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Barodontalgias, dental and orofacial barotraumas

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SUMMARY
Changing ambient pressure can lead to medical conditions in body cavities filled with air. Intraoral pain elicited by changes in pressure is referred to as barodontalgia. Dental barotraumas are defined as pressure–induced damages of teeth and restorations. The pathophysiologic background so far is not completely clear. The present study deals with dental and orofacial symptoms which can occur as a result of pressure variations.

With the aid of cantonal administrations, diving associations, and tunnel construction firms, 520 pressure–exposed individuals (499 scuba/professional divers, 21 caisson workers operating at excess pressure) were questioned regarding dental problems. A personal interview was conducted with affected individuals.

Problems in the dental area were experienced by 15% of all respondents. Toothaches were suffered by 10.2% of the participants. Tooth injuries occurred in 6.3% of all interviewees (26 fractured amalgam restorations, 4 crown fractures, 3 losses of tooth fragments). A proportion of 11.3% among the respondents complained about temporomandibular joint problems or mucosal irritations (for example aphthae) related to the mouthpieces. Barotraumas outside the dental area were incurred by 31.9% of the divers. Of these, 69.9% concerned the ears and 65.6% occurred during the descent.

Based on the results obtained from the survey and taking into account the current literature, recommendations for the prevention of barotraumas in divers and caisson workers were prepared.

Diagnostic exclusion of dental pathologies and avoidance of retentive reconstruction materials are important factors for the prevention of barodontalgias and dental barotraumas.

KEYWORDS
dental trauma; barotrauma; barodontalgia; soft tissue injury; diving accidents
Introduction
According to the law of Boyle–Mariotte, the pressure of an ideal gas is inversely proportional to the volume, provided that the temperature and the amount of gas are constant. If pressure rises during the descent of a dive, the volume of the gas declines. If pressure diminishes during the ascent of a dive, the volume increases. This also applies to body cavities filled with air. Divers and caisson workers experience variations in ambient pressure during their dives and work. At construction sites with high groundwater level, caisson workers operate in shafts secured by excess pressure against the intrusion of water.

Traumas due to pressure (barotraumas) in the orofacial area comprise barotitis media, barosinusitis, pressure–induced headache, barodontalgia, and dental barotraumas (Zadik & Drucker 2011). Dental barotraumas are defined as damages to teeth and dental reconstructions, which can manifest with or without pain, when ambient pressure changes (Zadik & Drucker 2011). It is assumed that they occur in connection with defective dental restorations or pathologies such as apical periodontitis, infections, secondary caries, and cysts (Kieser & Holborow 1997, Robichaud & McNally 2005, Zadik et al. 2006, Zadik et al. 2007, Zadik 2009a, von See et al. 2010). Intraroral pain elicited by changes in pressure is referred to as barodontalgia (Zadik & Drucker 2011). Thus far, the pathophysiology has been clarified only incompletely (Zadik & Drucker 2011). According to an official Swiss statistics of diving accidents from 1984 to 2006, traumas caused by pressure are listed as 952 “open wounds of the ear” and 410 “other open wounds of the head (including teeth)” (SSUV 2006). A more precise classification is missing.

The aim of the present study was to evaluate dental and orofacial symptoms in pressure–exposed individuals using questionnaires and personal interviews and, taking into account the current literature, to elaborate recommendations for a reduction of barotraumas.

Materials and Methods
Scuba divers and professional divers (police divers and diving instructors) as well as caisson workers were approached once with the aid of diving associations, cantonal administrations, and tunnel construction firms. Using a questionnaire, general data such as gender, age, and diving experience in years were collected. In addition it was noted if professional divers and caisson workers underwent regular dental checks for occupational reasons. It was also recorded whether respondents had experienced dental problems after dives or working, problems related to mouthpieces, barotraumas or other pain in the head region (excluding teeth). Some questions and the corresponding possible answers varied between the questionnaires of divers (“D”) and caisson workers (“C”; Tab. I). A personal interview was conducted with all affected individuals. The interview guideline used is listed in Table I. In the present work, the term dental reconstruction comprises both fixed dental prostheses and fillings.

For the categorical variables, contingency tables of numbers of cases as well as percentage proportions were prepared. Corresponding P-values were calculated using Fisher’s exact test. A two–sided error probability of 0.05 was defined as level of significance in all tests. Because of the descriptive nature of the study, no adjustments after multiple comparisons were made. All analyses were carried out using the statistics program R version 2.12.2 (R Development Core Team 2011).

Results
Out of over 750 persons approached, a total of 520 participated in the survey (499 divers and 21 caisson workers, 80.6% males). From these, 42.7% had dental reconstructions (n=222). Among the divers, 56.9% were scuba divers (n=284), 43.1% professional divers (n=215; 67.4% police divers [n=145]), 24.2% diving instructors [n=52], 4.2% underwater workers [n=9], 2.3% military divers [n=5], 1.9% fire brigade divers [n=4]). The majority had long diving experience of more than 10 years (61.1%; n=305) and dived between 10 and 50 times per year (56.7%; n=283). Mainly compressed air served as breathing gas (65.3%; n=326), and most dives were made to depths of 50 m or less (66.1%; n=330). For the caisson workers, weekly numbers of working hours were recorded and annualized. The majority of them did between 140 and 230 operations per year (76.2%; n=16) at 1.5–2 bar ambient pressure (90.5%; n=19).

Seventy–eight respondents (15%) reported toothaches, tooth injuries, and pressure–related dental conditions during their dives and operations. From these individuals, 36 were scuba divers, 20 professional divers, and 2 caisson workers. Contrary to the assumption that experienced divers are less affected, the number of problems increased with growing diving experience (p=0.005). On the other hand, data confirmed the expectation that the breathing gas used has no effect on the occurrence of dental problems (p=0.012).

In 53 respondents (10.2%), toothaches appeared upon a change in pressure (27 scuba divers, 24 professional divers, and 2 caisson workers). Among these, 23 felt shooting pain and 21 pressure pain. Nine participants did not elucidate the type of pain.

Upon a change in pressure, 33 (6.3%) of the respondents incurred a tooth injury. In 26 of the 33 affected individuals, amalgam restorations fractured. The remaining injuries concerned 4 crown fractures and 3 losses of tooth fragments. According to the information of the participants, acrylic reconstructions

<table>
<thead>
<tr>
<th>Tab. I Questions and answers varying between the questionnaires of divers (“D”) and caisson workers (“C”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D: Frequency of diving per year?</td>
</tr>
<tr>
<td>C: Working hours per week in the caisson?</td>
</tr>
<tr>
<td>D: Usual diving depth?</td>
</tr>
<tr>
<td>C: Usual atmospheric pressure?</td>
</tr>
<tr>
<td>D: Breathing gas used?</td>
</tr>
<tr>
<td>Do you use breathing gas?</td>
</tr>
</tbody>
</table>
were not affected. Twenty-six of the 33 tooth injuries happened in the posterior tooth area. Nineteen victims were professional divers.

Among the divers, 11.3% (n = 59; 38 scuba and 21 professional divers) reported problems in the temporomandibular joints or irritations of the oral mucosa such as pain (n = 34), inflammations or aphthae caused by mouthpieces.

A total of 31.9% (n = 166) of all study participants experienced an orofacial barotrauma (excluding teeth) during their dives and operations. Among these were no caisson workers. Affected hollow organs and respective frequencies are illustrated in Figure 1. As a result of the barotraumas, 78.3% of divers felt shooting pain (n = 130), 17.5% pressing pain (n = 29) and 3% pulsating pain (n = 5). According to the specifications of the participants, 1.2% were painless barotraumas (n = 2). A proportion of 65.6% of reported barotraumas occurred upon a rise in pressure (during the descent of a dive; n = 109). In 56% of affected individuals, pressure-related symptoms appeared repeatedly (n = 93) and in 58.4%, pain was still felt after the dive (n = 97).

Only 28.2% of the interviewed professional divers and caisson workers (n = 66) underwent a yearly dental check for occupational reasons. The group of scuba divers was not questioned in this respect.

Discussion

von See et al. 2010). In rare instances, symptoms can be so severe that affected individuals jeopardize diving safety due to pain–related misbehavior (Zadik 2006, Zadik & Drucker 2011). A possible exacerbation of preexisting subclinical symptoms is also taken into consideration (Zadik 2009a). Pain appearing during a dive or a caisson operation in an already root-treated tooth can be accounted for by small inclusions of air apical to the root canal filling, which are compressed or expand upon the change in pressure (Robichaud & McNally 2005). In association with an apical periodontitis or an impacted tooth, symptoms can be caused by bone lesions or cysts (Goethe et al. 1989, Robichaud & McNally 2005). If a trepanation of the maxillary sinus is suspected, the dentist must first identify the causative tooth using a medical history and clinical examination and subsequently treat it (Zadik 2009a). Special attention should be directed at recently performed therapies and preexisting symptoms (for example secondary caries) as well as the time of occurrence and the type of pain (Zadik 2009a) (see Tables III and IV). Following a conservative dental treatment under local anesthesia, patients should be advised to refrain from diving for 24 hours (Robichaud & McNally 2005). After an oral surgical intervention, this time limit is raised to 7 days (Robichaud & McNally 2005). If a trepanation of the maxillary sinus is suspected, diving should be resumed after 2 weeks at the earliest (Zadik & Drucker 2011).

The most important factors regarding prevention of diving accidents are diagnostic exclusion of dental pathologies which therefore, could constitute a source of error. However, the benefit of acrylic reconstructions is also corroborated in other studies (Robichaud & McNally 2005, von See et al. 2010, Zadik & Drucker 2011).

Problems in the dental area rose with increasing experience of the divers. This could be explained by increasing numbers of dives which potentially entail more frequent symptoms. Moreover, the finding shows that such incidents can hardly be influenced by the diver. The breathing gas used did not affect the frequency of dental problems. A final conclusion concerning the effect of yearly numbers of dives and average diving depths could not be drawn in the present work.

In patients exposed to pressure, dentists should follow certain recommendations regarding treatment, which are summarized in Table IV (Robichaud & McNally 2005, Zadik 2009a, Zadik 2009b, von See et al. 2010, Zadik & Drucker 2011). If a barodontalgia or a dental barotrauma occurs, the dentist must first identify the causative tooth using a medical history and clinical examination and subsequently treat it (Zadik 2009a). Special attention should be directed at recently performed therapies and preexisting symptoms (for example secondary caries) as well as the time of occurrence and the type of pain (Zadik 2009a) (see Tables III and IV). Following a conservative dental treatment under local anesthesia, patients should be advised to refrain from diving for 24 hours (Robichaud & McNally 2005). After an oral surgical intervention, this time limit is raised to 7 days (Robichaud & McNally 2005). If a trepanation of the maxillary sinus is suspected, diving should be resumed after 2 weeks at the earliest (Zadik & Drucker 2011).

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### Tab. III  Classification of barodontalgias (Zadik 2009a, von See et al. 2010)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Trigger</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Irreversible pulpitis</td>
<td>Shooting pain for seconds upon a rise in pressure (descent/entry in caisson)</td>
</tr>
<tr>
<td>2</td>
<td>Reversible pulpitis</td>
<td>Dull, pulsating pain upon a rise in pressure</td>
</tr>
<tr>
<td>3</td>
<td>Pulp necrosis</td>
<td>Dull, pulsating pain upon a decrease in pressure (ascent/exit from caisson)</td>
</tr>
<tr>
<td>4</td>
<td>Apical pathologies</td>
<td>Strong, persistent pain upon a decrease and rise in pressure</td>
</tr>
</tbody>
</table>

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### Tab. IV  Treatment recommendations for patients exposed to variation in ambient pressure (Robichaud & McNally 2005, Zadik 2009a, Zadik 2009b, von See et al. 2010, Zadik & Drucker 2011)

<table>
<thead>
<tr>
<th>Recommendation for dental care</th>
<th>Recommendation for dental care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevention</td>
<td>Yearly dental check (including dental X-ray)</td>
</tr>
<tr>
<td></td>
<td>Sensitivity test for exclusion of a pulpitis</td>
</tr>
<tr>
<td></td>
<td>Oral health</td>
</tr>
<tr>
<td>Restorative treatment</td>
<td>Check of fillings regarding marginal gaps and fractures</td>
</tr>
<tr>
<td></td>
<td>Preferably adhesive filling materials</td>
</tr>
<tr>
<td>Prosthetic treatment</td>
<td>Completed prosthetic treatments</td>
</tr>
<tr>
<td></td>
<td>Preferably fixed dental prostheses (using adhesive cement)</td>
</tr>
<tr>
<td></td>
<td>Check of accuracy of fit upon the insertion of a bite block</td>
</tr>
<tr>
<td>Endodontic treatment</td>
<td>Completed root canal treatment with adhesive restoration</td>
</tr>
<tr>
<td></td>
<td>Symptom-free direct or indirect pulp cappings upon dental follow-up checks</td>
</tr>
<tr>
<td>Surgical treatment</td>
<td>Apical surgery in cases of endodontic failures, if a preservation of the tooth is possible</td>
</tr>
<tr>
<td></td>
<td>Completed wound healing</td>
</tr>
</tbody>
</table>
can cause barotraumas, as well as utilization of adhesively fixed restorations. The literature reveals that variations in pressure can impair dental health (Goethe et al. 1989, Robichaud & McNally 2005, Zadik 2009a). The causes of this are currently obscure. Yearly dental checks should be carried out (Weiss 2003).

Mouthpieces are stabilized through a firm bite on the bite block. Thereby, masticatory pressure rests primarily on the canines and premolars (Zadik & Drucker 2011). Lip closure seals the mouthpiece to the outside. This static and heavily localized load can lead to myoarthropathic conditions. In the literature, individualized bite blocks extending into the molar region are therefore recommended (Zadik & Drucker 2011).

Barotraumas of the face comprise those of the middle and external ear, the paranasal sinuses, and the mouth. In the present study, the ears were affected most frequently (69.9%). This confirmed findings of previous investigations demonstrating that symptoms of the external (otitis externa) and middle ear (barotrauma of the middle ear) constitute the main problems of divers (Klingmann et al. 2007, Gonnermann et al. 2008, Strutz 2008). Out of all incidents, 65.6% happened during the descent of a dive, when a fast adjustment of pressure (pressure equalization) between the external and middle ear is required. Barotraumas of the middle ear occur when pressure equalization is impaired, for example by a swelling of the mucosa resulting from an upper airway infection (Nussberger et al. 2007). These pressure gradients can lead to lesions in the entire hearing and vestibular organ (Nussberger et al. 2007). In the paranasal sinuses, 22.9% of all barotraumas occurred. A so-called barosinusitis emerges because of hindered pressure equalization between paranasal sinuses and the surroundings, for example due to an inflammation. It can cause pain and epistaxis (Zadik & Drucker 2011). Pain resulting from all orofacial barotraumas can spread into oral regions and be misinterpreted as toothaches (indirect barodontalgias) (Zadik & Drucker 2011).

Regular dental checks are important for the prevention of barotraumas and orofacial soft tissue injuries. Since diving has become a mass sport, both divers and dentists should be aware of the triggering factors and the respective preventive measures.

Résumé

Un changement de pression environnante peut causer des problèmes au niveau des cavités corporelles remplies d’air. On appelle barodontalgie la douleur intraoraale causée par un changement de pression. Les barotraumatismes dentaires sont définis comme des lésions aux dents ou aux reconstructions dentaires dues à la pression. La base pathophysiologique n’est pas entièrement éclairée à ce jour. La présente étude est orientée vers les symptômes dentaires et orofaciaux qui peuvent subvenir en cas de fluctuations de la pression.

520 personnes exposées (499 plongeurs de loisir et professionnels, 21 ouvriers travaillant en caisson de surpression) ont été questionnées. Recrutées par l’intermédiaire d’administrations cantonales, d’associations de plongée et de sociétés de construction de tunnels, elles ont été interrogées quant à d’éventuels problèmes dentaires liés à la pression. Les personnes concernées ont été interviewées personnellement.

15% de tous les participants avaient déjà connu des problèmes dentaires liés à des variations de pression. 10,2% des participants avaient déjà souffert de maux de dents. Des lésions aux dents ont été mentionnées par 6,3% de tous les participants (26 reconstructions d’amalgame fracturées, 4 fractures de couronnes, 3 pertes de fragments de dent). 11,3% des questionnés se placent de douleurs de la mâchoire ou d’irritations de la muqueuse (p. ex. aphtes) occasionnées par l’embout. 31,9% des plongeurs ont subi des barotraumatismes en dehors du domaine de la médecine dentaire (dont 69,9% de troubles au niveau de l’oreille), 65,6% de ces cas se produisant lors de la descente.

Sur la base des résultats de l’étude et en tenant compte des données les plus récentes de la littérature, des recommandations sur la prévention des barotraumatismes ont été émises.

L’exclusion de pathologies dentaires et l’utilisation de matériaux sans rétention sont des facteurs importants pour la prévention des barodontalgies et barotraumatismes dentaires.