Dental Barotrauma in French Military Divers: Results of the POP Study

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OBJECTIVE: The aim of the POP (odontological problems among divers) study was to assess dental barotrauma among French military divers exposed to an underwater environment.

METHODS: A questionnaire on dental barotrauma was completed by the divers who presented at the SMHEP (Centre for Hyperbaric Medicine and Diving Expertise) for their quadrennial medical exam from March 2011 to July 2014.

RESULTS: There were 1317 questionnaires completed, representing 60.6% of all French military divers. A total of 5.3% of divers had a dental barotrauma (70/1317), mainly fracture and/or loss of dental restoration. Dental barotrauma disrupted diving in 34.3% of cases. A total of 76.4% of divers were informed by a military physician of the importance of maintaining good oral health and 88.5% of divers consult their dentist at least once a year. Of the participants, 82.5% made their dentist aware they are divers, but only 4.9% of the dental practitioners advised their patient not to dive after some types of dental treatments and 12.8% indicated that, as divers, they need adapted dental treatments.

CONCLUSIONS: Dental barotrauma was experienced by 1 in 19 military divers. Nevertheless, a contradiction exists between the frequency of dental barotraumas and the rigorous medical and dental follow-up of military divers. We note that there is inadequate dental management of divers when dental issues are identified. To avoid this unsatisfactory situation, "diving dentistry" should be taught to military and civilian dentists and physicians to make them aware of the potential dental complications and preventive measures associated with operating in a subaquatic environment.

KEYWORDS: dental barotrauma, diving dentistry, diving, prevention.

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Since the development and use of the self-contained underwater breathing apparatus (scuba) in the middle of the 20th century, barodontalgia and dental barotrauma have been reported.[9,10] Dental barotrauma, as other diving-related dysbaric accidents (barotraumatism) affecting the body's rigid cavities (middle ear, sinus, tooth, etc.), is caused by changes in the volume of gas when the pressure varies according to Boyle's Law.[10] Beyond the need of dental treatments, dental barotrauma can have deleterious consequences on the diver's health. Complications may include the ingestion or inhalation of parts of the fractured tooth and/or restoration and pain, which may be severe enough to affect the objectives of the dive.[2] Dental barotrauma may be manifested as:

- Tooth fracture or fracture of dental restorations (these two types of barotrauma are included in the term "dental fracture"). These fractures can occur during ascent (most frequent case) but also during descent.[10] These two types of fracture involve different mechanisms:
  - Dental fracture occurring during ascent are due to the presence of a cavity, which is, most of the time, related to a secondary dental caries lesion which has developed adjacent to the restoration.[1] During the ascent, the air contained in the cavity expands and as a consequence the tooth and/or restoration fracture.[3]
  - Dental fractures occurring during the descent are rarer. They are due to restorations of least resistance (e.g., a temporary filling) or to the presence of a cavity under a restoration (defective restoration with or without secondary

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caries, cotton pellet under temporary filling, unfilled root canals, etc.).[10] During descent, two phenomena favor the collapse of the restoration, namely the increase of pressure on the dental filling material and the contraction of air contained in the cavity under restoration.

- Reduction of prosthetic device retention.
  - Fixed prosthesis. The variations in atmospheric pressure in the microbubble of air contained in dental cement used to sealed dental prostheses can weaken the cement and lead to a significant reduction of the retention of prosthetic devices sealed with zinc oxyphosphate cement or glass ionomer cement and temporary cement, contrary to crowns sealed with resin cement, which have adequate retention even with pressure changes.[5,6]
  - Removable prosthesis. Changes in barometric pressure can impair the retention of removable dentures (especially on maxillary dentures).[7] However, this is mainly observed in flight conditions (reduced pressure).[9]

Theoretically, dental barotrauma can be prevented because they are mainly due to pre-existing risks factors related to pathologies (e.g., secondary caries), defective dental treatments (e.g., inadequate restorations), and inappropriate dental treatments (e.g., use of temporary filling or cement other than resin cement).[2,10] In the military area, the potentially deleterious impact of dental barotrauma on diving security and operational capabilities of forces led the French military health service to conduct an epidemiological study, the POP study (odontological problems in military divers), focused on the dental consequences of the exposure of military divers to the subaquatic environment and on the military divers' perceptions of the importance of maintaining good oral health.

METHODS

Subjects

The protocol and procedures of the POP study were approved by the Institutional Review Board of the Sainte Anne Military Hospital of Toulon. The study was conducted in accordance with the declaration of Helsinki and good practice guidelines in odonto-stomatology.

French military divers undergo strict medical examinations over their entire career, annually at their military unit and every 4 yr at the Centre for Hyperbaric Medicine and Diving Expertise (SMHEP) of the Sainte Anne Military Hospital of Toulon. All divers of all three services and the gendarmerie nationale who attended the quadrennial medical exam in the SMHEP institute between March 2011 and July 2014 were asked to participate in the study.

Procedure

A questionnaire was distributed by the SMHEP and the Subaquatic and Hyperbaric Operational Research Team of the Military Institute of Biomedical Research (SHORT). In the questionnaire, divers were asked about experiencing diving related dental problems, the level of dental education provided by healthcare practitioners, and attendance to dental care. The questions were:

- Did you experience dental barotrauma during your career (tooth fracture, fracture of dental restorations, and/or loosening of fixed or removable dental prostheses)?
- Did this problem disrupt diving?
- Have you been informed by a military practitioner of the importance of maintaining good oral health to dive?
- Do you think that an improper oral health may have deleterious consequences during diving?
- Do you consult a dentist at least once a year?
- Did you alert your dentist that you are a diver?
- Did your dentist tell you that, as a diver, you need adapted dental treatments?
- Did your dentist tell you that you must not dive after some types of dental work?

RESULTS

A total of 1389 questionnaires were distributed to divers, of which 1317 (94.8%) were fully completed and included in the study, representing 60.6% of all French military divers (N = 1317/2172). Men comprised 98.0% of the studied population.

A total of 70 divers experienced a dental barotrauma event (5.3% of divers, 70/1317; **Table I**). In 34.3% of cases (24/70), the dental barotrauma disrupted diving (**Table II**). The frequency of dive disruption is higher for fracture and/or loss of dental restoration and loosening of fixed dental prostheses (Table II).

Most military divers were fully aware of the need for having a rigorous dental follow-up. Of the divers, 76.4% (1006/1317) were educated about the importance of maintaining good oral health and almost all divers (N = 1301/1317, 98.8%) knew that improper oral health may have deleterious consequences during diving (**Table III**). The awareness of divers needing a rigorous dental follow-up makes most of them consult a dentist at least once a year (1165/1317, 88.5%) and make their dentist aware that they are divers (1087/1317, 82.5%) (Table III). But only 12.8% of divers indicated that their dentist told them that

Table I. Types and Frequencies of Dental Barotrauma.

DENTAL PROBLEM	NUMBER OF PROBLEMS	FREQUENCY OF THE PROBLEM IN THE SAMPLE (N = 1317)	FREQUENCY IN ALL DENTAL BAROTRAUMA ENCOUNTERED (N = 70)
Fracture and/or loss of dental restoration	48	3.6%	68.6%
Tooth fracture	11	0.8%	15.7%
Loosening of fixed dental prosthesis	8	0.6%	11.4%
Loosening of removable dental prosthesis	3	0.2%	4.3%

Table II. Impact of Dental Barotrauma on Dives.

DENTAL PROBLEM	NUMBER OF PROBLEMS	NUMBER OF CASES (AND FREQUENCY) FOR WHICH THE DENTAL PROBLEM DISRUPTED DIVING
Fracture and/or loss of dental restoration	48	18/48 (37.5%)
Tooth fracture	11	3/11 (27.2%)
Loosening of fixed dental prosthesis	8	3/8 (37.5%)
Problem with a removable dental prosthesis	3	0/3 (0%)
Total	70	24/70 (34.3%)

they need adapted dental treatments and 4.9% of divers indicated that their dentist advised them not to dive after some dental work (Table III).

DISCUSSION

The prevalence of barometric-related dental fracture varied according to studies in the literature from 0.8 to 6.6%, with a mean prevalence of 5.3%.[4,12] In French military divers, the prevalence of dental fracture (4.5%) is not statistically significantly different from this mean prevalence. A study including a sample of 125 Australian divers did not show any loosening of dental prosthetic devices during diving.[8] The POP study highlights that, in French divers, 0.8% had a prosthetic crown unseal during a dive and 0.2% had a loosening of removable dentures.

The attendance of the French military divers to dental health is adequate and similar to other military populations.[11] However, it may seem that these appointments are not fully used for relevant patients' education and preventive activities in order to prevent diving-related dental consequences (including the correction of faulty restorations). The results of the POP study show a contradiction between:

- The rigorous medical and dental follow-up of military divers and the awareness of divers of the importance of maintaining good oral health. As a part of the determination of their medical fitness, divers undergo, as every French military personnel, a dental follow-up with periodic panoramic radiographs and dental check-ups. The objective of the dental examination is to identify any oral conditions that may involve a dental emergency. Divers need to have these conditions treated to keep their fitness to dive. Our study showed that divers are fully aware of this need because they:
  - are informed by military physicians of the importance of maintaining good oral health to dive and they regularly consult a dentist;
  - know that improper oral health may have deleterious consequences during diving; and
  - regularly consult a dentist and made him aware that they are divers.
- The occurrence of in-diving dental problems. Preexisting leaking restorations and/or secondary caries lesions underneath restorations in the affected tooth prior to exposure to the barometric changes are the predisposing factors that constantly appear in dental barotrauma reports, as well as in in vitro studies and theoretical discussion.[9] Dental barotrauma can be considered as predictable and preventable by preventing, screening, and treating pre-existing dental pathologies before the dive.[2,10]

This situation raises the question of the adaptation of the current dental management of military divers to the real ways to prevent diving-related dental problems. Currently, the dental follow-up of divers is strictly identical to the one existing for all military personnel, regardless of their specialty. This situation is not consistent with the fact that the exposure of divers to a subaquatic environment involves specific consequences, especially to oral health. To study and prevent these consequences, a new discipline appeared a few years ago: "diving dentistry," including a detailed protocol of maintenance, diagnosis, and treatment.[2,10] This discipline, not yet taught in universities, is still unknown by most dentists, who, indeed, cannot effectively help their patients to prevent the appearance of diving-related dental problems. Thus, even if most divers make their dentist aware that they are divers, only very few dentists suggest specific follow-up to their patients. In the military area, dental problems occurring during diving can have a deleterious impact on operations, with the risk of making the divers incapable of performing their mission. So, diving dentistry should be included in the curriculum for military dentists and physicians.

A dental barotrauma was experienced by 1 in 19 French military divers. These dental barotraumas, which are mainly due to pre-existing oral conditions, disrupted diving in almost one-third of cases, with a potentially deleterious operational impact. These occurrences are a contradiction to the rigorous medical and dental follow-up of divers and to the awareness of

Table III. Frequency of the Responses to the Questions on Oral Health and Dental Follow-Up.

QUESTION	YES (FREQUENCY)	NO (FREQUENCY)
Have you been informed by a military practitioner of the importance of maintaining good oral health to dive?	1006 (76.4%)	311 (23.6%)
Do you think that an improper oral health may have deleterious consequences during diving?	1301 (98.8%)	16 (1.2%)
Do you consult a dentist at least once a year?	1165 (88.5%)	152 (11.5%)
Did you alert your dentist that you are a diver?	1087 (82.5%)	230 (17.5%)
Did your dentist tell you that, as a diver, you need adapted dental treatments?	169 (12.8%)	1148 (87.2%)
Did your dentist tell you that you must not dive after some types of dental work?	65 (4.9%)	1252 (95.1%)

divers of the importance of maintaining good oral health. In the dental field, the mission of the military health service is to allow for the availability of soldiers without any loss of time or efficiency attributable to a dental cause. To achieve this objective, diving dentistry should be taught to military and civilian dentists and physicians to make them aware of the specific dental consequences of the exposure to the subaquatic environment and the ways to prevent these consequences.

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