Bite Motivation of Sharks Reflected by the Wound Structure on Humans

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Abstract: Bite wounds on humans have rarely been comparatively analyzed, and the behavior leading to such bites is virtually unknown. Nevertheless, the behavior of a shark is reflected in the bite structure and should be an essential part of shark-accident analysis. This paper compares 3 nonfatal accidents on humans, caused by bull sharks, *Carcharhinus leucas*, that occurred within a 12-month period in the same area of the Bahamas. Examination focused on wound analysis and accidental reconstruction to determine the most likely bite motivation of the sharks. Two sharks targeted the left calf areas of the victims; another one bit the back area of a person. Although both calf bites had a very similar appearance, examination concluded that one of them showed the same triggering behavior as for the shark who inflicted the very different-looking back bite. Those 2 bites were competitive, whereas the other calf bite was initially of exploratory nature, turning into a stress-related bite.

Key Words: bite motivation, bull shark, wound structure

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In the past, shark bites on humans hardly revealed more information beyond the place of accident, the victim’s activity, and the damage the shark caused. But even if the species could be determined, the likely behavior leading to the accident was unknown. Nevertheless, the bite motivation of a shark is reflected in the structure of a wound and must be an essential part of a shark accident analysis. This paper compares 3 nonfatal accidents with bull sharks, *Carcharhinus leucas*, that occurred in the same area of the Bahamas within a 12-month period between August 2001 and 2002. The most likely bite motivation of the animals is discussed based on wound analysis and accident reconstruction.

Materials and Methods

Between the 12-month period of August 2001 and 2002, 3 people were bitten by bull sharks, *C. leucas*, in the Bahamas. The bites were nonfatal. The size of the animals was estimated by comparing the curvature of the individual wound margins with jaws from known-sized animals and rounded to the nearest 10 cm. Each wound was photographed prior to surgery or treatment. Wound examination focused on number of bites, margin structure, tooth imprints, wound depth, and tissue loss.23 Wound reconstruction determined the relative bite angle (RBA) and symphyseal axis projection (SAP). RBA is defined as the angle between the vertical axis of jaws when positioned onto the affected area and the main axis of the targeted human body area (rounded to the nearest 10°), where 0° is with the body or limb axis, 180° against it. SAP is defined as the vertical line between the upper (palatoquadrate) and lower jaw (Meckel cartilage) symphyseal articulation, to estimate (1) theoretical bite volume and (2) bite center. RBA and SAP are determined by using sets of the estimated jaw sizes on victim-sized mannequins. Wound margins of upper and lower jaws are referred to as bite top and bite bottom, respectively. Figure 1 shows SAP of a bull shark that was 240 cm in length, including individual upper and lower teeth. Upper teeth of this species are broad, triangular, and strongly serrated, with erect or slightly oblique cusps, and their bases overlap with each other; lower teeth are slender with broad serrated cusps, but no overlapping with adjacent teeth bases occurs.4 Upper teeth are primarily used to cut and saw (sideways movement along a surface when embedded in it, with ongoing perpendicular pressure); lower teeth are primarily used to puncture and hold a structure in position, with a limited capability of cutting and sawing. A tooth series is defined as the active teeth of a longitudinal jaw axis; a row is defined as the in-line teeth of any individual tooth of the active series.5

Results

Case 1

Figure 2A and B shows the posterior and lateral side of the lower left leg of a 177-cm man. The affected muscles included the gastrocnemius, soleus, and peroneus longus. The
180-cm (approximate length) shark bit the lower leg of the victim 3 times. The first bite (B1) is represented by a superficial puncture wound of the lower jaw around its symphysis area, with a very slight sideways motion (Fig. 2A). The second bite (B2) is visible by a small segment of a margin created by the right upper jaw (Fig. 2B), with an RBA of approximately 130°. The third bite (B3) consists of the primary bite with an RBA of 80°. Its curvature margin shows extensive sawing (Fig. 2B). SAP excluded tibia and fibula for any of the 3 bites.

Case 2

Figure 3A and B shows the left lateral and medial side of the lower left leg of a 179-cm man. The affected muscles included the gastrocnemius, soleus, peroneus (longus, and brevis), extensor digitorum longus, and tibialis anterior. The external component shows a clear-edged bite top, with a well-defined sawing motion (Fig. 3A), and an RBA of 90°. The nearly severed gastrocnemius matches the upper jaw curvature. The bottom area shows cuts and puncture wounds. The tissue flaps show a slight change of the RBA during the bite. A second much smaller and only partially visible bite (X) exists as well (Fig. 3B). SAP included tibia and fibula (which was severed). The length of the shark was 240 cm.

Case 3

Figure 4 shows the back area of a 183-cm man. The approximately 300-cm-long shark approached the victim with a 0° RBA. The bite top is seen by the superior puncture wound, the bite bottom by the inferior one. Both teeth sets caused superficial imprints, with a very light closing motion of the upper teeth towards the bite center (but without
protraction of the palatoquadrate). Some upper-tooth imprints show bending ends due to a slight body turn of the shark or the victim. Wound diameters of individual teeth indicated midlevel tooth penetration for both upper and lower teeth. Upper jaw wound shows 7 tooth imprints of the active series and 2 imprints from in-row teeth; the lower one shows 9 tooth imprints of the active series and 5 imprints from in-row teeth.

**DISCUSSION**

The motivation for sharks to bite humans is poorly understood and primarily of theoretical nature.6-8 Hardly any case studies exist where a shark was observed approaching and biting a human being to connect the resulting bite pattern with the triggering behavior.1 Nevertheless, the wound structure can reveal important hints to the antecedent motivation of the animal to initiate and execute a bite, even when no information from the victim or a witness is available. Cases 1 and 2 show a very similar bite structure. Nevertheless, these 2 bites show differences, pointing to unrelated bite motivations. In case 1, the shark bit 3 times. The first bite is represented by a few very superficial and irregular tooth imprints. Only a lower jaw in the symphyseal area where several rows of teeth are often active can create such a pattern. This first bite was created without great force, suggesting a slowly approaching animal whose initial bite was interrupted. This was most likely due to a reaction of the victim at first contact or due to the large RBA, nearly against the target area axis, making a forceful bite impossible and necessitating a change of RBA. The bite top of this first bite lies within the main bite and was destroyed during the process. The second bite was more forceful. This is indicated by the well-developed upper jaw margin, which is clean-edged. This bite was also interrupted. The reason remains unclear, but since the animal readjusted its RBA, the still-large RBA could have been a reason, or the victim moved his leg. The third bite was executed without interruption. Despite the victim’s tissue loss, the bite pattern does not show a hunger-motivated behavior with the victim as the primary target, since SAP reveals a much larger theoretical bite.
volume than what was actually removed. Nevertheless, a
hunger-oriented motivation is likely but with the human as
the secondary target, and the person was seen as a competitor
(eg, being too close to a potential prey). Since the shark
applied several bites in quick order without the intent to
remove tissue, its motivation points indeed toward competi-
tion. Since human beings are unknown objects to sharks,\textsuperscript{1}
it is crucial to look for similar bite patterns in their biology to
understand and explain such a scenario and its triggering
behavior. Biting without causing damage is known among
sharks when they, for example, compete for food.\textsuperscript{9} At close
range to a food source, they hit and bite each other prior to
initiating a bite, should another shark be too close.\textsuperscript{9} The
rather severe damages to the victim's leg occurred because
the shark used a similar force that it would also apply for
conspicuous that have a much tougher skin than humans,
even when wearing dive suits, and so this particular animal
just followed a general action pattern for such a situation.\textsuperscript{10}
When the bites occurred, the person was certainly in a
vertical position. A horizontal position would have triggered
the initial bite in the 90° RBA area and not against the leg
axis.

Although the wound of case 2 shows close visual
similarity to case 1, it shows a different motivation. The
wound pattern even indicates a motivation change during the
incident itself. This victim was bitten twice, as seen by the 2
different bite bottoms. The first bite (X) is only manifested by
a few lower jaw imprints. The rest of this bite is erased by the
main bite. Both bites were terminated early. It cannot be
determined by the wound pattern if the first interruption was
caused by the person through pulling the leg away or by the
animal readjusting its bite. But it is clear that the second bite
was terminated early due to a reaction of the victim. Three
facts support this conclusion: (i) the still partially attached
muscle flap that follows the margin of the upper jaw, (ii) the
tissue flaps created by the lower teeth, and (iii) the change of
RBA within the second bite structure. For unknown reasons,
the shark attempted to remove muscle tissue during the
second bite by applying a sawing motion. When sharks gouge
removing tissue from an object that exceeds the bite volume
of the feeding animal), they normally do not terminate the
bite until the piece is removed; hence, the still partially
attached muscle flap points towards an interruption. That the
interruption was indeed caused by a leg motion of the victim
is also evidenced by the tissue strips from the lower teeth.
Sharks cannot swim backwards, and such a pattern can only
occur if the person moved the leg. The changing RBA
supports this conclusion as well. RBA rarely changes if the
object does not move when a bite occurs. Since the bites were
initiated from behind the person, visual contact of the animal
prior to the bite was not likely. The RBA of the second bite
showed a 90° angle and suggests that the victim could have
been in either a horizontal or vertical position when bitten.

However a horizontal position is unlikely due to the large size
of the animal. If being bitten at the surface, the victim would
have laid on his back and been able to lift his left leg out of
the water with the animal attacked. The size of the animal
makes such a scenario impossible, and a vertical position is
more favorable where the person could pull the weight of the
shark within the water. Exploratory behavior, as the initial
motivation suggests by th superficial imprints of the lower
jaw during the first bite, then seemed to have evolved into a
stress-related bite, suggested by the upper-jaw damage of the
second bite. That a competitive bite was not the case is
indicated by the much greater bite volume of the second bite
with clear edges.

Case 3 showed a completely different wound picture,
but its analysis groups it with case 1. The shark swam into
the victim with a fully open mouth. The upper jaw was not in
protraction\textsuperscript{11} at the time of impact, since it would have
created more and deeper imprints with the upper-jaw teeth
and created different imprint angles. No sawing motion was
detectable, indicating that the animal's intention was not to
remove tissue from the person but to only trigger a reaction.
Although the same motivation occurred for the first case, the
wound picture of case 1 and case 3 shows a very different
appearance, what is due to (i) body area of the person and
Langer lines,\textsuperscript{12,13} (ii) body motion of the shark or the person
at impact, and (iii) much larger size of the involved animal.
Considering the large size of the shark in case 3, the midlevel
tooth imprints indicate a slow swimming animal at impact as
well. The 0° RBA indicate the victim was ascending or
descending but not floating. On a person, floating horizontally
in the water, facing skywards, a bite would be located closer
to the lateral side of the rib cage or hip area, with an RBA
around 90°, or even more likely, bites to the limbs. The latter
would also be most likely if a person would be in a vertical
position at the surface. Such a position requires sculling with
arms or treading water, and bites would certainly occur to the
moving parts of a body.\textsuperscript{1} The person was not at the surface
during the bite but either diving down or ascending towards
the surface. That the shark hit the person only 1 time and not
repeatedly, as in case 1, is likely due to its much larger size
relative to the person. The way the shark hit the person, with
fully open jaws at impact, prevented the shark from closing
its jaws and removing tissue, indicating that the motivation
was indeed competition in which hitting rather than biting is
a means to initiate a reaction from the target.

CONCLUSIONS
The analysis of bite marks from sharks can determine
the likely motivation of the animal to initiate and execute a
bite and the position the victim was in when being bitten. The
findings suggest that older cases of shark bites should be
reevaluated where motivational reasons of a shark or victim

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position were of importance to understand the structure of the wound picture.

REFERENCES