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Cathy M. Puskas,[1] *B.A. and Daisy T. Rumney,*[2] *B.A.*

Bilateral Fractures of the Coronoid Processes: Differential Diagnosis of Intra-Oral Gunshot Trauma and Scavenging Using a Sheep Crania Model

ABSTRACT: Approximately half of the skeleton of an adult male (minus the cranium) was found in a forested part of Greater Vancouver, Canada, in August 2000 by the Royal Canadian Mounted Police (RCMP). Authorities ruled the death as suicide. The only compelling signs of perimortem trauma were symmetrically fractured coronoid processes of the mandible, which can be attributed to a gunshot in the mouth. However, the remains had also been scavenged by canids, raising a problem in differential diagnosis. Could canid scavenging produce bilateral fracturing of the mandible indistinguishable from gunshot wounds to the mouth?

We found that canid scavengers could not mimic the type of damage to the mandible caused by intra-oral gunshot wounding using a sheep model ($n = 20$). Bilateral fracturing of the coronoid processes was found to be characteristic of intra-oral gunshot wounding, while canid scavengers typically ignore this region of the mandible.

KEYWORDS: forensic science, differential diagnosis, ballistics, scavenging, forensic osteology, taphonomy

The skeletonized remains of an identifiable male (SFU Case 00-4), age 49, were recovered from the Buntzen Lake Reservoir Recreation Area, Coquitlam, British Columbia, on August 27, 2000. The park, a wooded area covering an area of 182 ha, is a popular location, especially in the summer, drawing visitors to its lake and numerous hiking trails. The remains were approximately a 15-min walk beyond the end of the public road on inclined and rugged terrain. Scavengers had scattered the remains, leaving approximately half of the skeleton, minus the cranium, for recovery.

The mandible was found and, although signs of scavenging were present, this also offered the only indication of what could be interpreted as perimortem trauma. The coronoid processes were symmetrically fractured by what appeared to be a medial-to-lateral force on both sides, as indicated by external beveling (Figs. 1 and 2). A line of dried soft tissue exists parallel to, but shrunken away from, the fracture margin on the right lateral coronoid process. This retraction of the tissue indicates that the fracture occurred prior to the drying of the tissue. No signs of scavenging were directly related to either coronoid process fractures. The mandibular condyles were also symmetrically absent; however, there were signs of scavenging at these locations. It is unclear whether the mandibular condyles were fractured by the same event that caused the coronoid fractures and then later scavenged, or if they were simply absent as a result of scavenging. The victim had left a suicide note, and, consequently, the coroner's office ruled the death a suicide.

The trauma to the mandible showed similarities to two previous cases (80-1 and 81-4) examined by Dr. Mark Skinner, a forensic anthropologist at Simon Fraser University. The former is a case of firearm suicide using a Ross .303 caliber rifle. The rifle has a 76-cm barrel, with 86 cm between the muzzle and the trigger, and a muzzle velocity of 2000 to 2800 ft/s (1). The damage to the remains, combined with physical evidence of the site, permitted a diagnosis of intra-oral placement of the barrel. The second case (81-4) involved a suicide using a Cooey shotgun carrying a 20-gage slug with a muzzle velocity of approximately 1600 ft/s (1). Both cases exhibited fractures of the coronoid processes, along with craniofacial damage, believed to have been caused by intra-oral gunshot trauma (Figs. 3 and 4). However, in the case in question, no firearm or spent ammunition was recovered. Nor was there any radiographic evidence indicative of gunshot trauma found on the mandible.

Despite the absence of a firearm, based on the similarities between Cases 00-4, 80-1, and 81-4, it is hypothesized that the mechanism of death in Case 00-4 is gunshot wound to the mouth area, with fractures of the coronoid processes, and possibly the mandibular condyles, as a result of the explosive effect of muzzle gases. In cases of contact gunshot trauma, expanding muzzle gases follow the projectile into the wound. If the amount of available space in the wound track is inadequate for the amount of gas produced by the blast, tearing of the surrounding tissues will occur (2–4). The trauma from the blast would attract scavengers to the cranial region initially, rather than the typical sequence of scavenging, which would see the first skeletal trauma on the thorax and the arms (5). Typically, the mandible shows a relatively high survival rate in canid-scavenged human remains, suggesting it is largely ignored in favor of other regions of the body (5–7). In addition, the relationship between muzzle velocity and the degree of damage to the cranium is explored, with the expectation that there is a significant relationship (2,8–13). We report this case as a problem in differential diag-

[1] Simon Fraser University, Burnaby, B.C., Canada.
[2] Firearm and tool mark examiner (understudy), RCMP, Ottawa, Ontario, Canada.
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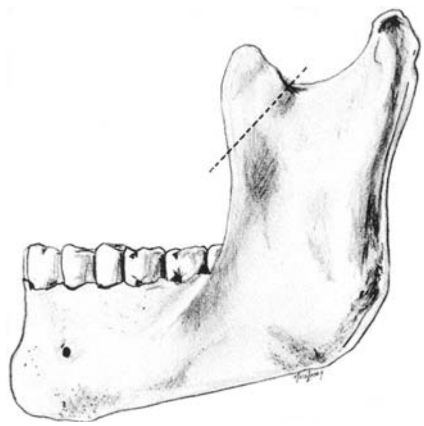

FIG. 1—*Case 00-4. The location of coronoid fractures in respect to the entire mandible. The region superior to the dotted line was absent.*

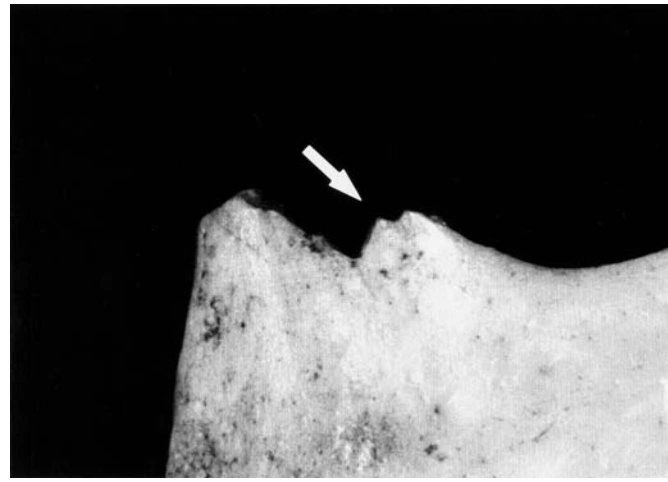

FIG. 4—*Case 81-4. Medial view of right coronoid process with angular fracture line, shown by the arrow.*

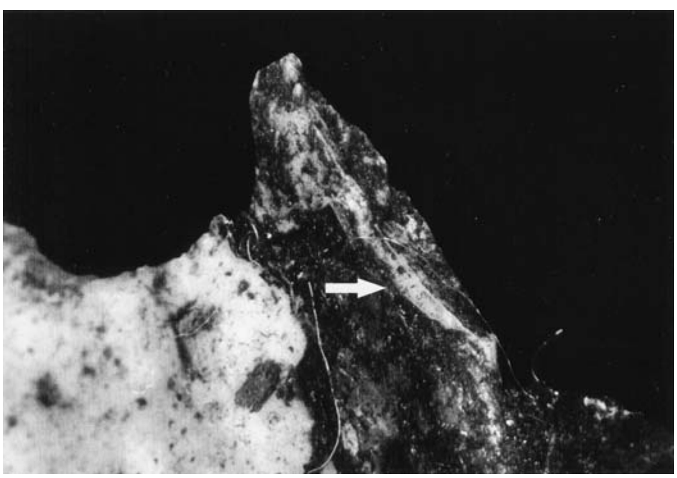

FIG. 2—*Case 00-4. Lateral view of the right coronoid process. The external beveling of the fracture suggests the force traveled laterally from the midline. The line of soft tissue parallel to the fracture margin, as shown by the arrow, indicates the fracture occurred prior to decomposition.*

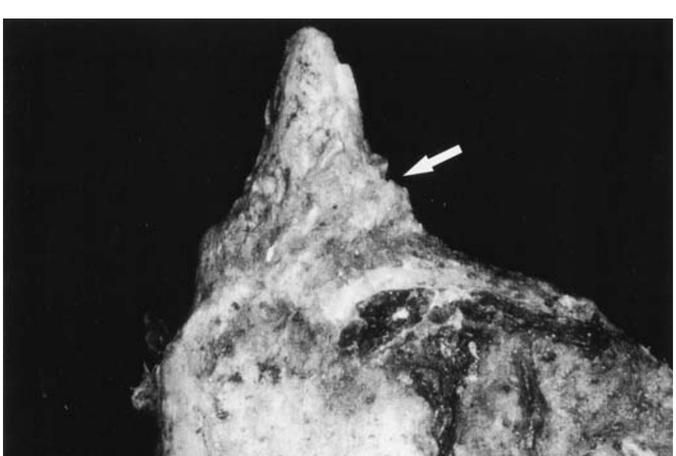

FIG. 3—*Case 80-1. Lateral view of left condylar process. The grooving and pitting, shown by the arrow, are indicative of scavenger activity.*

nosis. Can scavenging produce bilaterally symmetrical damage to the coronoid processes indistinguishable from damage due to intraoral gunshot wounding? We provide an experimental model using animal remains.

Materials and Methods

The hypothesis that the mandible of Case 00-4 demonstrates trauma caused by gunshot wounding and not solely canid scavenging was tested using three different groups of immature sheep (*Ovis aries)* crania and mandibles. The "shot" group consisted of ten heads shot using various firearms and projectiles, with the focus being on the Lee-Enfield No. 4 rifle with .303 caliber ammunition, as this is considered a relatively common firearm in Canada. The "scavenged only" group consisted of five heads, one scavenged by a coyote (*Canis latrans*) and four scavenged by three arctic wolves (*Canis lupus arctos*). The "shot plus scavenged" group consisted of four heads that were shot with a Lee-Enfield No. 4 rifle and then scavenged, one by a coyote and the remainder by the three arctic wolves (Table 1).

Sheep crania were selected as the closest available approximation to human crania. Pigs were rejected, as they were too robust at the typical age of slaughter (25 weeks). The sheep were six to eight months in age and of unknown sex. They were obtained from Windsor Packing Co., Ltd., Vancouver, B.C. The thickness of the sheep mandible at this age is roughly comparable to an adult human, with the human mandible being slightly denser, as seen in radiographs. The similar thickness allows for the assumption that should a sheep mandible fracture from gunshot trauma, a human mandible would fracture similarly. Canada health regulations dictate that the sheep head must be skinned prior to sale. As the skin would likely assist fracture production in close or contact gunshot wounds by trapping gases within the mouth area, one can assume that fracture production and/or soft tissue trauma would be slightly lessened in this study. The sheep had been euthanized by means of a bolt injected approximately midline in the parietals, just posterior to the frontal bones. This process leaves a round hole and, in some cases, radiating cracks. The hole in the vault could provide an outlet for the muzzle gases and a weak point that may alter the fracture pattern resulting from the firearm trauma.

Another skeletal similarity between human and sheep is the shape of the posterior mandible. The sheep ramus is angled at approximately 90°, as is typical of a human male. The major morphological differences between the human and sheep mandibles are in the width of the mandibular notch and the length and position of the coronoid process. The sheep mandible has a narrower mandibular notch and a far more salient coronoid process than does the human mandible. The human coronoid process has greater protection than that of the sheep, since its shorter length leaves it covered by the zygomatic arch, whereas the sheep coronoid process extends superiorly beyond the zygomatic arch. Although sheep and human heads vary a great deal morphologically, a sheep head model was the most suitable available model in terms of bone thickness.

One specimen, C1, was used as a control sample. The ammunition and firearms used for the "shot" sample were chosen by D. T. Rumney with the assistance of experienced firearm and tool mark examiners at the RCMP, Vancouver Forensic Laboratory (RVFL). The initial ballistic group, consisting of seven specimens, was shot with various firearms and ammunition. This was done to observe variations in skeletal destruction with different muzzle velocities and projectiles. These seven specimens were shot inside the RVFL, while the remaining specimens were shot outdoors at the Coquitlam RCMP Firing Range. Six different firearms and ammunitions were used in total. The muzzle velocity, bullet cross-sectional area, and powder weight were recorded for each (Table 2).

TABLE 1—*Distribution of the specimens and the factors affecting them.*

Specimen	Group	Factor
C01	Control	…
B01	Shot	Winchester 12 Gage Shotgun
B02	Shot	.303 ca. Lee Enfield No. 4 Rifle
B04	Shot	.45 ca, Colt Pistol
B05	Shot	.357 Magnum Smith & Wesson Revolver
B06	Shot	9 mm Parabellum Browning Model High Power Pistol
B07	Shot	.22 LR Smith &Wesson Revolver
B09	Shot	.303 ca. Lee Enfield No. 4 Rifle
B10	Shot	.303 ca. Lee Enfield No. 4 Rifle
B11	Shot	.303 ca. Lee Enfield No. 4 Rifle
B12	Shot	.303 ca. Lee Enfield No. 4 Rifle
D01	Shot plus Scavenged	.303 ca. Lee Enfield No. 4 Rifle, and coyote scavenging
D02	Shot plus Scavenged	.303 ca. Lee Enfield No. 4 Rifle, and wolf scavenging
D03	Shot plus Scavenged	.303 ca. Lee Enfield No. 4 Rifle, and wolf scavenging
D04	Shot plus Scavenged	.303 ca. Lee Enfield No. 4 Rifle, and wolf scavenging
W01	Scavenged Only	Wolf
W02	Scavenged Only	Wolf
W03	Scavenged Only	Wolf
W04	Scavenged Only	Wolf
W05	Scavenged Only	Coyote

The heads were shot in The "Snail" Passive Bullet Trap, with the cranium placed on a block of plasticene to stabilize the head and to maintain a roughly anatomical, or horizontal, position of the head. The muzzle of the firearm was inserted along the midline 8 cm, which is roughly up to the sheep's third molar. This length was chosen so that there would be some soft tissue lateral to the muzzle end as a simulation of the cheeks present on a human victim, which would trap the escaping muzzle gases. The muzzle maintained a roughly horizontal position. The Lee-Enfield No. 4 with .303 British ammunition was chosen for the remainder of the shot crania, which included four crania that were just shot and four crania that were shot and scavenged.

The five specimens to be scavenged were taken to the Greater Vancouver Regional Zoo and fed to a coyote or a group of three wolves. Two were fed individually to both a coyote and a wolf, and the remaining three were fed simultaneously to the three wolves. The animals were not fed the day prior to being fed the sheep crania to ensure their interest in the remains. Since Case 00-4 showed apparent signs of coyote or dog scavenging, based on the size of the pit and puncture marks left on the skeleton, initially the remains were only to be fed to the coyote. The coyote showed only a limited interest in the head. It took approximately three days for the coyote to create noticeable damage to the head. Thus, only two of the six scavenged specimens were fed to the coyote. The remaining four specimens were fed to the arctic wolves, which produced a great deal of damage within a half hour of being fed. The specimen W5 was left with the coyote for three days, W1 was fed to the wolves for 1 h, and W2, W3, and W4 were fed to the wolves for 20 min. When possible, the feeding activity was observed; however, the animals, especially the coyote, were sometimes hesitant to eat with onlookers.

Four crania, D1, D2, D3, and D4, were shot and then fed to the coyote or the wolves to observe the potential for differential scavenging of shot crania. These crania were shot with the Lee-Enfield rifle at the Coquitlam RCMP Firing Range in the same manner as the second group of shot specimens. Prior to feeding these crania to the wolves and coyote, they were visually examined for bullet fragmentation to ensure the safety of the animals. The crania were then fed to the animals, as in the scavenged group. D1 was fed to the coyote and left for approximately three days. D2, D3, and D4 were fed to the three wolves and left for approximately 15 min.

The specimens were defleshed by placing them in boiling water for approximately 6 h or until the soft tissue was easily removable from the skeletal remains. To degrease the remains, the bones were then placed in a solution of 28% ammonium hydrox-

TABLE 2—*Firearms and ammunitions used in this study.*

Firearm	Ammunition	Muzzle Velocity (ft/s)	Powder Weight (g)	Cross Section Diameter (in.)
12 Gage Winchester Shotgun	Winchester Super X Hollow Point	1500	2.28	.787
.303 Lee Enfield No. 4 Rifle	Imperial .303 Brit	2750	2.76	.303
.45 ACP Colt Government Model Pistol	.45 ca. Remington Solid Point	885	.32	.450
.357 Magnum Smith & Wesson Revolver	.357 ca. Magnum Norma Hollow Point	1235	.83	.357
9mm Parabellum Browning Model High Power Pistol	9 mm Federal Soft Point	1160	.27	.354
.22 LR Smith & Wesson Revolver	.22 ca. Remington Yellow Jacket Hollow Point	1200	.12	.220

ide in a sealed container in a fumehood. After 12 h the bones were removed from the solution, rinsed thoroughly with water, and left to dry. The bones were then placed into a solution of 3% hydrogen peroxide for approximately 12 h. This was done in order to bleach the remains. As with the previous steps, the bones were rinsed thoroughly and left to dry for another 12 h. When dry, the bones were labeled using clear nail polish, as a writing surface, and permanent marker. The bones were labeled as control (C), shot (B), scavenged (W), and both shot and scavenged (D), along with the specimen number.

The bones were then examined and any fractures, cracks, and absences noted and entered into a database and photographic record sheets. In this study, a fracture refers to full break in the element, leaving two distinct pieces, while a crack refers to an incomplete fracture, with the element remaining intact. Elements that were observed separated at the sutures were not treated as fractures (although some may have been), as the boiling process loosens the areas of fusion. Also, any cracking or fracture associated with the defect on the parietals left by the bolt was unrecorded.

This method of defleshing would generally take four days in total, and, due to time constraints, an alternative method had to be undertaken. Specimens B9 to B12, W1 to W5, and D1 to D4 were defleshed by this alternative method. The fleshed crania were boiled in water with about two tablespoons of Bio-Ad, an enzymatic agent, for approximately 4 h, or until the soft tissue was easily removable from the bone. The bones were then left to dry for approximately 12 h. Since the Bio-Ad aids in degreasing to some extent, the ammonium hydroxide stage was omitted. The dried skeletal material was placed into the 3% hydrogen peroxide bath for approximately 12 h and again dried for another 12 h, then labeled and recorded.

All crania were documented in databases using Statview 5.0.1, Power PC Version, and with a picture form. Analysis of variance was used to observe differences among sample groups. In addition, simple bar graphs, using Microsoft Excel X for Mac, are provided to illustrate the differences in damage frequency and symmetry between the different regions of the mandible, as well as between the sample groups.

Results

A significant variation in the frequency of damage (both fractures and cracks) over the entire cranium based on muzzle velocity was found to exist. This result was expected, as damage should increase with greater energy transfer. To increase the sample size for this examination, an unpaired t-test was conducted to assure that the "shot" and "shot plus scavenged" samples were similar enough to be combined. As the frequency of damage between the "shot" and the "shot and scavenged" samples did not differ significantly ($p = 0.9065$), the two groups could be combined. In addition, the shotgun specimen was ultimately excluded from this analysis since a shotgun projectile is a number of pellets and not a single mass, as with the other firearm specimens used in this study.

The hypothesis that the frequency of damage is dependent on muzzle velocity was tested using analysis of variance (ANOVA). As the sample firearms did not demonstrate a spectrum of muzzle velocities, but rather an obvious division into two groups, "fast" and "slow" velocities, for regression analysis was not appropriate. Lee Enfield rifles were categorized as having a "fast" muzzle velocity with a speed of 2750 ft/s, while all of the other firearms used were labeled "slow," having a range of 885 to 1235 ft/s (shotgun Specimen B1 excluded).

A significant difference was found between the "fast" and "slow" muzzle velocities in the frequency of damage ($p = 0.0005$). This suggests that the degree of damage is, in part, dependent on the velocity of the projectile, with firearms with faster muzzle velocities creating more damage to the crania than their slower counterparts. Whether a linear relationship exists between muzzle velocity and degree of damage cannot be stated from this study; however, it ought to be explored using a larger sample size and a broader spectrum of muzzle velocities.

Based on the three observed forensic cases, it was believed that the coronoid processes and mandibular condyles would demonstrate the highest frequency of damage on the mandible in the "shot" sample. Fractures and cracks were combined into a general damage category, and the damage is not noted as side-specific but rather as an occurrence to either side and whether symmetry is present. Simple bar graphs are used to illustrate the patterns of damage (both fractures and cracks) observed based on the information provided in Table 3. In addition, ANOVA was used to test whether there were significant differences in the frequency of damage by location.

The coronoid process was the most frequently damaged location, fracturing on at least one side of the mandible in 100% of the "shot" specimens (Fig. 4). However, the frequency of damage symmetry was fairly unremarkable, with the coronoid process and mandibular ramus both exhibiting symmetry in only 50% of the specimens. In terms of the amount of damage occurring at each anatomical location, there was found to be a significant relationship between the frequency of damage and the location ($p = 0.0118$). The ramus was damaged most frequently, followed by the mandibular condyle (Table 4).

The main goal of this research was to examine whether the damage left by canid scavengers could mimic the damage caused by intra-oral gunshot trauma. To illustrate the differences between the two groups, simple bar graphs of frequency of damage to specific locations and the occurrence of symmetry were created (Figs. 5 and 6). When compared to each other, a clear difference is visible.

TABLE 3—*Locations of the mandible showing damage and damage symmetry.*

	Shot			Scavenged			Shot and Scavenged		
Location	*N*	Damage %*	Symm. %	*N*	Damage %	Synmm. %	*N*	Damage %	Symm. %
Symphysis	10	50	30	5	80	80	4	75	0
Ant. corpus	10	20	0	5	80	80	4	25	0
Post. corpus	10	40	10	5	100	20	4	50	50
Ramus	10	80	50	5	100	80	4	100	75
Coronoid	10	100	50	5	40	0	4	100	100
Condyle	10	60	40	5	20	0	4	75	50

* Damage to both fractures and cracks.

TABLE 4—*Variance between the "shot" and "scavenged only" samples and the frequency of damage at specific anatomical locations of the mandible.*

Anatomical Location	N*		Mean Damage†		Standard Error			
	Shot	Scav.	Shot	Scav.	Shot	Scav.	*P*-Value	Significance‡
Symphysis	10	2	2.100	1.500	1.016	1.500	0.8090	No
Anterior Corpus	10	3	0.200	4.333	0.133	2.963	0.0165	Yes
Posterior Corpus	10	4	1.400	3.500	0.897	2.179	0.3010	No
Ramus	10	4	5.100	7.500	1.269	2.533	0.3641	No
Coronoid	9	4	2.111	0.250	0.351	0.250	0.0070	Yes
Condyle	10	4	2.200	0	1.062	0	0.2254	No

* Variations in specimen numbers indicate that a given region of the mandible was not recovered.
† Fractures, cracks, left and right sides combined.
‡ Significance: $p \leq 0.05$.

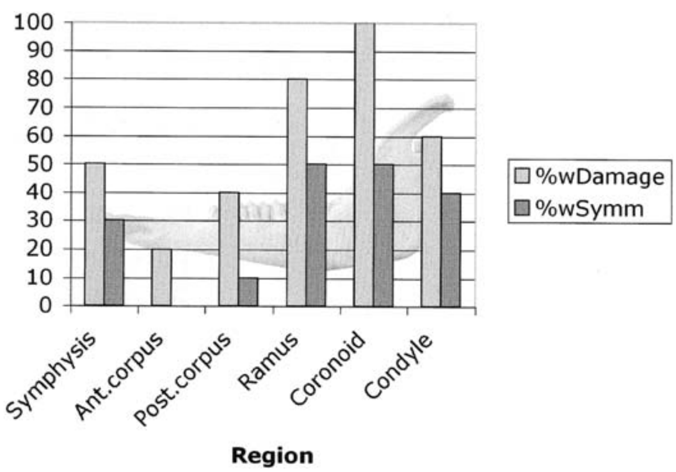

FIG. 5—*Frequency of damage to specific regions of the mandible and presence of symmetry in the "shot" sample.*

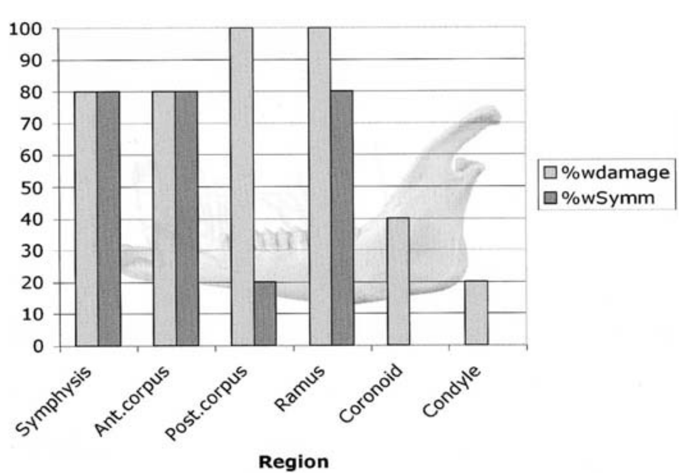

FIG. 6—*Frequency of damage to specific regions of the mandible and presence of symmetry in the "scavenged" sample.*

Damage is concentrated at the anterior mandible on the "scavenged only" sample, with the coronoid process and mandibular condyle being damaged relatively infrequently. In addition, the damage to the anterior of the mandible tends to be symmetrical. The "shot" sample exhibits damage to the anterior of the mandible relatively infrequently, with most damage being concentrated on the posterior. However, statistical comparisons were needed in order to examine the significance of these differences.

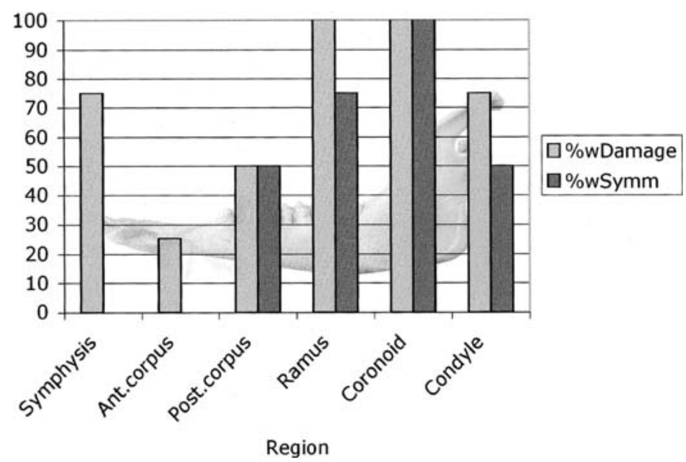

FIG. 7—*Frequency of damage to specific regions of the mandible and presence of symmetry in the "shot plus scavenged" sample.*

ANOVA was used to examine the frequency of damage by anatomic location (see Table 4). There were statistically significant differences in the frequency of damage to the anterior corpus and coronoid process between the "shot" and the "scavenged only" samples ($p = 0.0165$; $p = 0.0070$, respectively) (see Table 4). A greater degree of damage was observed on the anterior corpus in cases of scavenging and to the coronoid process in cases of intra-oral gunshot wounding.

The "shot plus scavenged" sample, though being an amalgam of both variables, was expected to show differences in the locations and frequency of damage when compared to the "scavenged only" sample. As with the other two samples, a simple bar graph of the data was created (Fig. 7). Based on this graph, the "shot plus scavenged" sample appears to have a similar damage pattern to the "shot" sample, but with a greater frequency of damage to the symphysis. Like the "shot" sample, the "shot plus scavenged" sample appears to have a greater frequency of damage to the posterior mandible, specifically the coronoid process and mandibular condyle.

The pattern of damage to the "shot plus scavenged" sample was also examined with ANOVA in order to observe whether it would be significantly different from the "scavenged only" sample (Table 5). There was a significant difference between the frequencies of damage to the coronoid process between the two samples ($p = 0.0036$)(see Table 5). The coronoid process was seldom damaged in the "scavenged only" sample, but was damaged in the entire "shot plus scavenged" sample, which was also seen in the "shot" sample.

TABLE 5—*Variance between the "scavenged only" and "shot plus scavenged" samples and the frequency of damage at specific anatomical locations of the mandible.*

Anatomical Location	*N*		Mean Damage		Standard Error			
	Shot/Scav.	Scav.	Shot/Scav.	Scav.	Shot/Scav.	Scav.	*P*-Value	Significance
Symphysis	4	2	1.000	1.500	0.408	1.500	0.6741	No
Anterior corpus	4	3	0.750	4.333	0.750	2.963	0.2316	No
Posterior Corpus	4	4	2.250	3.500	1.315	2.179	0.6408	No
Ramus	4	4	7.750	7.500	2.926	2.533	0.9506	No
Coronoid	4	4	2.750	0.250	0.479	0.250	0.0036	Yes
Condyle	3	4	1.000	0	0.577	0	0.0932	No

Discussion

The results of this study show that the mandibular fractures seen on Case 00-4 are entirely consistent with intra-oral perimortem gunshot trauma using an animal model. This is based on the location of the fractures at the base of the coronoid processes, the tissue shrinkage parallel to the fracture, the color of the fracture in comparison to the rest of the element, and the lack of scavenging artifacts in the direct vicinity of the coronoid fractures. According to this study, the coronoid process is the most common region of the mandible to fracture in cases of intra-oral gunshot trauma, with one or both coronoid processes fracturing in 100% of the "shot" and "shot plus scavenged" samples. Symmetrical coronoid fractures occurred in 50% of the "shot" sample. This degree of symmetry may not be typical, since a comparatively large sample of Lee Enfield .303 rifles, which have a high muzzle velocity and powder weight, were used. However, it does suggest that symmetrical fracturing of the coronoid processes is not a rare event and that the coronoid process fractures of 00-4 are characteristic of gunshot trauma to the mouth.

It should be stressed that the high incidence of coronoid fracture does not indicate that the coronoid is necessarily the weakest region of the mandible, but, in terms of the stresses applied by gunshot trauma to the mouth, it is the most easily fractured area. As previously stated, the area of the mandible that fractures is a function of the type and direction of force applied.

The condyle, also absent in Case 00-4, fractured in only 60% of the shot specimens. Other regions, such as the ramus, fractured more frequently (80% of the sample) than the condyle. The implication of this is that condylar fractures tend to occur most commonly when there is a relatively high-energy transfer. Symmetry of condylar fractures occurred in 40% of the "shot" and 50% of the "shot plus scavenged" samples. Thus, it is not unusual that 00-4's condyle fractured, but it cannot be concluded that the damage to that area is the result of the gunshot, as opposed to scavenging alone.

The ramus showed the highest frequency of damage in the gunshot sample, when looking at the actual numbers of fractures and cracks, rather than presence or absence of damage. This is because the ramus tended to have multiple fractures as opposed to the single fractures most often seen on the coronoid processes. The multiple fractures of the ramus tended to be centered at the mandibular foramen, perhaps indicating that it is a weak area of the mandible.

Although the cranium of Case 00-4 was not recovered, the degree of overall sheep skull fracturing and cracking was recorded and compared to the muzzle velocity. The muzzle velocity showed a significant relationship with the degree of damage to the entire head. As mentioned earlier, an increased sample size for the various firearms and ammunition is needed. However, these results are exactly what are expected, as transfer of energy to the target is directly related to the degree of damage. Higher velocities offer more energy to be transferred to the target, as it slows down the projectile.

It was found in this study that bilateral fractures of the coronoid processes are characteristic of intra-oral firearm trauma. This observation makes it more likely that the fractures of the coronoid processes of Case 00-4 were caused by intra-oral gunshot trauma. The entrance of muzzle gases into the oral cavity, as well as the cavitation caused when the projectile came into contact with tissues, would have created an outward force, causing fractures of the coronoid processes.

Statistical analysis (ANOVA) was conducted to examine whether "shot" samples were damaged differently than "scavenged only" specimens. The anterior corpus and coronoid processes were found to be damaged with a significant difference between the two groups; the scavengers focused on the anterior of the cranium, as the jaws project in this region, while the coronoid processes were more susceptible to damage in cases of intra-oral gunshot trauma.

The significant differences observed between the "shot plus scavenged" and the "scavenged only" remains were restricted to the coronoid process. Scavenging alone seldom damaged the coronoid process, while it was frequently damaged in specimens involving intra-oral gunshot trauma. Therefore, the damage to this region, as represented in the "shot plus scavenged" sample, was very likely due to the gunshot trauma rather than different scavenging patterns.

The projection of various bony areas of the head raises an issue regarding the ability to compare the human head to a sheep head. While a human head is very rounded, a sheep head is almost triangular in shape. The anterior face and mandible of the sheep project a great deal farther than that of the human. Therefore, it can be expected that scavengers will damage the remains somewhat differently. The crushing of the anterior mandible and premaxilla observed in this study may not occur on humans, as that region of the face does not project as far.

The coronoid process on the human mandible is relatively well protected by the zygomatic process, whereas it extends superiorly by half its length beyond the zygomatic process on the sheep. As scavenging alone seldom damaged the more vulnerable coronoid processes on the sheep, it can be implied that the more protected coronoid processes of humans would be even less likely to be damaged by scavengers.

Another variable that may affect the accuracy of the scavenging patterns observed in this study is the use of heads lacking bodies. The expected difference with this variable is that the head may be less scavenged when the entire body is available, as the scavenger may show preference for the body core and limbs. Also, the attachment of the cranium to the vertebral column would hinder scavenging to the inferior cranium. Since the remains fed to scavengers in this study were simply the head, one could make the assumption that the damage to the remains from this source is maximal.

The trauma observed on the coronoid processes of 00-4 is consistent with the explosive effect of the entrance of muzzle gases from a firearm into the oral cavity. Based on our animal model, the damage in question is not caused by scavenging. Notably, no firearm was recovered from the scene despite repeated searches. Nevertheless, given prior knowledge of the victim's personal history and the context of the remains, this death was certified as suicide by authorities.

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Additional information and reprint requests:
Cathy M. Puskas, B.A.
Department of Archaeology
Simon Fraser University
8888 University Drive
Burnaby, B.C., V5A 1S6
Canada

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Erratum

Erratum/Correction of Bilateral Fractures of the Coronoid Processes: Differential Diagnosis of Intra-oral Gunshot Trauma and Scavenging Using a Sheep Crania Model. J Forensic Sci 2003 Nov;48(6).

It has come to the attention of the Journal that for personal reasons, Rumney DT has chosen to remove herself from the position of co-author of the above-mentioned article. Puskas CM will be the sole author.

The Journal regrets this error. Note: Any and all future citations of the above-referenced paper should read: Puskas CM, Rumney DT. Bilateral Fractures of the Coronoid Processes: Differential Diagnosis of Intra-oral Gunshot Trauma and Scavenging Using a Sheep Crania Model. [published erratum appears in J Forensic Sci 2004 Jan;49(1)] J Forensic Sci 2003 Nov;48(6).