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The Importance of Periodic Oral and Dental Health Examination of Aircrew

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Abstract

The importance given to aviation and space science has increased with the advanced technological breakthroughs that made the 21st century to be called the "Space Age". As the aviation industry evolved, it was found that exposure to flight conditions and atmospheric pressure alterations has a variety of adverse effects on the physiological and psychological states of aircrew. There are several disorders that might cause medical incapacitations and thus jeopardize flight safety in such conditions. Oral, dental, and maxillofacial diseases are among those that, although manifesting locally, affect all bodily systems. For this reason, the diagnosis and treatment of such disorders should be thoroughly evaluated and carried out in accordance with aeromedical concerns. The purpose of this review is to emphasize the importance of periodic aeromedical examinations for the prevention of potential oral and dental health-related diseases, as well as medical issues of aircrew that require special attention in terms of flight safety.

1. Introduction

High altitude, changes in air pressure levels and accelerative (G) forces caused by discrete high-speed flight maneuvers are some of the unfavorable environmental effects of aviation that may cause serious medical problems for aircrew. For this reason, they are subjected to detailed aeromedical examinations on a regular basis. The basic requirement for medical fitness to fly cannot be simply defined as the absence of disease. Besides, good health does not always mean fitness to fly, and disease of aircrew does not always imply unsuitability. A healthy person who has minor illnesses may be less fit to fly than a chronically ill person at times and in certain situations. From the viewpoint of the certifying authority, aircrew may be considered fit to fly if they are at or above the mental and physical level necessary to carry out flight duties safely under all flight conditions, and if it is safe to assume that the certificate will remain valid for the duration of its expiration (JAA, 2009).

There are several disorders that might cause medical incapacitations and thus jeopardize flight safety. Oral, dental, and maxillofacial diseases are among those that, although manifesting locally, affect all bodily systems. Even if an aircrew member is fully asymptomatic, an insidious condition such as dental caries and, eventually, acute pulpitis, which may cause severe pain within minutes of onset, might have a negative effect on flight missions. Clinical and radiographic evaluation of oral and dental health in periodic aeromedical examinations helps in minimizing such hazardous situations and thus, increases flight safety. Early diagnosis of oral and dental health problems, which may or may not be noticed, is very important for the aircrew.

"Aerodontia", also known as "aerodontics", is a branch of dentistry that deals with the evaluation and treatment of oral, dental and jaw diseases that present in high altitude conditions (Fairpo J. & Fairpo C., 1973; Sipahi et al., 2007; Zadik, 2009). The effects of pressure changes that take place at various altitude levels are the most important concern in aerodontia. According to Boyle's Law, the volume of a gas increases as the air pressure decreases while the temperature remains constant. When air pressure is reduced with altitude, gas tends to expand to cover greater space (Stepanek & Webb, 2008). There are many parts in the human body where gas can remain or form and become trapped. Dental field is one of those body parts where trapped gas may form, such as between tooth mineral and filling material, inside a tooth decay, or as a result of an infectious process like a dental abscess (Figure 1). The presence of trapped gas may result is discomfort, pain, and even tissue damage.

Over the last 60 years, as great developments in the aviation industry have been achieved, many aeromedical disorders related to the oral and maxillofacial region have been shown to cause severe impairments such as pain, vertigo, and other manifestations that led to medical incapacitation, resulting in flight terminations and even accidents (Nielsen, 1991; Sipahi et al., 2007; Zadik, 2009; Yüce et al., 2016). During World War II, the toothache experienced by aircrew was first referred to as "aerodontalgia". This kind of dental pain has been reported by divers as well, and the broader term "barodontalgia" has been used to describe this phenomenon (Robichaud & McNally, 2005; Zadik, 2009).

As a result of the lack of standardization in the frequency and content of periodic oral and dental examinations performed by air forces around the world, there is no general agreement about the appropriate examination periods of aircrew (Nielsen, 1991; Yüce et al., 2016). It was claimed that maintaining orodental health in aircrews is necessary to avoid in-flight medical incapacitations caused by oral and dental problems and their accompanying impairments, such as increased soreness and struggling to get adequate nourishment (Rayman, 1996). Panoramic (orthopantomograph) and periapical radiography screenings might be beneficial for the early detection of dental pathologies in individuals who are not suffering any symptoms (Nielsen, 1991; Rayman, 1996; Ellingham, 2002; Yüce et al., 2016).

The purpose of this review is to emphasize the importance of periodic examinations which aims to prevent possible oral and dental health-related diseases in aircrew. We believe that oral and dental health-related diseases require special attention in terms of flight safety.

2. Barodentalgia (Barodontalgia)

Barodentalgia, previously known as aerodentalgia, refers to the intense toothache that may be triggered by the increased air pressure of trapped gas in the teeth caused by ascending to higher altitudes (Figure 1). A tooth /teeth with an unknown and undiagnosed trapped gas may be asymptomatic if there is no change in air pressure in normal life; however, an increase in dental pain might lead to severe discomfort, medical incapacitation, and thus, an early flight termination.

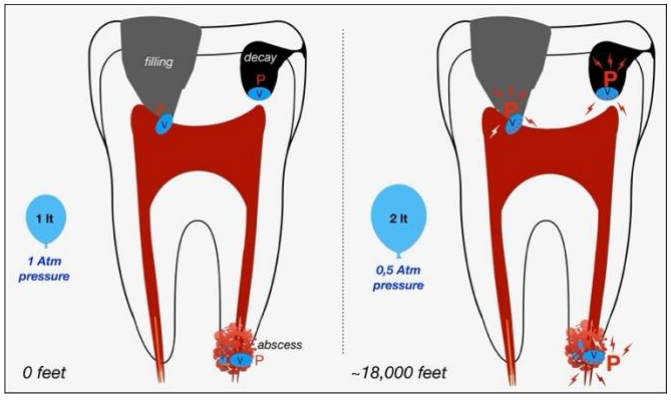

Figure 1. Trapped gas pockets. At around 18,000 feet, air pressure in a balloon drops by half and air volume rises by two times. When there is no chance of gas leakage, the air pressure inside the trapped gas increases (V: Volume; P: Pressure; Atm: Atmosphere; lt: liter).

Most studies on dental barotrauma and barodontalgia have been conducted mainly within the field of military aviation. In many published studies, dentistry in military aviation, including diagnostic criteria, surgical and pharmaceutical treatment guidelines, concepts about barotraumas, barodontalgia, the significance of periodic examinations, and flight restrictions related to dental issues, are described (Ellingham, 2002; Kamran et al., 2017; Rossi, 1995; Zadik et al., 2007). In World War II, barodentalgia was ranked fifth among the physiological disturbances reported by American pilots during flight, and it was also reported to be the third leading cause of early landings (Yüce et al., 2016). In a retrospective study conducted in U.S. Air Forces following World War II, it was found that 9.5% of the US flight crew had experienced barodentalgia at least once while in flight (Kennebeck et al., 1946). Studies have shown that 2.4% of 499 Spanish Air Force pilots, 8.2% of 331 Israeli Air Force pilots, and almost half of 135 Saudi Arabian and Kuwaiti Air Force personnel have experienced barodentalgia at least once in their careers (Gonzalez Santiago Mdel et al., 2004; Al-Hajri & Al-Madi, 2006; Zadik et al., 2007). In another research, it was reported that around 1% of Israeli Air Force pilots suffered with barodentalgia (Zadik et al., 2007). Besides these, military aircrew have a higher incidence of dental barotrauma than commercial airline passengers or aircrew (Wilson et al., 1983). This may be due to some differences between the flight characteristics of commercial aircraft and military combat aircraft. Both commercial and military aircraft can ascend to approximately 40,000 feet, where it is impossible to maintain vital functions. Therefore, aircraft cabins are artificially pressurized to reduce the risk of hypoxia, barotrauma, and decompression sickness, and thus, prevent passengers and aircrew from being medically incapacitated at such altitudes. Commercial aircraft cabins are pressurized to approximately 8,000 feet (Ahmedzai et al, 2011). Dental pain may develop at 6,000 feet (1829 m) due to changes in atmospheric pressure. Yet, the incidence of pain increases on long-haul flights at altitudes greater than 7,000 feet (2134 m) (Zadik & Einy, 2006). On the other hand, the cabin pressures of military combat aircraft gradually decrease to 22,000 feet and remain constant from that altitude (Gradwell & Macmillan, 2016). Moreover, military aircrafts are faster and more maneuverable than commercial aircrafts, enabling them to execute more complex maneuvers with significant altitude gain or loss in a shorter amount of time. These specific differences in military combat aircrafts are more likely to cause discrete and abrupt changes in air pressure, leading to significant rises in barometric fluctuations.

Barodentalgia can also be observed during hypobaric chamber trainings (Fairpo J. & Fairpo C., 1973; Sipahi et al., 2007; Zadik, 2009; Aydıntug et al., 2011). During this training, the effects of hypoxia- a decrease in the partial pressure of oxygen in inhaled air and hypobaric conditions on human physiology can be demonstrated by simulating high altitudes in a stainless-steel hypobaric chamber with a vacuum system that maintains a low-pressure environment. In a hypobaric chamber training, the oxygen flow through the mask is adjusted to simulate an altitude of 25,000 feet, and thus, aircrew have chance to experience the damaging effects of hypoxia and to learn how to cope with these effects (Neuhaus & Hinkelbein, 2014). Military aircrews are required to undergo this training on a periodic basis - the time interval varies by country - and are frequently exposed to hypobaric conditions. In the 1940s, the rate of barodentalgia was found to be between 0.7% and 2% in hypobaric chamber studies undertaken by the United States (U.S.) Air Forces (Kennebeck

et al., 1946). In studies performed in hypobaric chambers in 1964 and 1965, barodentalgia rates were found to be between 0.23% and 0.3% among U.S. Air Force cadets (Hanna & Thomas-Yarington, 1985). In 1980, the incidence of barodentalgia was found to be 0.26% in hypobaric chamber tests performed in Germany, and 0.3% in real flights in research published in Turkey in 2007 (Sipahi et al., 2007; Zadik, 2009).

Barodentalgia is more of a symptom rather than a pathological condition in itself. Barodentalgia is also an exacerbation of a pre-existing subclinical oral maxillofacial disease caused by changes in environmental barometric pressure. Many oral pathologies are considered as potential causes of barodentalgia. These are tooth decay, dental restorations with excessive substance loss, pulpitis, pulp necrosis, apical paradontitis (cyst, granuloma), periodontal pocket, impacted tooth/teeth, insufficient cement fill/ insufficient restoration and mucosal retention cysts (Boggia, 1998; Kennebeck et al., 1946; Kollmann, 1993; Stoetzer et al., 2012; Zadik, 2006; Zadik et al., 2007).

Barodentalgia can also occur as a manifestation of pain caused by barosinusitis or barotitis media. While barosinusitis or barotitis media generally presents with pressure change, barodentalgia usually presents with exacerbation of pre-existing dental pathology owing to pressure change (Zadik, 2009). According to the studies conducted in America U.S. (1946), Germany (1993), Spain (2004), Israel (2007), and Turkey (2007), the following conditions and interventions were reported as the causative factors of barodentalgia: new restorations, restorations in teeth with a lot of substance loss, deep caries without pulp opening, pulp opening in vital teeth, pulpitis, periapical periodontitis (pulp necrosis), and barosinusitis (Gonzalez Santiago Mdel et al., 2004; Sipahi et al., 2007; Al-Hajri & Al-Madi, 2006; Zadik et al., 2007).

Pulpitis has been identified as the leading cause of barodentalgia since the 1940s. Table 1 depicts various theories attempted to explain barodentalgia caused by pulpitis. The theory of Orban et al (Orban & Ritchey, 1945) is based on the presence of gas bubbles in histological sections of extracted tooth after the development of barodentalgia. Bergin (Bergin, 1949) also accepted this theory. However, Lyon et al. (Lyon et al., 1999) do not subscribe to this theory, because in their research, they observed gas bubbles in just six of 75 teeth they analyzed. From another point of view, these gas bubbles are considered to be artifacts caused by fixative materials used in histological preparations (Stanley & Weaver, 1968). Today, there is still a lack of consensus regarding the mechanism of barodentalgia due to pulpitis.

Table 1. Theories attempted to explain barodentalgia caused by pulpitis

Author	Theory
Levy BM, 1943	Expansion of intrapulpal gas formed as a by-product of acids, bases and enzymes found in inflammatory tissue
Orban et al., 1945	The transfer of intravascular gas into tissue because of decreased solubility
Kennebeck et al., 1946	Direct ischemia due to inflammation
Harvey W, 1947	Indirect ischemia due to increased intrapulpal pressure as a result of vasodilation and fluid transfer into the tissue

When comparing the findings of direct (pulp-related) and indirect (barosinusitis and barotitis media-induced) barodentalgia, contrary to studies suggesting that the majority of cases of barodentalgia are cases of pain caused by barosinusitis (Hutchins & Reynold, 1947; Shiller, 1965; Mumford, 1982), more recent studies have that the rates of non-dental facial barotrauma ranged from 7% to 57,8% (Agackesen, 2019; Kennebeck et al., 1946; Kollmann, 1993; Zadik et al., 2007).

Previous studies have shown that it might be hard to identify the exact pathological process that results in barodentalgia (Kennebeck et al., 1946; Senia et al., 1985; Boggia, 1998). It is difficult for clinicians to identify which tooth causes pain since this tooth might be a restored and/or endodontically treated (clinically healthy) tooth, or the pain could be caused by an adjacent anatomical structure (i.e, the maxillary sinus). Furthermore, in an ordinary dental clinic, even in a hypobaric chamber environment, it is very difficult for the clinician to pinpoint the source of the pain since the factor that triggered the pain -the barometric change in pressure- cannot be re-created (Zadik, 2009).

3. Identification in Accidents and Crimes

An adult human has a total of 32 teeth in the right and left oral cavity, upper jaw, and lower jaw (including wisdom teeth). A significant number of people have sought treatment for their teeth as a result of the high frequency of tooth caries. This indicates that a physical history of dental treatment, including metal crowns, fillings, or adhesive teeth, etc., has been formed. In addition, many types of materials can be applied in dental treatment. The findings of these treatments are obviously present in the oral cavity and are also archived in dental clinics with treatment records (clinical, radiographic). Treatment records are required by law to be saved for at least 5 years in many countries. From this point of view, the probability of one person's dental findings matching another's tooth findings is remarkably low. Besides, it is almost impossible to match the anatomy of different people's mouths, teeth, and cheeks even in orthopantomographic (panoramic radiography) imagings (Whittaker & MacDonald, 1989; Suzuki, 1996; Utsuno, 2019). Identification based on dental findings is therefore a very useful approach in aviation accidents. There are published cases and investigations that emphasize the significance of forensic odontology combined with DNA analysis and dental identification of victims, especially when dealing with mass disaster events (Brannon & Morlang, 2003; Nambiar et al., 1997; Obafunwa et al., 2015). In some situations, a comparison between the victim's teeth and the putative teeth's morphology can be made by analyzing the photographs (Dahal et al., 2023). This technique is also successful in achieving favorable outcomes.

The most common approach for identifying disaster victims is the comparison of dental records or DNA-profile analysis in samples collected from dental pulp, because the tooth structure is generally the best-preserved anatomical structure in traumatic deaths (at temperatures exceeding 1600°C). If the victims have pre-accident dental treatment records, then the identification process can be completed in a short time using the dental arch structure that was preserved in the accident. Comparison of the dental arch with the updated radiographic images of the victim and the radiographic images taken after the accident is the preferred method since it can provide results in a very short amount of time after an accident-

crash (Zadik, 2009). Therefore, it is of great importance that aircrew are subjected to periodic oral, dental health examinations and that clinical-radiographic data be recorded on a regular basis.

4. Periodic Oral and Dental Examinations and Treatments of Aircrew

Oral and dental checkups of aircrew should be scheduled to ensure that there is an adequate and acceptable amount of time between the planned examination and the flight duty following the examination (at weekends or holidays if necessary). Although routine tooth filling (restoration) treatments do not require flight restrictions, newly applied dental filling (restoration) treatment has been reported as one of the most important causes of barodentalgia (Kennebeck et al., 1946; Zadik et al., 2007). While planning the treatment, dentists should notify their patients who are aircrew - and even patients who plan to fly - regarding the potential post-treatment problems and restrictions that flight may cause.

Published studies and research reports indicate that it is mandatory to pay special attention to fractured or cracked restorations (fillings and veneers), restorations with weakened adhesion, and secondary (under-filled) carries (Zadik, 2009; Aydıntug et al., 2011; Yüce et al., 2016). Prior to the filling procedure, it should be carefully determined whether pulp necrosis has developed, especially in teeth with extensive material loss, by cold tests and/or periapical films (Zadik, 2009).

Panoramic films are used to archive general oral and dental health records of aircrew so that oral and dental health issues may well be followed. In cases when panoramic filming is not possible, periapical films taken from the lower and upper incisors may also be used for keeping records of aircrew.

Aircrew members work in a unique environment that can lead to a variety of health problems and contribute to chronic stress. The researchers speculated that the high prevalence of jaw parafunctional activity in aircrew was linked to a number of adverse effects experienced during flight, such as acceleration forces, vibration, etc. (Lurie et al., 2007). Other work-related parameters, such as irregular shifts, have also been associated with bruxism (Zadik, 2009). Long-term consequences of bruxism can include tooth wear, periodontal problems, and temporomandibular joint (TMJ) dysfunction, as well as headache and facial myalgia, especially in the morning. Bruxism was shown to be significantly more prevalent among pilots than in non-pilots (69% vs. 27%, respectively) (Lurie et al., 2007; Zadik, 2009). Since there have been many studies on the prevalence of bruxism (clenching and grinding) among aircrew, dentists should also check for wear marks on opposing jaw teeth during periodic oral and dental health examinations.

Another important consideration for dentists who participate in periodic oral and dental health examinations of divers and aircrew is the durability of dental treatment procedures and materials, which have changed or improved over the recent years, against environmental and atmospheric conditions. Recent studies have shown that changes in environmental pressure can affect the functionality of dental restorations (crown retention, etc.) due to the cementation technique and type of dental material (Ata et al., 2022; Geramipanah et al., 2016; Mocquot et al., 2017; Ozkan Ata et al., 2023; Sadighpour et al., 2018). In an in-vitro study conducted by Ata et al, similar to their prior findings published in recent literature, they reported that the luting cement-type, mixing methods of cements, and changes in environmental pressure have a significant effect on bond strengths. Besides, they proposed that dentists could use auto-mixed self-adhesive resins on patients who are likely to be exposed to hypobaric pressure (Ata et al., 2022).

Initial and periodic (renewal and revalidation) medical assessments of civil aircrew in our country are conducted in accordance with the medical requirements under regulations (Aviation Health Directive; SHT-MED) issued by The Directorate General of Civil Aviation. In SHT-MED, dental examinations are not routinely included within the periodic medical examinations (SHGM, 2022). During these examinations, a dental consultation may be requested if further evaluation is necessary. A similar procedure is carried out in periodic aeromedical examinations of military aircrew.

5. Aeromedical Limitations in Terms of Oral and Dental Health

If a medical condition is harmful to aircrew health and, thus, reduces flight safety, thorough investigations should be conducted, and participation of aircrew to flight duties should be suspended until these investigations are completed. Some pharmaceutical agents which do not require unfitness to flight may be used -taking into account the medical condition requiring medication- with certain aeromedical limitations. But nonetheless, direct effects of drugs, interactions between pharmaceutical agents, or any allergic reaction may cause drowsiness, poor judgment, gastrointestinal discomfort, and vision problems, which are only some of the adverse effects that could render a pilot incapable of performing flight duties (Muntingh, 2007). For example, some pain relievers may cause dizziness, concentration impairment (Zadik, 2009), and upset stomach (Muntingh, 2007); and many antibiotics can cause some health problems such as diarrhea (Ashish et al., 2022). No matter how uncommon, doxycyclin use may trigger phototoxic reactions, macrolides can lengthen the Q-T interval, and these side effects can easily lead to medical incapacitation and loss of flight control, especially flying in adverse conditions (Hipskind, 1993; Muntingh, 2007). Nevertheless, it should be noted that unfitness for flight is directly related to the medical condition that requires the pilot to use medication itself.

In the event of a medical treatment process for a dental pathology, the flight restriction may be extended until the symptoms are alleviated, and/ or the medication is discontinued, and the blood clot is stabilized at the operation site (Zadik, 2009; Aydıntug et al., 2011).

Since toothache may also often cause sleeping problems, the dentist should advise the aircrew member not to fly at least until the pain has subsided and they are able to sleep comfortably again (Aydıntug et al., 2011; Yüce et al. 2016; Shah et al., 2018).

Rossi (Rossi, 1995) recommends military aircrew not to fly after determining the need for endodontic treatment until appropriate treatment has been totally completed in order to avoid experiencing barodentalgia during the flight. The recommended grounding time for regional (regional) and local anesthetic applications, which are the most common practices in dentistry, is 24 hours (Aydıntug et al., 2011). Apart from that, changes in ambient pressure can trigger the blood clot to dislodge, which can lead to bleeding several hours after a tooth extraction or oral/periodontal surgery. This condition may also

hinder the ability to perform oral tasks properly, including the comprehensibility in speech functions. Moreover, in an environment with pressure changes, the risk of developing emphysema at the surgical wound site is quite high (Wilson et al., 1983).

Another reason for grounding after surgical tooth extraction is facial swelling, which can make it difficult for helicopter and jet pilots to wear flight helmets comfortably. In addition, if the oro-antral opening occurs in the maxillary posterior region after tooth extraction, atmospheric pressure changes during flight may cause problems in wound healing. Therefore, it is recommended to avoid flying until the wound site with oro-antral opening has healed completely.

The oral and dental conditions which might require grounding of aircrew, as recommended by Zadik (Zadik, 2009) are:

1. Acute intraoral infection findings presenting systemic symptoms (lymph adenopathy, high fever, weakness, etc.),
2. Insomnia due to toothache.

The treatment procedures again recommended by Zadik (Zadik, 2009) are:

1. Use of Nonsteroid Anti-inflammatory (NSAID), Opioid (codeine and paracetamol, oxycodone etc.) and Systemic Antimicrobial drugs without a definitive diagnosis of the underlying cause has been determined,
2. Local / Regional Anesthesia,
3. Tooth Extraction,
4. Oral/ Periodontal Surgery,
5. A general weakness, drowsiness related to oral and dental health.

In addition, it is highly probable that normal functions such as intelligible speech cannot be performed after dental procedures, especially tooth extraction or oral/periodontal surgery. Moreover, the risk of developing emphysema is extremely high in environments where pressure changes occur. Facial edema and/or trismus, which can prevent helicopter and jet pilots from wearing flight helmets comfortably and speaking while wearing them, are a further reason for restricting flight activities after oral/periodontal surgery (Zadik, 2009). Therefore, the return to flight duties of aircrew who have received oral and dental treatment should be contingent upon an additional oral and dental examination.

According to the Federal Aviation Administration (US FAA) guidelines, when considering the conditions and durations that require oral and dental health-related flight restrictions for pilots, 24-72 hours after tooth extraction and/or intraoral surgery, 24 hours after endodontic treatment, dental flight restriction is recommended for 10 days after implant surgery, and 7-14 days after tissue graft/membrane application. If a pilot has significant malocclusion or maxillofacial tissue disease, it is advised that they be prohibited from flying and assigned to an air-ground role (Holt & Wiseman, 2002; Yüce et al., 2016).

6. Conclusion

Because of the unique nature of aerospace medicine, practitioners with specialized training in aviation dentistry are required. The concerns and difficulties associated with oral and dental health treatments being planned for aircrew are substantially different from those encountered in individuals who reside and work on the ground. Both dentists and aircrew should be aware and increase their knowledge about aviation dentistry. Oral and dental health examinations of aircrew should be performed on a regular basis to ensure flight safety. Both medical considerations and flying restriction periods should be determined by the dentist who has obtained specific training in aviation. In our opinion, it is appropriate for aircrew to undergo periodic oral and dental health examinations by a trained dentist every six months, just as is recommended for the general population.

Ethical approval

Not applicable.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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