

Space and aeronautical dentistry: A review

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Abstract

Human beings are not just limited to moon today but are trying their level best to reach Mars and even beyond. Microgravity conditions can have various physiological implications on the astronaut's general as well as dental health. Aeronautical dentistry is a newly recognized dental specialty concerning the application of dentistry to aeronautical environment. This article highlights the physiological changes in human body exposed to microgravity and radiation as well as prevention, diagnosis and management of dental emergencies which can arise during space mission.

Keywords: Aeronautical, Barodontalgia, Dentistry, Microgravity.

Introduction

Human physiological adaptation to the conditions of space is a challenge faced in the development of human space flight.¹ A round trip to Mars with current technology is estimated to involve at least 18 months in transit alone, thus there will be a greater time laps since the crew members last terrestrial dental examination, which routinely occurs every year. Moreover exposure to microgravity and radiation environment during short & long duration space mission has serious effects on human physiology, including the oral cavity.² This increased time since professional dental care as well as exposure to microgravity & radiation could increase the chance of dental problems like dental caries, periodontitis, bone loss, fracture of jaw bones, facial pain, numbness of teeth, stones of salivary duct and oral cancer.³⁻⁶ Therefore, space and aeronautical dentistry is an important area of future research. Aeronautical dentistry is a specialized branch of dentistry in space environment including microgravity, hyper gravity and radiation. This research relates to astronauauts, space plane travelers, hyper-velocity jet travelers and to those involved in living in microgravity and elevated areas of radiation.

Microgravity

On earth, gravity is a force, our bodies have to work against, which keeps our cells, bones and muscles strong. Gravity on Mars is 0.38 g as compare to on Earth which is 1g. Removal of force of gravity from the equation for a longer period of time, the human bodies undergo dramatic changes.⁷

Radiation

The space environment presents a different radiation conditions from Earth and moreover, the degree of radiation is not uniform.⁸ Galactic cosmic rays are the primary radiation source which are trapped in the Earth's magnetic field and known as Van Allen

Bells. Another source of radiation is solar energetic particles known as solar flares. Radiation levels depend on perimeters like altitude, geographical latitude and the activity of the sun. The most important variable that determines the average dose rate in flight is altitude.

Radiation level in space

The average total dose of radiation of a person on Earth is less than .005 sievert (sv) per year. At the International space station (ISS) the dose is about .3 sv per year. In the coming decades, round trip to Mars, an astronaut will receive an approximate dose of Isv.

Effect of microgravity and radiation on health of astronauts

Exposure to microgravity and radiation has important medical and health implications in astronauts.⁷

Effect on cardio vascular system

Fluid under gravity (1g) is circulated throughout the body working against the gravity to prevent pooling of blood in the legs and bringing blood to the brain. Under microgravity conditions, cardio-vascular system does not work as hard, triggering a fluid shift. Due to this fluid shift heart rate increases and blood pressure rises. Astronauts experience puffy faces, headaches, nasal congestion and skinny bird legs as a result.^{9,10}

Space sickness

Almost 40 percent of astronauts experience headache, malaise and dizziness along with nausea and vomiting. These symptoms may be related to change in blood circulation which generally subsides within two or three days as astronauts adapt to the environment.

Changes in Red blood cells

RBCs appear to change shape in space and become more spherical and even fewer cells populate bone

morrow. Cells return to normal under Earth's gravity or after a long term mission.

Compromised immune system

Human immune response may be attenuated during space flight resulting in increased number of neutrophils and decreased count of lymphocytes and eosinophils. Isolation and sleep deprivation may result in weaker T- Lymphocytes causing compromised immunity.¹¹ Increase in epinephrine and glucocorticoid have been suggested as possible cause for the immune alterations.

Back aches

Under microgravity conditions back vertebrae separate slightly, back muscles and ligaments are relaxed leading to back aches. Once astronauts return back to earth, they shrink back to their formal height.

Fatigue

Constant noise, irregular light patterns and disturbed sleep result in stressed and fatigued astronauts.¹²

Poor balance and orientation

Astronauts in microgravity usually lose their sense of direction and feel uncoordinated.

Psychological effects

Isolation, monotony, limited mobility and living in close quarters with other astronauts could lead to depression, conflicts, anxiety, insomnia and even psychosis.

Effect on facial bones

Osteoporosis of both maxilla and mandible has been reported under microgravity conditions.¹³ Demineralization of bone occurs as a result of imbalance between the process of bone formation and bone resorption. Decrease in MIP 1 alpha level in microgravity is a potential marker of bone loss. The demineralization in microgravity environment is about 1-2% of total bone mass per month. Loss of bone mass is not uniform throughout the skeleton, but varies at different sites depending on the type of bone and mechanical loading. Eventually, there is significant reduction in the ability of the bone to withstand forces of gravity and bones are more susceptible to fracture.

Effect on saliva

The fluid intake by the astronauts has been found to be low leading to reduced plasma volume and ultimately saliva flow. Increased sodium, potassium, calcium, phosphate, protein, levels in saliva have been reported in simulated microgravity environment.¹⁴ This could be because of increased muscle breakdown and calcium mobilization from bones and reduced fluid intake by the astronauts. Other environmental and

dietary factors may adversely affect salivary composition and increased risk of stone formation during space flight.

Oxidative stress

Decreased levels of vitamin E, C and increased malonaldehyde level denotes an increase in free radical activity in microgravity environment.¹⁵

Effect on Oral bacteria

Under microgravity conditions there is an increased count of Mycoplasma and cariogenic Streptococia and decreased count of enteric bacilli. Diminished gravity stimulates biofilm formation which further makes them highly resistant to antimicrobial agents. Bacteria such as E.coli and S.aureus show increased resistance to selected antibiotics due to increased cell wall thickness. The increased virulence of microbes and compromised immune system within the oral cavity can lead to periodontitis, delayed wound healing, necrosis, ulcerations and cancerous lesions of oral cavity including soft and hard tissues, so called space AIDS syndrome.^{16,17}

Increased prevalence of caries

Prevalence of dental caries is high in space. This may be due to combined result of reduced salivation, attenuated human immune response and increased virulence of bacteria. Moreover, incidence of caries in mandibular anteriors is high in space as compared to on Earth.¹⁸

Odontocrexia

Physical disruption of teeth caused by barometric pressure change is known as odontocrexia. It occurs due to expansion of gases trapped beneath a leaky restoration.^{19,20}

Periodontal defect

At high altitude, due to decreased salivation, there is an increased incidence of developing periodontal diseases. Predisposing factors of flying personnel include poor oral hygiene, nervousness and fatigue.

Reduction in prosthetic device

Retention of complete denture is solely based on atmospheric pressure adhesion under gravity. Thus, reduced barometric pressure can impair the retention of complete denture.²¹ In case of full cast crown, pressure changes occurring in microtubules of cement layer result in reduced retention of the crown luted with either zinc-phosphate or glass ionomer cement.^{22,23} Resin cements should be use to cement crown and fixed partial dentures for patients who are likely to be exposed to pressure cycling.²⁴

Barotrauma

According to Boyle's Law, the volume of gas at constant temperature varies inversely with the surrounding pressure. Barotrauma is the condition experienced by the tissues due to change in the gas volume inside the body's rigid cavities with the changing atmospheric pressure. It includes head and face barotrauma, barotitis media, barosinusitis, barotrauma related headache, dental barotrauma and barodontalgia.²⁵

Barodontalgia is defined as tooth pain occurring with changes in ambient pressure. Barodontalgia is a symptom rather than a pathologic condition itself. It is usually a flare-up of pre-existing sub-clinical oral and maxillofacial disease caused by a change in barometric pressure.^{26,27} Common oral conditions which have been reported to be associated with barodontalgia are: dental caries, defective tooth restoration, pulpitis, pulpal necrosis, apical periodontitis, periodontal pockets, impacted teeth, and mucous retention cysts.^{21,28}

Pulpitis is the main cause of barodontalgia²⁹ and mechanism underlying barodontalgia in pulpitis can be:

1. Direct ischemia resulting from inflammation itself.
2. Indirect ischemia resulting from intra-pulpal increased pressure as a result of vasodilatation and fluid diffusion to the tissue.
3. The result of intra-pulpal gas expansion, which is a by-product of acids, bases and enzymes in the inflamed tissue.
4. The result of gas leakage through the vessels because of reduced gas solubility.

Prevention

Special attention must be denoted to prevent dental problems and for oral health maintenance. Dentists have the responsibility to educate their patients about the importance of a healthy diet and motivate them towards maintaining meticulous oral hygiene. Early diagnosis of initial visible and occult oral disease is of special importance. Special attention should be given to defective (fractured or cracked) restorations, restorations with poor retention and secondary caries lesions. Cold test and /or periapical radiographs should be taken for teeth with pre existing restorations to rule out occult pulpal necrosis. Panoramic radiographs should be used to reveal any additional occult dental pathology and for documentation purposes. Since, high reports of bruxism among aircrews has been reported, dentists should look for signs of dental attrition.

Endodontics

On Earth the destructive potential of arrested carious lesions is minimal as it is not active and progression toward the pulp is unlikely. But such lesions carry danger in a pressure changed environment and should be removed.

In suspected invasion to the pulp chamber, Indirect/direct pulp capping is recommended on earth environment but contra indicated and endodontic treatment is recommended indeed for persons, who are exposed to barometric pressure changes.³⁰

Root canal treatment should be completed before flight as in a pressure – changing environment, open unfilled root canals can cause facial emphysema as well as leakage of the intra canals infected content to the peri-apex tissues.³¹ A protective layer of liner and or base is recommended before restoration.

Prosthodontics

When treating aircrews, every effort should be made to enhance the retention of prosthodontic devices. From retention point of view, implant supported prosthesis are advised.²⁵

Oral surgery

When extracting a posterior upper tooth, the dentist should rule out the existence of oroantral communication. Presence of oroantral communication can lead to sinusitis and adverse potential consequences upon exposure to a pressure- changing environment.²¹ Referral to an oral surgeon for its closure should be indicated.

Flight restriction

Flight restriction is required when interference in the flight capabilities of the aircrew member is suspected i.e. conditions like tooth extraction, periodontal surgery etc. Intra oral pressure changes several hours after tooth extraction or other oral /periodontal surgery can dislodge the blood clot causing intraoral bleeding with obvious interference to normal function (especially clear speech) as well as risk of emphysema.²⁵ Pressure changes can also interfere with wound healing in cases of oro-antral communication, hence grounding should be advised until healing is evident. Facial swelling can prevent jet and helicopter pilots from wearing helmet comfortably. Moreover, some medications can cause dizziness or lack of consciousness. (eg analgesics) where as other can cause diarrhoea (eg antibiotics).

Periodic examinations

Currently, there is no evidence based guideline or any consensus regarding the frequency and extent of periodic aircrew dental examinations. NASA has established strict standard for the selection, retention and preflight dental examination of astronauts chosen for a specific space flight, and a strict clinical schedule is followed. At six months before launch, crew members undergo an examination and if dental treatment is deemed necessary, all such treatment is completed by three months before launch, so as to minimize the potential for problem during flight.

Documentation

Available updated dental records are most useful for identification purpose in cases of air crashes. Dental comparison is the primary method of identifying disaster victims due to high likelihood of dental anatomy preservation in traumatic death. (at up to 1600°C).³²

Non-invasive Diagnostic tools for oral and systemic health

During space mission, monitoring of medical health of astronauts is critical for the success of the space mission. Only limited non-invasive diagnostic tools can be used for diagnosis of diseases.

Saliva as a Diagnostic tool

Saliva has become an important tool for evaluating physiological, psychological, and pathological conditions in humans. Saliva can be considered an important diagnostic tool during space flight as:

1. Saliva measures free, bio-available fraction of steroid hormones
2. More reliable measurement of tissue uptake in case of topical hormone supplements.
3. Collection of sample is painless, non- invasive and needle free.
4. Hormones are stable at room temperature for weeks in saliva

Use of LASERS, LED (Light emitting diodes) and Ultrasound

Management of soft tissue by conventional methods are further complicated by problems such as bleeding, time needed for wound healing and suturing all in microgravity environment. These disadvantages have led to the use of LEDs and LASERS as potential alternative for oral- dental hard tissue and soft tissue management. LEDs have been shown to be a safe, efficient, light weight and less expensive alternative to treat wounds. Ultrasonic echography has been used as an on the spot use, non invasive method for the observation of relatively deep areas. It could be of great value in assessment of possible dental emergencies. That might be faced during space mission i.e. dental caries, barodontalgia, bone loss, fracture of jaws, stones of salivary duct etc.

Oral –Dental surgery using robotic technology

Open surgery is impossible because microgravity does not permit surgeon to deal effectively with body fluids. Tele-operated dental surgical robotic systems

offer a technological solution to replace or greatly enhance the capability of flight surgeon on board of spacecraft.

Dental Pharmacology

Physiologic changes due to microgravity may contribute to differences in pharmacokinetics, which could in turn have meaningful implications for dosing of therapeutic response and toxic effects of medications. Optimized drug regimens in microgravity will be critical to ensure the safe, effective and definitive treatment of future space travelers. Dental pharmacologic therapy may or may not have the side effect in space as on earth. Some orally administered medications taken during flight were reported to be less effective.

Dental Emergencies during space mission

Dental emergencies have occurred only infrequently in space flight. Such emergencies are typically prevented though the use of comprehensive preflight examination and preventive measures while the crew is training. As the duration of space flight increases, problem of prevention becomes progressively more difficult. The longer the mission, the greater the possibility of a dental emergency occurring in space flight.

Dental emergencies like barodontalgia, periodontitis, dental caries, bone loss, fracture of jaw bones, facial pain, numbness of teeth and oral cavity tissues, stone of salivary ducts and oral cancers might be faced during space mission.

Management of Dental Emergencies

Astronauts and mission specialists should be trained personally in emergency dental treatment to include oral diagnosis, pain control, local anesthesia, dental infection treatment, placement of temporary filling, extraction of teeth. Addition to the training programs a manual with diagrams of each procedure is in all instances, to be provided on the space vehicle to serve as a guide for all crew members.

Specific dental instrument, materials and supplies should be included in a dental kit aboard every space vehicle and space station. The best selection of analysis and antibiotics appropriate for dental treatment and inclusion in the dental kit space mission should be determined by a dental expert in microgravity and radiation.

Emergency dental kit⁸:

Proposed Medicines	Proposed instruments	Proposed non-medical supplies	Other proposed supplies	Proposed Devices
Analgesics (in medical kit)	Wooden plastic instruments	Tooth paste and mouth wash (non – toaming, anti caries, anticancer, anti-inflammatory patient by Balwant Rai and Jasdeep Kaur)	Gauge/sponge (2x in) (2 packs)	<i>Laser technology for dentistry</i>
Anesthesia Carpule 3% Mepivacaine HCL 4% Anticaine HCL With 1.100000 epinephrine	Front surface dental mouth mirror	Instruments disinfection packet	Anesthesia aspirating dental syringe	<i>Anesthesia syringe needle</i>
Extraction forceps antibiotics such amoxicillin and choxacillin others such as 5% antexanox, non alcoholic tooth paste and mouth wash, antioxidants and calcium supplements, melatonin, 0.05% oxymetazoline and 0.5-1% phenylephrine.	Handheld light with batteries	Gauge long	Examination gloves	<i>Extraction elevators</i>
Cavit- G, Dycal (tubes and applicator)	Excavator (small)	Cotton rolls	Periodontal scalar	<i>Set of elevators</i>
<i>Topical application such as ibuprofen and antibiotics</i>		<i>Dental floss and tooth brush</i>	<i>Arch wires and instruments for tagging of arch wire</i>	<i>Explorer, Giggle saw</i>

Efficacy of medications used during space mission

Physiologic changes due to microgravity may contribute to differences in pharmacokinetics of drugs which can effect therapeutic response and toxic effects of medications. National Aeronautics and Space Administration (NASA) has reported that the expected effects of the drugs were less than anticipated. Typical dose of a medication used to treat toothache on Earth did not relieve the tooth ache completely when taken during spaceflight.

Conclusion

In flight, dental emergencies have been reported rarely in current data but long duration mission like

Mars raises the probability of a significant in-flight dental emergencies. Increasing probability of an event and the potential for mission impact, exploration mission will need to focus on pre-flight and in-flight prevention as well as preparing crew members by training to treat various dental emergencies.

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References

- 1 David L. Space travel-Inherently hazardous to human health. NASA report (2001).
- 2 Space travel and the effects of weightlessness on the human body. Canadian space agency (2001). Available

- online at [www.asc-csa.gc.ca/pdf/educator - microgravity _ science _stu.pdf](http://www.asc-csa.gc.ca/pdf/educator_microgravity_science_stu.pdf).11-16
- 3 Rai B. Virulence of oral cavity bacteria and microgravity: Aeronautic dentistry. *IJDS* 2008;7(1).
 - 4 Rai B. Effects of Microgravity on Teeth and Periodontium: Aeronautic Dentistry. *IJDS* 2007;5(2).
 - 5 Rai B. Effect of simulated microgravity: a dentist on Mars. *Indian J Dent Edu* 2009;2(1):12-16.
 - 6 Rai B. Human oral cavity in simulated microgravity environment: dentist on Mars. *JAMDSR* 2009;3(2):35-9.
 - 4 Rai B and Kaur J. The history and importance of aeronautic dentistry. *J Oral Sci* 2011;53(2):43-146.
 - 5 Rai B and Kaur J. Space and aeronautical Dentistry. Pee pee publishers. 1st ed 2012.
 - 6 Rai B, Denning K. Effect of long term space flights on human body. *JAD* 2009;1(1):15-17.
 - 7 Antonutto G, Di Prampero PE. Cardiovascular deconditioning in microgravity: Some possible counter measures. *Eur J Appl Physiol* 2003;90:283-91.
 - 8 Taylor GR. Overview of spaceflight immunology studies. *J Leukoc Biol* 1993;54:179-88.
 - 9 Gundel A, Polyakov VV, Zulley J. The alteration of human sleep and circadian rhythms during spaceflight. *J Sleep Res* 1997;6-8.
 - 10 Oganov VS, Grigor'ev AI, Voronin LI, Rakhmanov AS, Bakulin AV, Schneider VS, LeBlanc AD. Bone mineral dentistry in consmonauts after flights lasting 4.5-6 months on the MIR orbital station. *Aviakosm Ekolog Med* 1992;26:20-4.(in Russian)
 - 11 Brown LR, Frome WJ, Wheatcroft MG. The effect of skylab on the chemical composition of saliva. *J Dent Res* 1997;56(10):1137-43.
 - 12 Rai B, Kaur J, Catalina M, Anand SC, R. Jacobs R, Teughels W. Effect of simulated microgravity on salivary and serum oxidants, antioxidants, and periodontal status. *J Periodontol* 2011;82(10):1478-82.
 - 13 B Rai and J,Kaur, "Oral cavity in simulated microgravity: a dentist on Mars," In proceedings of the 18th IAA Humans in space symposium, Houston, Tex, USA, April 2011, <http://www.dsls.usra.edu/meetings/IAA/pdf/2002.pdf>.
 - 14 Rai B. Human oral cavity in simulated microgravity: new prospects. *JAMDSR* 2009;3(1):35-9.
 - 15 The increase in prevalence of dental diseases during flights. Available from the following link <http://4saliva.Com/news/press-released/dentistry-space-the-story-of-the-principal>.
 - 16 Zadik Y, Einy S, Pokroy R, Bar Dayan Y, Goldstein L. Dental fractures on acute exposure to high altitude. *Aviat Space Environ Med* 2006;77:654-57.
 - 17 Cadler IM, Ramsey JD. Odontocrexis-the effect of rapid decompression o restored teeth. *J Clin Diagn Res* 1984;11(4):318-23.
 - 18 Anuradha P, Grover S. Aviation dentistry: the neglected field by dentists in India. *JIAPHD* 2010.
 - 19 Musajo F, Passi P, Girardello GB, Rusca F. The influence of environmental pressure on retentiveness of prosthetic crowns: an experimental study. *Quintessence Int* 1992;23(5):367-69.
 - 20 Lyons KM, Rodda JC, Hood JA. The effect of environmental pressure changes during diving on the retentive strength of different luting agents for full cast crowns. *J Prosthet Dent* 1997;785(5):522-27.
 - 21 Zadik Y. Aviation dentistry: current concepts and practice. *Br Dent J* 2009;6(1):11-6.
 - 22 Zadik Y, Chapnick L, Goldstein L. In-flight barodontalgia: analysis of 29 cases in military aircrew. *Aviat Space Environ Med* 2007;7:593-56.
 - 23 Orban B, Ritchey B T. Toothache under conditions stimulating high altitude flight. *J Am Dent Assoc* 1945;32:145-80.
 - 24 Seria ES, Cunningham KW, Marx RE. The diagnostic dilemma of barodontalgia: report of two cases. *Oral Surg Oral Med Oral Pathol* 1985;60:212-17.
 - 25 Zadik Y. Barodontalgia due to odontogenic inflammation in the jawbone. *Aviat space Environ Med* 2006;77:864-6.
 - 26 Rossi DG. Health policy directive no-411: aviation and diving-dental considerations. Surgeon general, *Australian defence force* 1995.
 - 27 Verunac JJ, Bump RL. Recurrent severe facial emphysema in a submariner. *J Am Dent Assoc* 1974;88(1):35-6.
 - 28 Smith A. Disaster victim identification of military aircrew. *ASEM* 2003;75:1198-200.

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