforementioned outlying results, the angle of impact determinations were approximately within 10 degrees of the known impact angle. Such information may be sufficient for determining the general origin of a shooter's position.

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