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TECHNICAL NOTE

CRIMINALISTICS

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Firing Distance Estimates with Pellet Dispersion from Shotgun with Various Chokes: An Experimental, Comparative Study

ABSTRACT: There are several studies suggesting models for firing distance estimation due to pellet dispersion, but few of them consider the degree of choke of a shotgun. The purpose of this research is to suggest some models for estimation of the firing distance for choked and cylinder bore shotguns. Twelve gauge with full chokes, and 12 and 16 gauge with cylinder bore shotguns were fired with #2 and #5 shots from 75, 100, 300, 500, and 1000 cm distances. Statistically significant pellet dispersion values were found for each shotgun by using #2 and #5 shots for different firing distances. All the data obtained were analyzed with linear regression and four models were constituted. Investigators should use special formulae for each shotgun, degree of choke, and pellet type while determining the firing distance. Therefore, more experimental and comparative studies should be designed for each type.

KEYWORDS: forensic science, ballistics, shotgun, choke, cylinder bore, firing distance, pellet dispersion, estimation

Shotguns are popular worldwide, and these weapons are more common compared with the rifled firearms. Shotgun injuries take a big share from firearm committed crimes. Correct interpretation of shotgun wounds by forensic pathologists not only provides valuable information that can assist law enforcement in their investigation but also is essential for the final determination of manner of death. Discussion of the practical, basic, and essential skills required to interpret shotgun wounds include distinguishing a classic entrance wound from an exit wound; recognizing a typical entrance and exit wounds; utilizing the features of soot and stippling patterns to differentiate among contact, close, and distant range shotgun wounds; understanding the trauma produced by shotgun wounds; and understanding the importance of recovering and documenting/handling any projectiles recovered at autopsy. Firing distance can be the key point of solution for some cases. Firing distance of shotguns may be estimated by the distribution of gunshot residue, provided that the muzzle to be closed enough to the target for such residue to reach it. Pellet dispersion patterns are also useful for estimating the firing distance at a distance over the range of powder remains. However, pellet dispersion patterns are variable depending on different barrel length, diameter of the barrel of the shotgun, level of chock process, and the size of the fired pellets (1–3).

There are three main methods for estimating the firing distance in shotguns; the "effective shot dispersion" method of Mattoo and Nabar (4), another method in which the area of the smallest circumscribed rectangle enclosing the pellet pattern is calculated, and an overlay method for determining the radius of the smallest circumscribed circle that will just enclose the pellet pattern (5–7). Each of them has several advantages besides their limitations. But none of them considers the degree of choke of shotgun. Most shotgun barrels have some degree of "choke." Choke is a partial constriction of the bore of a shotgun barrel at its muzzle so as to control shot patterns. The choke may be either formed as part of the barrel at the time of manufacture, by squeezing the end of the bore down over a mandrel, or by threading the barrel and screwing in an interchangeable choke tube. The choke typically consists of a conical section that smoothly tapers from the bore diameter down to the choke diameter, followed by a cylindrical section of the choke diameter. The choke holds the shot column together for a greater distance as it moves away from the muzzle. There are detailed levels of choke classification (Table 1), but the most common degrees of choke are full, modified, improved cylinder, and cylinder in descending order. Different degrees of choke will give different spreads for a particular shotgun charge and range, and the tighter choke causes smaller pattern of pellets. However, the use of too much choke and a small pattern increases the difficulty of hitting the target. The use of too little choke produces large patterns with insufficient pellet density (Table 2; [8–10]). Some studies on the effect of choking degrees and the firing distance on pellet dispersion are summarized in Tables 3–5 (10–12).

There is a common area of confusion concerning gauge and choke. No matter what the shotgun gauge is, weapons of identical choke produce approximately the same size patterns at the same range. The pattern will differ only in density.

The purpose of this research is to determine the pellet dispersion for #2 and #5 shots that are fired from various distances by different gauges, choke, and cylinder bore shotgun, and to suggest some models for estimation of firing distance for choked and cylinder bore shotguns.

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TABLE 1—*Shotgun chokes for a 12-gauge shotgun using lead shot.*

Constriction (μm)	Constriction (in.)	American Name	Percentage of Shot in a 76 cm (30 in.) Circle at 37 m (40 yards)	Total Spread at 37 m (cm)	Total Spread at 40 yards (in.)	Effective Range (m)	Effective Range (yards)
0	0.000	Cylinder	40	150	59	18	20
127	0.005	Skeet	45	132	52	21	23
254	0.010	Improved Cylinder	50	124	49	23	25
381	0.015	Light Modified					
508	0.020	Modified	60	117	46	32	35
635	0.025	Improved Modified					
762	0.030	Light Full		109	43		
889	0.035	Full	70			37	40
1143	0.045	Extra Full					
1270	0.050	Super Full					

TABLE 2—*Percentages of shot that can be expected in the different degrees of choke (8–10).*

Choke	Percentage at 40 yards in 30-in. Circle
Full choke	65–75
Modified choke	45–65
Improved cylinder	35–55
Cylinder	25–40

TABLE 3—*Berg (11).*

Distance (cm)	Full Choke	Modified Choke	Improved Cylinder	Cylinder
914	23	31	41	46
1371	33	46	61	71
1828	48	61	81	97
2285	61	79	104	122
2742	79	97	127	147
3199	97	117	152	173
3656	117	140	178	203
4113	137	163		
4570	163	188		
5027	188	216		
5484	216	244		

Methods

This study is a prospective, experimental, and comparative statistical analysis.

Shotguns

- 12-gauge choke shotgun: Huglu brand, superposed, with 71 cm barrel length, upper barrel full choke, lower barrel modified choke and 141573 serial numbered (Huglu Av Tufekleri Kooperatifi, Beyşehir/Konya, Turkey). Only full choke upper barrel was fired with this shotgun.
- 12-gauge cylinder bore shotgun: Turanlar brand, side by side, with 71 cm barrel length, two barrels have no choking and 4030 serial numbered Turanlar Av Tüfekleri Imalat ve Pazarlama Ithalat – Ihracat ve Ticaret, Düzce – Bolu, Turkey). Only right barrel was fired with this shotgun.
- 16-gauge cylinder bore shotgun: Huglu brand, single cylindrical barrel, with 71 cm length, and 4030 serial numbered.

Ammunitions

- Winchester brand, 12-gauge shotgun shells, 32 g, 7 cm with plastic tube (Winchester Repeating Arms, Morgan, UT).
- Winchester brand, 16-gauge shotgun shells, 32 g, 7 cm with plastic tube.

#2 (3.8 mm in diameter) and #5 (3 mm in diameter) shots were used in both shotgun shells.

TABLE 4—*Parikh (12).*

Distance (cm)	Full Choke	Modified Choke	Cylinder
914	22.9	30.5	48.3
1828	40.6	50.8	81.3
2742	66.0	81.3	111.8
3656	101.6	116.8	144.8

TABLE 5—*Hirch (10).*

Distance (cm)	Full Choke	Modified Choke	Cylinder
447	7.6	12.7	20.3
914	22.9	30.5	50.8
1371	30.5	40.6	60.0
1828	38.1	51.0	76.2

Shooting Range

Shooting Range of Military Service Department, Kucukcekmece-Istanbul, Turkey.

Air Conditions

Open air, 20°C average temperature, mild breeze, and normal atmosphere pressure.

Target

Unbleached and coarse calico stretched into 2×2 m wood frame.

Test Fires

Firing distances were 75, 100, 300, 500, and 1000 cm and direction was vertical to the target. #2 and #5 shots were used. Shootings were repeated five times for each shooting range. Shotguns were fixed on a wooden hinge having the same height with the target. Pellet dispersion on the target was measured for each shooting. The distances between two furthest pellets were measured vertically and horizontally and the average of them was defined as the radius of the largest circumscribed circle in centimeters. Pellets that were departed from general dispersion pattern were excluded from measurement.

Relationship between #2 and #5 shots dispersion for each shotgun and each firing distance were analyzed. Besides, the relationship between different shotgun gauges and pellet dispersion for each #2 and #5 shots were examined. Statistical analysis was performed with Epi-info 2000 program (Centers for Disease Control and Prevention, Atlanta, GA) by using Mann–Whitney *U*- and Kruskal Vallis variant analysis tests. Obtained data were presented as average and standard deviation.

Results

Test fires were carried out with three different shotguns each having five different distances (75, 100, 300, 500, and 1000 cm) by using #2 and #5 shots in this study. Five fires were carried out for each distance and ammunition.

The relationship between firing distance and pellet dispersion for 12-gauge full choke shotgun were analyzed for #2 and #5 shots. The difference of the radius of pellet dispersion for #2 and #5 shots was determined to be statistically significant for over 300 cm distances (Table 6).

The relationship between firing distance and pellet dispersion for 12-gauge cylinder bore shotgun were analyzed for #2 and #5 shots. The difference of the radius of pellet dispersion for #2 and #5 shots was determined statistically significant for over 500 cm distances (Table 7).

The relationship between firing distance and pellet dispersion for 16-gauge cylinder bore shotgun were analyzed for #2 and #5 shots. The difference of the radius of pellet dispersion for #2 and #5 shots was determined statistically significant for over 500 cm distances (Table 8).

The relationship between firing distance and pellet dispersion for 12-gauge full choke, 12-gauge cylinder bore, and 16-gauge cylinder bore shotguns were analyzed for #2 shot. The difference of the radius of pellet dispersion for each shotgun was determined statistically significant for over 100 cm distances (Table 9).

The relationship between firing distance and pellet dispersion for and 12-gauge full choke, 12-gauge cylinder bore, and 16-gauge cylinder bore shotguns were analyzed for #5 shot. The difference of the radius of pellet dispersion for each shotgun was determined statistically significant for over 100 cm distances (Table 10).

Finally, four models were designed to use in linear regression analysis. First three models were constituted for each type of shotgun and pellet. The fourth and the last model was acquired from regression analysis of the overall data. While *R*-values were found to be highly reliable for the first three models, the last model's *R*-value was found 82% (Table 11). As a result of linear regression analysis, formulation for firing distance according to the radius of pellet dispersion was determined as: $FD = a + b \times R$ (FD: firing distance, a and b: fixed values for each shotgun, R: radius of the largest circumscribed circle of pellet dispersion as centimeter.)

Discussion

Pellet distribution on target according to distance depends on many variables. Some of these are type of shotgun, length and diameter of barrel, cylinder bore or choked barrels, degree of choke, type of ammunition, the type and amount of the powder used in cartridges, the type, structure and shot size, and conditions of the physical environment (1–3). It is obvious that some experimental studies that focus on the effects of mentioned variables are needed.

Twelve-gauge cylinder bore, 12-gauge with full choke, and 16-gauge cylinder bore shotguns were used in order to show the difference between these frequently used shotguns in our study. Shootings were carried out with #2 and #5 shots from 75, 100, 300, 500, and 1000 cm distances.

There was no statistically significant difference between pellet dispersions of test fires with #2 and #5 shots for 12 gauge with full choke shotgun up to 3 m. It was found to be statistically significant for same pellets for 5 and 10 m distances. It was detected, 5.4 cm in diameter for #2 shot, and 6 cm in diameter for #5 shot from 5 m distance and it was detected, 11.5 cm in diameter for #2 shot, and 12.6 cm in diameter for #5 shot from 10 m distance (Table 6). It is clearly seen that although differences in diameters are statistically significant, they actually do not differ from each other too much, and we think these differences are not useful in practice.

There was no statistically significant difference between pellet dispersions of shootings with #2 and #5 shots for 12-gauge cylinder bore shotgun up to 3 m and it was found statistically significant for the same pellets for 5 and 10 m. But unlike full choke shotgun, there were distinct differences in diameters of pellet dispersion. It was detected that 9.3 cm in diameter for #2 shot, and 13.1 cm in diameter for #5 shot from 5 m distance and it was detected 19.4 cm in diameter for #2 shot, and 24.7 cm in diameter for #5 shots from 10 m distance (Table 7). Therefore, we think this data is more valuable and useful for firing distance estimation for 12-gauge cylinder bore shotgun in practice.

The data obtained from testing 16-gauge cylinder bore shotgun were compatible with 12-gauge cylinder bore shotgun. There was no statistically significant difference between pellet dispersions of test fires with #2 and #5 shots up to 3 m and it was found statistically significant for the same pellets for 5 and 10 m. There were distinct differences in pellet dispersion diameters. The diameter was 8.2 cm for #2 shot and 11.2 cm for #5 shot from 5 m distance, and we found a distance of 15.6 cm for #2 shot and 18.4 cm for #5 shot from 10 m distance (Table 8). Consequently this data is also valuable for practicing the firing distance estimation for 16-gauge cylinder bore shotgun.

In studies of Üner et al. (13), Çoltu et al. (14), and Yücel and Örsal (15) conducted by various shotguns in different gauges and barrel sizes, different shot size pellet distribution patterns for different choke levels was shown. In these studies, it was found that

TABLE 6—*Pellet dispersion for #2 and #5 shots and 12-gauge full choke shotgun.*

		#2 Shot		#5 Shot		
Firing Distance (cm)	Shootings (n)	Average Radius of Pellet Dispersion (cm)	SD	Average Radius of Pellet Dispersion (cm)	SD	p
75	5	2.05	0.11	2.00	0.00	0.31
100	5	2.15	0.13	2.05	0.11	0.22
300	5	3.10	0.22	3.45	0.27	0.06
500	5	5.40	0.22	6.00	0.50	0.04
1000	5	11.50	0.61	12.60	0.65	0.02

TABLE 7—*Pellet dispersion for #2 and #5 shots and 12-gauge cylinder bore shotgun.*

		#2 Shot		#5 Shot		
Firing Distance (cm)	Shootings (*n*)	Average Radius of Pellet Dispersion (cm)	SD	Average Radius of Pellet Dispersion (cm)	SD	*p*
75	5	2.25	0.25	2.00	0.00	0.05
100	5	2.50	0.00	2.50	0.17	0.99
300	5	5.50	0.50	6.80	1.39	0.11
500	5	9.30	0.90	13.10	1.34	0.00
1000	5	19.40	2.65	24.70	2.97	0.02

TABLE 8—*Pellet dispersion for #2 and #5 shots in a 16-gauge cylinder bore shotgun.*

		#2 Shot		#5 Shot		
Firing Distance (cm)	Shootings (*n*)	Average Radius of Pellet Dispersion (cm)	SD	Average Radius of Pellet Dispersion (cm)	SD	*p*
75	5	2.00	0.00	2.10	0.13	0.13
100	5	2.30	0.20	2.30	0.20	0.99
300	5	5.00	0.61	5.40	0.65	0.21
500	5	8.20	0.90	11.20	0.83	0.00
1000	5	15.60	1.24	18.40	1.34	0.00

TABLE 9—*Pellet dispersion for different gauge shotguns with #2 shot.*

		12 Gauge (Full Choke)		12 Gauge (Cylinder Bore)		16 Gauge (Cylinder Bore)		
Firing Distance (cm)	Shootings (*n*)	Average Radius of Pellet Dispersion (cm)	SD	Average Radius of Pellet Dispersion (cm)	SD	Average Radius of Pellet Dispersion (cm)	SD	*p*
75	5	2.05	0.11	2.25	0.25	2.00	0.00	0.08
100	5	2.15	0.13	2.50	0.00	2.30	0.20	0.01
300	5	3.10	0.22	5.50	0.50	5.00	0.61	0.00
500	5	5.40	0.22	9.30	0.90	8.20	0.90	0.00
1000	5	11.50	0.61	19.40	2.65	15.60	1.24	0.00

TABLE 10—*Pellet dispersion for different gauge shotguns with #5 shot.*

		12 Caliber (Full Choke)		12 Caliber (Cylinder Bore)		16 Caliber (Cylinder Bore)		
Firing Distance (cm)	Shootings (*n*)	Average Radius of Pellet Dispersion (cm)	SD	Average Radius of Pellet Dispersion (cm)	SD	Average Radius of Pellet Dispersion (cm)	SD	*p*
75	5	2.00	0.00	2.00	0.00	2.10	0.13	0.11
100	5	2.05	0.11	2.50	0.17	2.30	0.20	0.01
300	5	3.45	0.27	6.80	1.39	5.40	0.65	0.00
500	5	6.00	0.50	13.10	1.34	11.20	0.83	0.00
1000	5	12.60	0.65	24.70	2.97	18.40	1.34	0.00

TABLE 11—*Linear regression analysis for each shotgun and overall data.*

Shotguns	Shot Size	*a*	*b*	Adjusted R^2
12 Gauge (full choke)	2	−60.4	94.1	0.97
	5	−45.1	84.3	0.98
12 Gauge (cylinder bore)	2	−7.8	51.7	0.96
	5	11.5	39.0	0.97
16 Gauge (cylinder bore)	2	−44.8	66.4	0.98
	5	−27.5	53.6	0.97
Overall		41.5	50.2	0.82

pellet dispersion decreases in smaller gauge shotguns, larger choke, and in larger shot sizes from the same firing distance. Our results are compatible with these studies.

Although gauge and degree of choke varies, the same barrel length (71 cm) shotguns are used in our study. But considering the studies of Üner et al. (13), Çoltu et al. (14), Yücel and Örsal (15), and Çakır (16), it is obvious that length of the barrel significantly affects the pellet dispersion. For example, with the 12-gauge shotgun, 55 cm barrel length results approximately two times larger pellet dispersion than 76 cm achieved from the same distance, by using same shot size. It is obvious that the short length of the barrel causes the large pellet dispersion in diameter.

The pellet dispersion difference for each shotgun was found statistically significant after 100 cm distance, for both #2 and #5 shots. But pellet dispersion differences for each shotgun were significantly larger for #5 shot compared with #2 shot. These data clearly show that diameter of pellet dispersion increases, while diameter of the shot decreases.

Besides the degree of chock process, pellet dispersion patterns are also affected from length and diameter of the barrel of the shotgun, even if the same size of shot used (5,8–12,17,18). Because of these many variables, it is hard to estimate the firing distance according to the pellet dispersion when the fired shotgun is not found at the crime scene. The investigators should be aware of this fact and must consider all these variables.

All data obtained were analyzed with linear regression and four models were constituted. First three models were developed for each shotgun and each pellet, the last model which combined the overall data was obtained from all shotguns and pellets used. Higher and reliable *R*-values were found for the first three models while it was calculated as 82% for the last model. This unreliable result indicates that general formulae cannot be used to estimate the firing distance by using pellet dispersion, but specific formulae that are acquired from experimental studies for each specific shotgun and choke degree are needed. That is why investigators should use special formulae for each shotgun, for each degree of choke, and for each pellet type while determining the firing distance.

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