Interpretation and management of oral symptoms experienced by scuba divers

Keywords: **oral symptoms, scuba divers**

Introduction

Globally, scuba diving as a recreational activity has experienced a remarkable increase in popularity and is one of the fastest growing sports in the world. This is also true for South Africa where thousands of newly qualified divers are introduced to this exhilarating sport annually. Specific knowledge and understanding of the pathological conditions that may occur in divers, and the relevant treatment modalities associated with these conditions are important to the oral health care worker.

Dental problems related to changes in ambient pressure, previously termed aerodontalgia, were documented as early as 1945 (Orban and Ritchey, 1945).

Since the causative factor is intimately related to differences in ambient pressure, and not necessarily to the presence of air bubbles (Rottman, 1981; Shiller, 1965), use of the term barodontalgia for this condition appears to be more appropriate (Senia, Cunningham and Marx, 1985). Diving-related complaints of importance to the oral health care worker may broadly be divided into two categories: those causing pain to the tooth *per se*, termed barodontalgia; and those related to the masticatory muscles and temporomandibular joints, referred to as diver's mouth syndrome (Grant and Johnson, 1998).

In this paper, the fundamental physical principles associated with barodontalgia are reviewed, and therapeutic guidelines are provided for the practitioner faced with diving-related dental problems.

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Physical principles

To understand the mechanism of toothache caused by pressure changes we need to examine the effect pressure changes have on air volume. According to Boyle's law, the volume of a gas at a constant temperature is inversely proportional to the absolute pressure exerted on the gas. Boyle demonstrated that it would take about 10 m of seawater to match the pressure exerted by the atmosphere. This implies that for every 10 m of descent the pressure increases by one atmosphere. With air pressure at sea level being one atmosphere, it means that the pressure is four atmospheres at 30 m, implying that a volume of air taken from the surface to a depth of 30 m will be compressed to one quarter of its original volume according to Boyle's law (Fig.1).

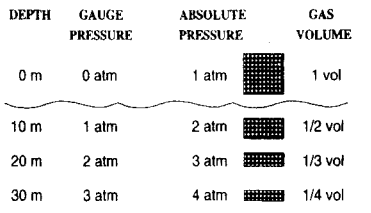

Fig. 1. Hyperbaric principles. The relationship between the volume of a gas and the pressure exerted on it is governed by Boyle's law. At the surface the absolute pressure is 1 atmosphere (atm). At a depth of 30 m, the gauge pressure is 3 atm, absolute pressure has increased to 3+1 = 4; a given gas volume has reduced its size to a quarter of its original volume. (Reproduced with permission from Kieser and Holborow, 1997).

Conversely, a volume of air will expand four times when taken from a depth of 30 m to sea level. This is why breath holding during scuba diving is potentially fatal; the lungs cannot expand four times their size and will rupture if a diver holds his/her breath while ascending from a dive (Kieser, 1997a).

The increased pressure experienced at depth on the tympanic membrane is the reason why divers need to blow compressed air (inhaled from the dive cylinder) through the Eustachian tubes into the middle ear to equalise the pressure from outside (Kieser and Holborow, 1997). Failing to do so can lead to rupture of the tympanic membrane (Green, Rothrock and Green, 1993).

Barondontalgia

Barotrauma is the process whereby tissue damage occurs as a result of the failure of an enclosed gas-filled space to adjust its internal pressure to the surrounding external pressure (Kayle, 1994). The most common dental complaint experienced by divers is that of dental squeeze, also referred to as barotrauma of descent (Kieser, 1997b). This is caused by conditions associated with exposed dentinal tubules or pulpal tissue, resulting in air being forced into the pulp as the diver descends due the increased pressure of the inspired air. The pain experienced is related to the diver's depth, and usually improves when the diver ascends, thereby relieving the pressure. Primary caries, recurrent caries along the margins of restorations, or leaking restorations will all allow compressed air to reach dentinal tubules or the pulp (Fig. 2). It was originally presumed that air trapped within amalgam restorations was the cause of the problem, but this has since been proven not to be the case (Shiller, 1965). Trapped air from cotton pellets or bubbles trapped within a restoration cannot cause any symptoms if it is completely sealed off and thus not leaking (Rottman, 1981).

Another possible cause of dental squeeze is pulpitis due to recent dental treatment (Holowatyj, 1996). Dental treatment invariably causes a slight degree of inflammation with subsequent swelling in the pulp, resulting in a tooth sometimes being sensitive for a few days after treatment. When pressure is applied to inflamed or bruised tissues, gasses formed due to the inflammation process are compressed and increase the pressure in the pulp cavity, causing the pain. This is the reason why it is not advisable to dive shortly after having a new restoration placed, especially not a deep dive. After tooth extraction or minor oral surgery, the inflammation should also be allowed to subside before diving, as pain and bleeding may be induced by increased pressure (Jagger, Jackson and Jagger, 1997; Kieser and Holborow, 1997). Similarly, an unsuccessful root-canal treatment may result in a cystic lesion at the root apex.

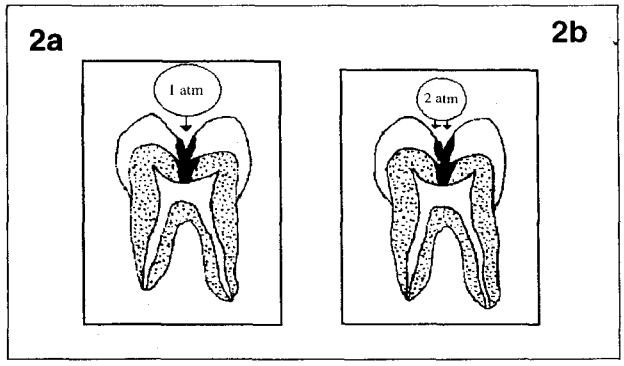

Fig. 2a. Barotrauma of descent. At the surface the pressure is 1 atm and a certain volume of air is exerting pressure on the pulp via a carious lesion or exposed dentinal tubules.

Fig. 2b. Barotrauma of descent. At a depth of 10 m the pressure is 2 atm, the volume of air exerting pressure on the pulp is halved and its pressure is doubled. The diver will experience dental squeeze.

While such an area may be symptomless on the surface, increase in pressure may cause pain, since the lesion cannot collapse under pressure and becomes filled with blood (Kieser, 1997a). In these cases the root-treatment should be redone.

Luting agents for prosthetic crowns, especially zinc-phosphate cements, are considerably weakened by pressure cycles due to repeated diving (Musajo *et al*, 1992; Lyons, Rodda and Hood, 1997). Resin cements are recommended for cementation in divers. Disruption of the cement layer due to increased pressure may present clinically as barodontalgia before debonding of the crown occurs (Lyons *et al*, 1997).

A second type of barodontalgia is referred to as barotrauma of ascent, and is caused by compressed air that has been trapped in an enclosed space and then expands as the diver ascends (Fig. 3). Teeth with uncompleted root canal treatments or neglected restorations are susceptible to this kind of injury (Holowatyj, 1996; Calder and Ramsey, 1983). Compressed air slowly enters these teeth during descent and at depth due to a poor physical seal between the tooth and restoration, but cannot escape quickly enough during ascent (Kieser, 1997b). The air expands as the diver's depth decreases, causing pressure build-up within the tooth, leading to tremendous pain and sometimes even fracture. Displacement of the intracanal medicaments through the root apex has been reported (Rottman, 1981). In severe cases the pressure build-up in the tooth may lead to explosion of the tooth, called odontecrexis (Calder and Ramsey, 1983). Barotrauma of ascent can be prevented by not diving with decayed teeth, temporary restorations or uncompleted root-canal treatments.

Barotrauma of congested sinuses, especially the maxillary antrum, frequently presents as dental pain, usually of the upper molars due to their close anatomical relationship (Kieser, 1997a). A thorough examination to exclude any tooth-associated aetiology and a detailed medical examination will direct the practitioner towards the maxillary antrum as the culprit (Boggia, 1998). Patients with chronic sinusitis should be referred to an ear, nose and throat specialist because the pharmacological agents used for treating congested sinuses may have side-effects of importance to scuba divers (Harrison, 1992).

Diver's mouth syndrome

This term describes the pain in the temporomandibular joints (TMJs) and orofacial muscles experienced after diving (Grant and Johnson, 1998). Diving can cause TMJ symptoms in previously symptom-free divers, or aggravate existing problems (Jagger *et al,* 1997).

Most divers will have experienced the sensation of not being able to get their teeth into occlusion after a dive. This is caused by biting onto the mouthpiece with the anterior teeth only, since most commercial mouthpieces

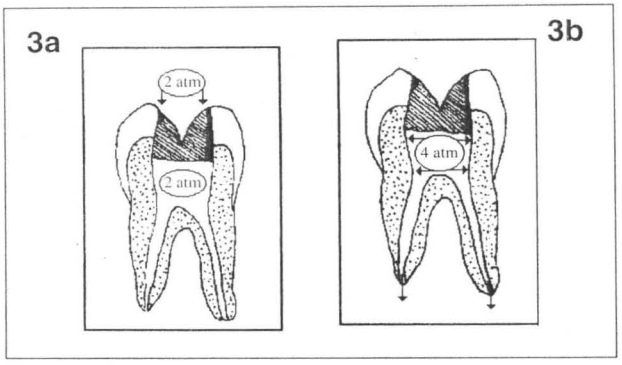

Fig. 3a. Barotrauma of ascent. At a depth of 10 m pressurised air is forced past the leaking temporary restoration into the pulp cavity.

Fig. 3b. Barotrauma of ascent. As the diver ascends, the gas trapped in the pulp cavity doubles in volume and since it cannot expand, it causes increased pressure in the tooth and apical tissues.

do not provide support for the posterior teeth. The mandible then rotates backwards and upwards, causing abnormally high pressure on the articular disc and retro-discal tissue (Pinto, 1966). In most divers this compression of the joints usually passes soon after the dive as the joints decompress.

Heavy regulators, cold water, or anxiety may all cause the diver to bite hard onto the mouthpiece, aggravating joint compression. Divers suffering from joint and muscle pain due to nocturnal bruxism, might not recover from joint compression as easily as others, and may even experience such severe pain that they cannot continue diving.

There is some debate as to whether pre-auricular pain after diving is due to TMJ dysfunction or middle ear barotrauma (Kieser and Holborow, 1997). Analgesics, non-steroidal anti-inflammatory drugs and physiotherapy may help to relieve these symptoms.

The solution to diver's mouth syndrome, however, is to manufacture a custom-made mouthpiece for the diver that provides support for the posterior teeth, and has a flange extending underneath the lips and onto the palate, providing a good seal without the need to bite hard or tense the circumoral musculature (Hurst, Tye and Byrd, 1986) (Fig. 4). Fortunately, diving regulators are becoming increasingly smaller and lighter, necessitating less biting force to keep them in position. Custom-made mouthpieces can also be made for divers undergoing orthodontic treatment, as orthodontic brackets may influence lip-seal around the mouthpiece (Jones and Graham, 1990).

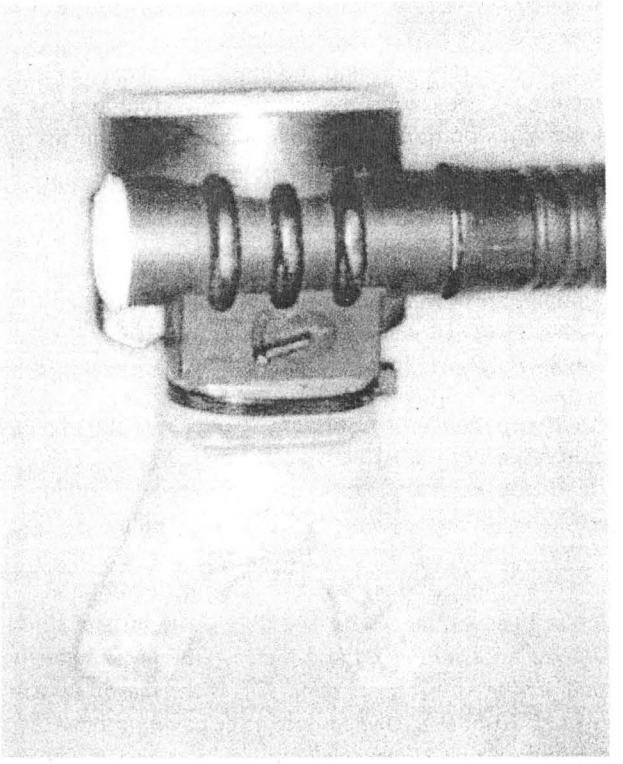

Fig. 4. An example of a lightweight regulator with a custom-made mouthpiece.

For divers wearing dentures, even more difficulties arise. If the dentures are removed before the dive, the mouthpiece can't be gripped properly. If, on the other hand, the dentures are kept in during the dive, the mouthpiece may dislodge them. For these patients a special 'diving denture' should be constructed with enough anterior and posterior support to bite on, but with spaces for the mouthpiece (Hurst *et al,* 1986).

Conclusion

Divers trained by most training agencies in South Africa are compelled to undergo a medical examination to ensure that they are medically fit to dive (Kayle, 1994), and a thorough dental examination should be part of such an examination. The teeth of divers tend to dete-

riorate quicker than those of other patients (Goethe, Bater and Laban, 1989) and therefore regular and thorough dental evaluation is of extreme importance in these patients. It is thus important for the dentist to understand the physical principles and to be able to interpret the possible complaints their scuba diving patients may experience.

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