Educational Objectives

Upon completion of this course, the participant will be able to:

1. Understand the possible effects of space environments on the oral cavity.
2. Possible dental emergencies during space missions.
3. Proposed dental emergency kit for space mission.
Abstract

Extraterrestrial environments can have a significant impact on the physiological and psychological well-being of astronauts including oral health and the acclimatization of astronauts to these conditions is of utmost importance. The new disciplines of aeronautical and space dentistry are a specialized branches of dentistry which deal with the study of oro-dental factors in aeronautical and extraterrestrial environments. Dental emergencies are real medical emergencies during short and long term space missions and must be handled accordingly.

Since environments in space can have adverse effects on the oral cavity including oral health, an aeronautical or space dentist has to be prepared to screen and select only those astronauts with optimal oral health prior to a mission as well as make guidelines for the preparation of dental emergency kits to deal with dental emergencies during missions. This article reviews the possible effects of space environments on the oral cavity, dental emergencies during space missions and the role of dental emergency kits.

Introduction

During Space missions such as Mars expeditions, international crews are involved in complex activities over long periods of time in isolated, harsh and extreme environments. Extraterrestrial environments have been found to affect human physiology causing bone loss, muscle atrophy, cardiac dysrhythmias, altered orientation and psychological status of astronauts during both short- and long-duration spaceflights. Very few studies have been conducted to show the effects of microgravity on the oral cavity. NASA and other space agencies have to date reported only limited dental emergencies in space. Astronauts, however, are likely to encounter more dental emergencies during long missions such as trips to Mars. For this reason, proper protocols and dental kits are vital tools necessary to address dental emergencies should these occur during long missions. This article addresses possible dental emergencies and the design and component parts of an Emergency Dental Kit for space.

As mentioned earlier, the effect of long duration on oral cavity has only been studied in limited fashion. The following studies have been reported so far:

a) Skylab studies: These studies highlight a significant increase among inflight increments of dental plaque, calculus and gingival inflammation. Oral microflora such as streptococci, Neisseria, lactobacilli, and enteric bacilli were significantly higher. Studies reported the relative absence of intraoral changes that are hazardous to health and in other studies it has been reported that higher levels of mycoplasma and cariogenic streptococci and decreased counts of enteric bacilli, decreased saliva flow rates, and increased secretory Immunoglobulin A and saliva lysozyme level were observed. Secretory IgA and salivary lysozyme elevations were considered to be responsive to an endogenous or environmental microbial in influence.

b) JBR studies during simulated space mission environments: Saliva based biomarkers of periodontal diseases, dental caries and bone loss biomarkers were found to be elevated in extreme and isolated environments. Wound healing is also significantly delayed during space missions. Trigeminal sensations and taste sensation are significantly affected in extreme conditions and during extravehicular activities in extreme conditions. Furthermore, temporomandibular joint and facial pain is elevated in extreme conditions. A simulated isolated
environment increases plaque formation, and anaerobic and aerobic bacterial levels were significantly increased.

The following oral-dental problems have been experienced and documented during space flight by astronaut crews and related ground based studies\textsuperscript{3-11}

- Barotrauma
- Periodontitis
- Dental caries
- Bone loss and fractures of the jaw bone
- Facial pain and numbness of teeth and oral cavity tissue
- Stones of the salivary duct and oral cancer
- Headache
- Rash, facial, recurrent inguinal
- Nasal congestion
- Acute maxillary sinusitis

Evidence based dental emergencies during long duration space missions: The evidence required to hypothesize and estimate the probability of oral dental problems occurring during space missions can be taken from several different sources.

Some of these include:

(a) Records of dental problems that were faced during previous space flights by crews as well as other international partners;

(b) information on the medical conditions that occurred during short- and long-term Earth expeditions i.e. simulated space flight missions (submarine, alpine, Arctic and Antarctic expeditions, expeditions to other remote ground-based locations, etc.);

(c) General population studies addressing the age-related probabilities of different diseases and incidence of trauma as well as injuries;

(d) Pre- and post-flight records of the health status and medical conditions of astronauts and cosmonauts;

(e) JBR studies of Martian sol bed rest (simulated microgravity) \{Investigator: Balwant Rai\};

(f) Mars analog mission \{Investigator: Balwant Rai\};

(g) Pilot surveys i.e. the study of oral dental problems faced by crew members including fighter pilots during long duration flights \{Investigator: Balwant Rai\}. 
Number of Dental Emergencies:

(a). Evidence can also be obtained from the Longitudinal Study of the Astronaut Health database that is maintained at NASA Johnson Spaceflight Center (JSC). Two dental emergencies occurred during March 14, 1995, through June 12, 1998.

(b). One dental emergency occurred during a Mars analog mission (Rai B 2009).

(c) Two dental emergencies occurred during JBR study of Martian sol study (Rai B, 2011).

Possible Dental emergencies during long duration space mission:

The following dental emergencies are most likely to be faced during space missions:

(a) Barodontalgia

(b) Periodontitis

(c) Dental caries

(d) Bone loss and fractures of the jaw bone as well as a delay in wound healing

(e) Facial pain and numbness of teeth as well as oral cavity tissues

(f) Stones of the salivary duct

(g) Oral cancer

Dental Kit for Long Manned Missions

Dental emergencies have occurred only rarely in space flights during ISS missions and Moon landings, however the frequency of occurrence during missions to Mars is likely to higher.

Dental problems can become a real medical emergency during these long duration missions. Typically dental problems have arisen in about 5% or less of all recorded missions. As noted earlier dental problems are now largely prevented by regular and complete preflight examinations and preventive measures during crew training. Long duration space missions are planned for travel to the Moon, Mars, and beyond and as the length of the mission increases the likelihood of dental emergencies occurring in space flight naturally increases. Space crews live and work as well as travel in a weightless, hyper gravity, zero gravity and a higher radiation-level environment. The forces exerted on the human body in these environments produce impact forces that can lead to tooth fracture and other significant injuries to the face and jaws.

There is also the possibility to observe cracked teeth, inflammation or infections of the tooth pulp, temporo-mandibular disorders, periodontal abscesses, and dental caries as well as a delay in wound healing during a long-duration flight. In order to allow for potential emergencies specific dental instruments, materials and other important supplies should be included in dental kit supplied to every space vehicle and space station (See Table1). The best selection of analgesics and antibiotics appropriate for dental treatment and inclusion in the dental kit for a space mission should be determined by a dental expert, i.e. a space dentist, with experience in microgravity and radiation as well as in extraterrestrial environments. The detailed formulation of a medical kit should be made in consultation with aerospace medical physicians.
who are also directly involved in the mission and mission planning. Physicians caring for astronauts, mission specialists, or those in long course residency training should help maintain and update the dental kit. This way they can provide a tool suitable for dental care in remote settings if needed in the absence of a dentist.

**Kit Design**

The external case for the Dental Emergency Kit should be well designed for use on extraterrestrial missions. This means that the casing should be lightweight, non-toxic, and also meet relevant packaging criteria for the retention of the instruments under gravity-free, thermal free conditions and should be resistant to the effects of extraterrestrial conditions. These requirements also suggest an optimized strength-to-weight relationship. I selected a hard-shell-foam core design (sandwich panel construction) for the packaging of the kit. The instruments were embedded in form-fitted detents providing a slight interference fit, thereby solving the problem of retention under weightlessness conditions.

**Dental Training for Astronauts**

Astronauts and mission specialists should be trained personally in emergency dental treatment such as oral diagnosis, pain control methods, technologies for local dental anesthesia, dental infection treatment, placement of temporary fillings, extraction of teeth, and bleeding control as well as management of oral and maxillofacial trauma and injuries. In order to make sure that the equipment will indeed provide the necessary dental assistance for the Astronauts adequate training and testing needs to be done. In order to ensure that the crew were familiar with appropriate use of the dental equipment and the introduction of unfamiliar technologies they were provided with thorough training sessions that went on for 15 to 180 days. Outpatient based procedures were discussed during the training programs. This process helped train the crew in how to address problems as serious as the treatment of maxillary bone fractures and other emergencies that are anticipated to be less serious than tooth removal. In addition to the training programs a manual with diagrams of each procedure should, in all instances, be provided on the space vehicle to serve as a guide for all crew members. This manual contains detailed instructions on procedures, information on diagnosis, and images sourced from personal radiographs of each astronaut to illustrate the oral structure for every astronaut on the mission.

**Recommendations for the Space and Aeronautical Dentist or Space Oral Physician**

a. Clinical examination\(^{19-21}\)

1. Very standard dental or oral health guidelines have been established for the selection and oral examination during pre-flight dental examination of astronauts to minimize the possibility of dental emergencies during flight

2. Astronauts have to undergo a dental examination at least 6 months before launch

3. Any dental treatment required should be done 3 to 6 months before launch depending on the types of treatment indicated.
4. Crew medical officers and crew dental officers should work together and discuss possible
dental emergencies during pre flight briefings.

b. Space Dentistry in the Dental Curriculum: I have proposed four types of training:\19-21:

1. an FAD (Fellowship of Aeronautic Dentistry) is to be awarded to students completing an
introductory course requiring 18 weeks of full-time study

2. a PGDAD (Postgraduate Diploma in Aeronautic Dentistry) is to be awarded to students
completing an advanced course requiring 36 weeks of full time study.

3. Masters in Space and Aeronautical Dentistry: is to be awarded to students completing a very
advanced course requiring 2 years of full time study.

4. PhD in Space and Aeronautical Dentistry: is to be awarded to students completing a highly
advanced course including a Ph.D thesis requiring 3 years of full time study.

CDE Programme and Journal Clubs: I have proposed this to different countries and dental
councils as well as dental credit awarding agencies to start a CDE programme. In addition this
has been proposed to Journal clubs.

Research and Development:\19-21

It is of prime importance for aeronautical or space dentists to design and conduct studies in
simulated space flight environments i.e. simulated space missions, ground-based studies, in the
ISS as well as at the Mars simulated lab., in aeronautical and space dentistry. Different smart
technologies as well as oral health care products should be formulated and used to care for the
oral health of astronauts during space missions, in addition to normal populations.

Conclusion

A well designed dental kit with the right combination of medicines, instruments, supplies and
devices with accompanying training manual can provide an important tool to address
emergency dental problems should they arise in space. Treatment of dental problems in space
remains a very challenging area. NASA and other space agencies have explored and carried
out research on how to address unexpected dental emergencies in space. Accordingly much
more dental research must be performed in the planning of future for long duration crewed
missions in space. To address this possibility NASA, among other activities, has sponsored the
development of an emergency dental kit. This kit has been designed to contain instruments,
materials, and drugs that would operate in the weightlessness of space and be easy to use and/
or operate in space. Moreover, astronauts, prior to flights, have been systematically required to
visit the dentist’s chair before their flight in order to anticipate and hopefully prevent any possible
dental problems that might occur during their mission. This process has been successful for
short duration flights but more needs to be done to address the needs of manned personnel on
longer duration flights.

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References


12. Taylor GR. Recovery of medically important microorganisms from Apollo astronauts. Aerospace Med. 1974; 45: 824-828


<table>
<thead>
<tr>
<th>Proposed Medicines</th>
<th>Proposed Instruments</th>
<th>Proposed Non-Medicinal Supplies</th>
<th>Other Proposed Supplies</th>
<th>Proposed Devices</th>
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<tbody>
<tr>
<td>Analgesics (in medical kit)</td>
<td>Wooden plastic or smart instruments.</td>
<td>Tooth paste and mouth wash (non-foaming, anti-caries, anticancer, anti-inflammatory) 17-18</td>
<td>Gauze/sponge (2X in) (2 packs)</td>
<td>Laser, LED technology for dentistry</td>
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<thead>
<tr>
<th>Anesthesia Carpule 3% mepivacaine HCl 4% articaine HCl with 1:100000 epinephrine</th>
<th>Front surface dental mouth mirror</th>
<th>Instrument disinfection packet</th>
<th>Anesthesia aspirating dental syringe</th>
<th>Anesthesia syringe needle</th>
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<tr>
<th>Extraction forceps</th>
<th>Handheld light with batteries</th>
<th>Long gauge</th>
<th>Examination gloves</th>
<th>Extraction elevators</th>
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<tr>
<th>Cavit-G, Dycal (tubes and applicator)</th>
<th>Excavator (small)</th>
<th>Cotton rolls</th>
<th>Periodontal scaler</th>
<th>Set of elevators</th>
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| Topical application such as ibuprofen and antibiotics | Robotic or smart instruments | Dental floss and tooth brush | Arch wires and instruments for tagging of arch wire | Explorer, Giggle saw |