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TECHNICAL NOTE

Odontology; Anthropology

Use of presence vs absence of symphyseal teeth in jaws for the forensic analysis of bites by large traumatogenic shark species

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Abstract

Identifying the species of shark responsible for a bite on humans is both complex and important for understanding and managing the shark risk. Depending on the species, tiny teeth may or may not be present in the symphyseal space at the junction of the upper and lower half-jaws. In the case of bites, these tiny teeth (if present) often leave specific marks that may enable species to be quickly and reliably distinguished. We first present the anatomo-morphological characteristics of the jaws of the three most traumatogenic species for humans which are the white, tiger, and bull sharks. The white shark has no symphyseal teeth, while the tiger and bull sharks do. On the basis of three confirmed real case studies involving those species, we then show that for the white shark, the wide symphyseal space between the first two teeth of each jaw usually leads to wounds including the presence of (quite) large flesh flaps, without any tooth imprint. Conversely, wounds following bites made by the tiger and bull sharks will generally leave characteristic small imprints of symphyseal teeth, especially in the case of incomplete or superficial bites. Although not systematic, this diagnostic approach provides fast, reliable, and clean results. The discrimination between two species with symphyseal teeth can then be made on the basis of complementary anatomic information such as jaw curvature and details linked to the anatomy of the teeth themselves, as well as the ecological context.

KEYWORDS

bull shark, marine predator identification, shark bites, symphyseal teeth, tiger shark, white shark

Highlights

- Forensic analysis of wounds linked to bites on humans helps to determine the shark species involved.
- In sharks, the junction between the two upper and lower hemi-jaws forms a symphyseal space.
- Depending on the species, symphyseal teeth may or may not be usually present.
- For white shark, the absence of these teeth often results in a imprint flesh flap without tooth imprints on the wounds.

- For tiger and bull sharks, the presence of these teeth leaves characteristic imprints on the wounds.

1 | INTRODUCTION

Although shark "attacks," that should be more neutrally named "bites" [1], are rare worldwide, with only a few hundred cases per year [2], they are a major issue for beach-orientated economies. In the 21st century, the number of shark bites seems to be on the increase [3], particularly in connection with the growing use of the aquatic environment by humans [4]. In addition, broad-scale programs of shark-bite mitigation implemented for several decades now are still struggling to prove their effectiveness, as has been the case in Eastern Australia since the 2000s [5]. Shark bites are likely to continue and even increase in the years to come, and this must be anticipated in their understanding and management [2].

The vast majority of bites resulting in death are caused by three species: namely the white shark (*Carcharodon carcharias*) (mentioned here after as WS), the tiger shark (*Galeocerdo cuvier*) (TS), and the bull shark (*Carcharhinus leucas*) (BS) [2]. Following a fatal bite on a human, it is important to identify the species of the biting shark and even its size [6]. This information makes it possible to direct risk management by targeting certain species and even individuals, rather than indiscriminate culling campaigns, which are not only unethical and ineffective but also have a significant deleterious ecological impact due to the vulnerability of taxa that are often endangered [7].

Given the rarity and stochasticity of these events on a global scale, the medical practitioners in charge of autopsies on victims are rarely trained in forensic identification methods. There are several articles on Forensic Medicine on the subject, sometimes based on several case studies [8, 9], but at this stage, only one book article has attempted to synthesize basic, generic data on the subject and is not commonly available to medical practitioners [10]. In this study, we propose a comparative analysis of a precise anatomical detail within the three traumatogenic species most involved in fatal bites on humans, which often allows a basic, quick, and effective diagnostic approach.

2 | MATERIALS AND METHODS

2.1 | Symphyseal space and teeth

The upper and lower shark jaws are each made up of two symmetrical cartilaginous hemi-mandibles incorporating rows of temporary teeth that develop from the inside of the oral cavity outwards in a conveyor-belt fashion [11]. The two hemi-mandibles are joined in the middle by a symphysis that ensures the rigidity of the mandible which evolved in different ways in different species [9]. The gap between the first two teeth of each hemi-mandible is called the "symphyseal space" [12].

Depending on the species, this symphyseal space may or may not include symphyseal teeth which are significantly smaller than the other teeth and only present in the first row of teeth [13, 14]. When a shark bites soft tissue, depending on whether or not these teeth are present, they will potentially leave marks that can help to identify the species (see Ref. [15]).

2.2 | Description of jaws and case studies

For didactic purposes, we selected from the collection of one of this study's co-authors (SDM) a jaw presenting the anatomo-morphological characteristics typical of the three shark species most implicated in fatal bites on humans (WS, TS, and BS). We photographed these jaws, detailing the symphyseal spaces and the presence or absence of symphyseal teeth as well as imprints taken in modeling clay.

At the same time, we drew on our personal professional archives (EC and DR) to present photographs of bite marks made by these three species (on humans or on inert substrates), to show concrete examples of marks left, or not, by symphyseal teeth.

3 | RESULTS

3.1 | Comparison of the three jaws and specific symphyseal space imprints

For the same or similar individual sizes, comparison of the three jaws shows major differences not only in their overall shape, with the WS's jaw stretched vertically (Figure 1A), the TS's horizontally (Figure 1B), and the BS's more symmetrical overall (Figure 1C). The shape of the teeth is also characteristic, with heterodont profiles in the WS and BS featuring triangular lower teeth that are wider on the upper jaw than the lower (Figure 1A,C), while the TS has homodont (similar) teeth on both jaws (Figure 1B). As for the symphyseal spaces, small teeth are generally present on top and bottom jaws in the TS and BS, whereas the WS never has symphyseal teeth (Figure 1). It is worth noting that, like other teeth, symphyseal teeth have a high propensity to fall out, often resulting in asymmetry with only one symphyseal tooth (until the other is replaced), instead of two, or even temporarily none in rare cases.

3.2 | Flesh slaps vs small teeth imprints

Based on the above-mentioned anatomical differences, the comparison of the features of bite marks in the real world can indicate the presence or absence of symphyseal teeth. In the case of a WS, the absence of symphyseal teeth and the wideness of the symphyseal space will—most of the time—allow the cutting of a flesh slap as it was observed on the leg of a young surfer, fatally bitten by a 2.7 m

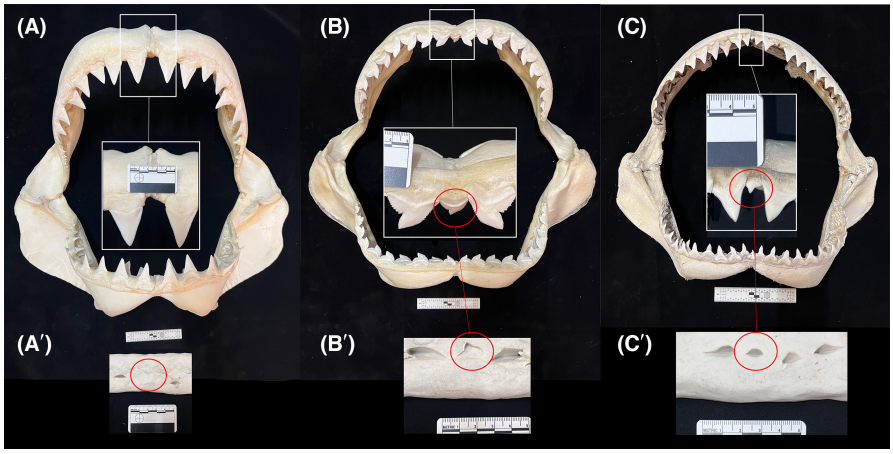

FIGURE 1 Comparison of the symphyseal space in the three most traumatogenic species. (A) White shark *C. carcharias* characterized by large teeth as well as inter-dental spaces and the absence of symphyseal teeth or potential imprints (red circle in A'). (B) Tiger shark *G. cuvier* characterized by smaller (compared to similar animals' sizes) bicuspid teeth with shorter inter-dental spaces and the presence of symphyseal teeth and imprints (red circle in B′). (C) Bull shark *C. leucas* also characterized by small (compared to similar animals' sizes) teeth with shorter inter-dental spaces and the presence of symphyseal teeth and imprints (red circle in C′).

total length (TL) WS in New Caledonia in 2011 [16] (Figure 1A,A'). On the contrary, small teeth imprints were observed on the leg of a young kitesurfer who was fatally bitten (based on other bites) by a 2.8 m TL TS in New Caledonia in 2013 [15] (Figure 2B). Our third case study from Eastern Australia involves a bite on a surfer by a 2.8 m TL BS, including two small symphyseal tooth imprints (Figure 2C).

4 | DISCUSSION

4.1 | Quick assessment of the shark species

Identifying the species of shark involved in a bite on a human requires a multifactorial approach, combining (i) direct information collected via potential witnesses (or images), (ii) ecological data concerning the presence of species potentially traumatogenic to humans (with a historical perspective if possible), and (iii) careful analysis of wound characteristics (subject to the possibility of complementary examinations such as genetics and X-rays). In view of the fact that 80% of fatal bites requiring forensic expertise involve only three species of large shark, this study provides a methodological approach that is certainly not 100% reliable, but does allow—if the characteristics of the bite permit—a rapid diagnosis between the WS and the other two species, the TS and the BS. Discrimination between the latter two species will be based on other factors, notably differential tooth shape and curvature of the jaws [10].

4.2 | Teeth penetration and jaw shearing issues

In all three case studies, the shark species was confirmed by a witness, thus guaranteeing the exact origin of the bite. However, the characteristics of bites are not always so obvious, depending on the strength and completeness (including duration) of the bite. It is important to note that the more superficial (and quick) the bite, the more likely it is that symphyseal teeth imprints might be visible; in fact, in the case of deep and completed bites with heavy loss of material, the regular edges of the wound render symphyseal teeth imprints indistinguishable.

In addition to penetrating teeth, another factor can interfere with the assessment of whether or not symphyseal teeth are present: jaw rotation during the bite. To facilitate the removal of tissue (sometimes including underlying bones), most large sharks will make one or more lateral movements to slice flesh. In this case of more sustained bites, the edges of the wound will be relatively clean-cut rather than show individual tooth imprints and it will be impossible to rely on the presence/absence of symphyseal teeth to be conclusive. An exception exists with the case of a bite-and-spit process (see details in Ref. [17]), when sharks close their jaws on tissue and reopen them instantly without any lateral cutting, with no loss of material and only shear wounds as after-effects; in that case, although the bite might be deep, the flesh slaps may still be present. Globally, identification of the shark species is all the easier if there are one or more incomplete bites on the victim.

4.3 | Improvement of medical protocols linked to shark bites for a forensic purpose

In terms of species discrimination, it is important not to overlook the potential presence of shark teeth or pieces of tooth that become detached during bites either on the victims or hard surfaces such as surf boards [10, 18]. If morpho-anatomical analysis is inconclusive, DNA analysis can unequivocally identify the species concerned [19]. On the other hand, victims of serious bites often survive, and medical treatment can interfere with the forensic analysis process, in particular by providing reconstructive surgery as quickly as possible. For this reason, we advocate the implementation of medical

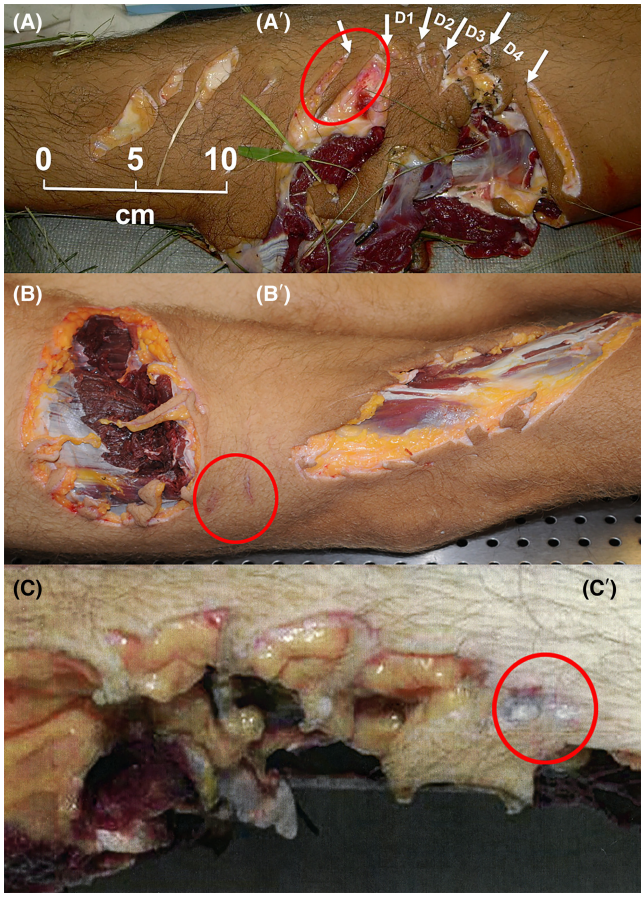

FIGURE 2 (A) Upper jaw imprint of a WS bite; the red circle (A') is indicating the presence of an elongated flesh flap resulting from the presence of a large symphyseal space on the upper jaw as well as the absence of symphyseal teeth which would have cut the flesh. It is interesting to note that the inter-dental space is also wider between the two teeth D3 and D4 which also allows such a specific cutting of a flesh slap. (B) Upper jaw imprints of a TS bite; the red circle (B′) indicates the two superficial imprints of two symphyseal teeth. (C) Upper jaw imprint of a bite by a 2.8 m BS. The red circle C′ indicates imprints of two symphyseal teeth.

protocols (very scarcely implemented) that include (i) an assiduous search, potentially including a scanner or X-ray, to identify (fragments of) teeth, and (ii) taking multiple photos (in wide and close-up shots)—that include a metric marker—to efficiently analyze the wounds details before tissue restoration.

4.4 | Symphyseal teeth in all Carcharhinus species

While the three species chosen as case studies account for the highest number of fatal bites to humans, other species such as the oceanic whitetip shark *Carcharhinus longimanus* (OWT) can also be considered potentially traumatogenic to humans. We did not consider appropriate to include this species, as its dentition is very similar to that of the BS, with symphyseal teeth as in all members of the *Carcharhinus* genus. If the teeth shapes are quite similar, the decisive factor in discriminating between these two species is the geographical area where the bite took place, given that the OWT is essentially an oceanic, pelagic shark [20], whereas the BS has a predominantly coastal ecology [7].

5 | CONCLUSION

Early discrimination between the three species is invaluable, particularly in areas affected by shark bites where they may co-exist, such as Australia, Hawaii, and New Caledonia in the Pacific Ocean, or South Africa, Reunion Island, and the Seychelles in the Indian Ocean. Indeed, it can enable authorities to better target a species during shark targeted fishing campaigns implemented in the hours and days following an incident, by authorizing eco-responsible non-lethal fishing that allows the release of sharks from the two non-target species as suggested by some authors [21], in order to limit the impact of unnecessarily culling individuals from taxa whose conservation is a high priority, particularly in view of the role they play in marine ecosystems [22].

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions.

CONSENT

Written informed consent was obtained from the patient to publish this report in accordance with the journal's patient consent policy.

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