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Barodontalgias, dental and orofacial barotraumas

A survey in Swiss divers and caisson workers

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barotrauma;
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diving accidents

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.

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, barodontalgias, 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). Intraoral 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 II. 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).

Tab. I Questions and answers varying between the questionnaires of divers ("D") and caisson workers ("C")

D: Frequency of diving per year?	☐ less than 10× ☐ 10–50× ☐ more than 50×
C: Working hours per week in the caisson?	☐ less than 10 hours ☐ 10–45 hours ☐ more than 45 hours
D: Usual diving depth?	☐ up to 10 m ☐ up to 20 m ☐ up to 50 m ☐ more than 50 m
C: Usual atmospheric pressure?	☐ 1–1.5 bar ☐ 1.5–2 bar ☐ 2–3 bar ☐ more than 3 bar
D: Breathing gas used?	☐ compressed air ☐ Nitrox ☐ mixture of gases (Heliox/Trimix)
Do you use breathing gas?	☐ no ☐ yes

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, 40 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

Tab. II Guideline for the personal interview of affected individuals

Dental problems following dives and operations	
Which ones?	☐ Shooting pain ☐ Pulsating pain ☐ Pressure pain ☐ Loss of tooth fragment ☐ Loss of crown/filling
Material of reconstruction?	☐ Amalgam ☐ Resin ☐ Crown
Where did the tooth injury happen?	☐ Posterior teeth ☐ Front teeth
Problems associated with mouthpiece	
Which ones?	☐ Pain ☐ Inflammation ☐ Temporomandibular articular troubles ☐ Aphthae
Barotrauma or other pain in the head area (excluding teeth)	
Where?	☐ Mouth ☐ Nose/paranasal sinuses ☐ Ears ☐ Eyes ☐ Upper airway
Type of pain?	☐ Shooting pain ☐ Pulsating pain ☐ Pressure pain
When did this happen?	☐ Upon a rise in pressure ☐ Upon a decrease in pressure ☐ Following the dive or operation
Once or several times?	☐ Once ☐ Several times ☐ At every dive or operation
Did pain persist?	☐ Yes ☐ No

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

Barodontalgia is an oral pain elicited by a pressure change in an otherwise asymptomatic tissue (Zadik 2009a, Zadik & Drucker 2011). These problems can be of both odontogenic and non-odontogenic origin (Zadik 2009a, Zadik 2009b). The currently accepted classification of the barodontalgias, which has been elaborated in the year 1982, is outlined in Table III (Zadik 2009a, von See et al. 2010). The pathophysiology thus far is incompletely understood (Zadik & Drucker 2011). Co-factors considered are odontogenic infections, sinusitides, secondary caries, pulp necrosis/apical periodontitis, insufficient fillings extending into dentin, and recently performed dental treatments (Carlson et al. 1983, Kieser & Holborow 1997, Robichaud & McNally 2005, Zadik 2006, Zadik et al. 2006, Zadik et al. 2007, Zadik 2009a, von See et al. 2010). Pain is severe, sharp, and localized (Robichaud & McNally 2005, Zadik 2010). It often emerges upon a rise in pressure (Zadik et al. 2007, Zadik 2009a,

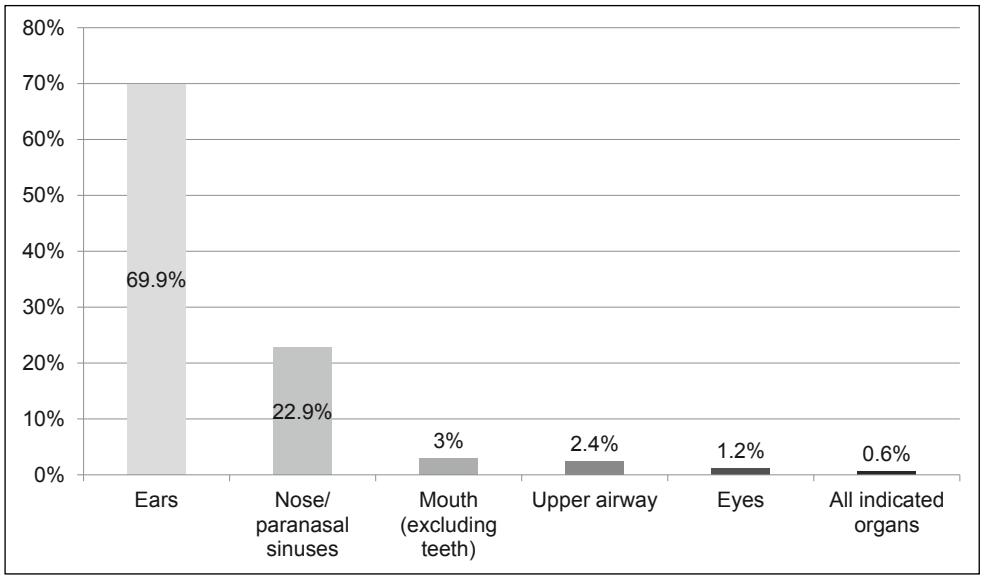

Fig. 1 Frequency distribution of hollow organs injured by pressure (n=166)

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

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

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, Zadik 2009a). The current literature does not reveal any differences in the frequency of barodontalgias between scuba and professional divers (von See et al. 2010). This was confirmed by the present study: from the scuba and professional divers questioned, 9.5% (n=27) and 11.2% (n=24) were affected, respectively.

Dental barotraumas also comprise pressure-related damages to teeth and reconstructions (Zadik & Drucker 2011). The drawbacks of retentive reconstructions during diving were confirmed in the present study: most tooth injuries occurred in association with amalgam fillings. Furthermore, retentively fixed reconstructions also include temporary prostheses or crowns/bridges. Provided that there is an inclusion of air (iatrogenic or caused by secondary caries) underneath a filling or a crown, this gas is also subject to the law of Boyle-Mariotte when pressure changes (Zadik & Drucker 2011). If retentively fixed reconstructions exhibit marginal gaps, air can intrude between tooth and reconstruction when ambient pressure rises and gases are compressed (Robichaud & McNally 2005). During the ascent of a dive, the trapped air can lead to the loss of a filling or a crown due to the expansion of the gas. In an intact adhesive restoration, intrusion of air is not possible because of the bond of tooth and filling. However, leaking composit fillings are subject to the same risks as retentively fixed reconstructions.

Since the present investigation relied on a survey, no conclusions were possible regarding existing dental pathologies or reconstructions and their condition. Preexisting dental diseases and insufficient fillings or crowns could be responsible for the barodontalgias and dental barotraumas found in this study. Moreover, it should be noted that the distinction between tooth and composit filling is virtually impossible for a layperson and, 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).

The most important factors regarding prevention of diving accidents are diagnostic exclusion of dental pathologies which

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)

	Recommendation for dental care
Prevention	☐ Yearly dental check (including dental X-ray) ☐ Sensitivity test for exclusion of a pulpitis ☐ Oral health
Restaurative treatment	☐ Check of fillings regarding marginal gaps and fractures ☐ Preferably adhesive filling materials
Prosthetic treatment	☐ Completed prosthetic treatments ☐ Preferably fixed dental prostheses (using adhesive cement) ☐ Check of accuracy of fit upon the insertion of a bite block
Endodontic treatment	☐ Completed root canal treatment with adhesive restoration ☐ Symptom-free direct or indirect pulp cappings upon dental follow-up checks
Surgical treatment	☐ Apical surgery in cases of endodontic failures, if a preservation of the tooth is possible ☐ Completed wound healing

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 intraorale 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 éclaircie 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 sont plaints 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.

References

Carlson O G, Halverson B A, Triplett R G: Dentin permeability under hyperbaric conditions as a possible cause of barodontalgia. Undersea Biomed Res 10: 23–28 (1983)

Goethe W H, Bäter H, Laban C: Barodontalgia and barotrauma in the human teeth: findings in navy divers, frogmen and submariners of the Federal Republic of Germany. Mil Med 154: 491–495 (1989)

Gonnermann A, Dreyhaupt J, Praetorius M: Otorhinolaryngologic disorders in association with scuba diving. HNO 56: 519–523 (2008)

Kieser J, Holborow D: The prevention and management of oral barotrauma. N Z Dent J 93: 114–116 (1997)

Klingmann C, Praetorius M, Baumann I, Plinkert P K: Otorhinolaryngologic disorders and diving accidents: an analysis of 306 divers. Eur Arch Otorhinolaryngol 264: 1243–1251 (2007)

Nussberger P, Knessl P, Wölfel C, Torti S: Tauchmedizin, ein Überblick, Teil 1. Schweiz Med Forum 7: 970–974 (2007)

R Development Core Team: R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna (2011)

Robichaud R, Mcnally M E: Barodontalgia as a differential diagnosis: symptoms and findings. J Can Dent Assoc 71: 39–42 (2005)

SSUV: Spezialstatistik UVG: Zahl der Diagnosen bei Tauchunfällen (1984–2006). Sammelstelle für die Statistik der Unfallversicherungen UVG (SSUV), Luzern, 24.10.2006, URL: www.unfallstatistik.ch (2006)

Strutz J: Otorhinolaryngologic disorders associated with diving. HNO 56: 499–504, 506–508 (2008)

von See C, Rücker M, Gellrich N C: Barodontalgia etiology, diagnosis and treatment considerations. Endodontie 19: 43–48 (2010)

Weiss M: Standards on medical fitness examinations for navy divers. Int Marit Health 54: 135–143 (2003)

Zadik Y: Barodontalgia due to odontogenic inflammation in the jawbone. Aviat Space Environ Med 77: 864–866 (2006)

Zadik Y: Barodontalgia. J Endod 35: 481–485 (2009a)

Zadik Y: Aviation dentistry: current concepts and practice. Br Dent J 206: 11–16 (2009b)

Zadik Y: Barodontalgia: what have we learned in the past decade? Oral Surg Oral Med Oral Pathol Oral Radiol Endod 109: e65–69 (2010)

Zadik Y, Chapnick L, Goldstein L: In-flight barodontalgia: analysis of 29 cases in military aircrew. Aviat Space Environ Med 78: 593–596 (2007)

Zadik Y, Drucker S: Diving dentistry: a review of the dental implications of scuba diving. Aust Dent J 56: 265–271 (2011)

Zadik Y, Einy S, Pokroy R, Bar Dayan Y, Goldstein L: Dental fractures on acute exposure to high altitude. Aviat Space Environ Med 77: 654–657 (2006)