Introduction

Since 1998, the International Space Station (ISS) has been orbiting the Earth at a distance of 400 km, travelling at speeds of around 7.66 km/s. One orbit takes about 90 minutes. At present, there are six crew members working on the ISS. Currently, ISS is the only space environment.

One of the most profound differences between the terrestrial and space environments is the absence of gravity. The absence of gravity has a number of physiological implications. Astronauts need the proper amount of exercise in order to mitigate loss of muscle strength and bone density. Absence of gravity causes a redistribution of body fluids. On the ground, fluid is drawn to the feet by the effect of gravity. However, in space there is no up and there is no down. Water is redistributed so that there is swelling of the face.

In space, there is a decline in various physiological functions. There is an increase in fatigue, reduction in ability to perform tasks, loss of balance, loss of bone density, loss of muscle mass and strength and psychological effects. There is increased exposure to radiation due to the absence of the Earth’s atmosphere’s protective effect against galactic cosmic rays and solar radiation. Astronauts receive a dose of 1 milliSievert per day, which is equivalent to the dose received from background radiation on Earth over the course of six months.

In this paper, the possible dental and oral problems in...
the space environment and the current dental management of astronauts by NASA are described and the countermeasures will be discussed. Moreover, we report the dental problems and countermeasures in the Antarctic environment which is as enclosed and isolated as the space environment.

**Dentistry in Space Environment**

1. **The dental incidences estimated by NASA**

A Russian astronaut was reported to have suffered incapacitating dental pain during the last two weeks of his 96-day flight on Salut-6 in 1978. A crown displacement in-flight occurred on the Space Station MIR from 1995 to 1998. Altogether, dental events comprised 1% of the medical events in spaceflight on the Space Station MIR. It was reported that an astronaut suffered from pulpitis 90 days before his launch and another at post-flight. Displacements of crown and tooth fractures were also reported.

In the Integrated Medical Model (IMM), a Monte Carlo simulation-based tool designed to quantify the probability of medical risks and potential consequences that astronauts could experience during spaceflight, the probabilities of the six dental problems in DRMs are estimated as follow: Caries 0.39, Abscess 0.02, Exposed Pulp/Pulpitis 0.02, Avulsion/Tooth Loss 0.003, Crown Replacement 0.005, and Filling Replacement 0.005 events per person-year (Table 1). These 6 dental problems are listed also in the Space Medicine Exploration Medical Condition List (SMEMCL).

2. **Oral hygiene in space environment**

Some of these issues can be related to poor oral hygiene (Fig. 1). In ISS, Water is very expensive to take and therefore a scarce resource. Water is not used to gargle after brushing. Excess toothpaste is expelled into a towel. Lee et al. has reported the increase of dental plaque and dental calculus, and aggravation of gingivitis in Skylab Oral Health Studies. Dental problems and countermeasures in the Antarctic environment which is as enclosed and isolated as the space environment.

3. **Effect of space food**

Dietary changes also present an increased risk of oral disease. For example, it has been found that periodontitis-associated bacterial levels increase in the space environment. This may be due to the fact that space food is soft and sticky. This is again due to the low water content of food but food cannot be powdery, as the absence of gravity means it would disperse inside the spacecraft, and thereby present risks such as trauma to the eyes of astronauts. Soft foods may contribute to the increased plaque levels in astronauts’ mouths.

4. **Oral symptom in Simulated Space Environment**

In the simulated space environments (enclosed environment or head-down tilted (HDT) bed rest experiments which simulated body fluid shift change), some dental/oral problems were reported.

In the “Mars-500” project, which tried to evaluate the influence of enclosed environment on human health and performance, oral mucous membranes were changed in some of the members during dynamic monitoring in the project. There is a report that some of the research participants did not keep the discipline for dental hygiene, due to the loss of motivation during the project.

Rai et al. have reported deterioration of periodontal status, decrease of salivary flow and aggravation of stress markers (Cortisol, CgA and amylase) in saliva, within HDT bed rest study for six weeks. The results of these reports suggest that the deterioration of oral defensive functions occurs in the simulated space environments.
5. Countermeasure of oral health in space environment

In order to improve preventive and risk management capabilities with regards to oral disease, Tokyo Medical and Dental University (TMDU) formed a multidisciplinary Space Dentistry team. It is tasked with carrying out basic research, diagnosis and treatment and prevention and countermeasures for dental problems in space.

The team collaborates with JAXA to provide training on how to perform simple oral self-examination using a dental mirror. A training video has been developed. An intra-oral camera is provided so that any problems found in space can be downloaded to the control room and a dentist can diagnose and provide advice. On the ground, astronauts are also provided with oral health instruction on proper tooth brushing techniques and the use of toothpaste.

Dentistry in the Antarctic Environment

1. Dental problem in the Antarctic Environment

Concurrently, TMDU is collaborating with the Japanese Antarctic Research Expedition (JARE) to conduct research on the oral health management in the Antarctic environment. JARE sends out annual expeditions to the Antarctic, where expedition members will live at the Showa station for one year and research on biology, climate and other areas is conducted.

Illness and injuries experienced by expedition members between 1956 and 1999 were reported, and 4233 incidents were recorded\(^1\) (Fig. 2).

Dental problems were the third most frequent, at 12%; first were surgical and orthopedic events and second were internal medical problems. Most common dental problem was crown dislocation, followed by dental caries, periodontitis, endodontic pathology and dental trauma.

Our hypothesis for the high occurrence of dental problems on these expeditions is insufficient oral health promotion along with the absence of a dentist in the Antarctic area.

2. Oral health promotion program for JARE

1) Dental Examination at time of hiring JARE members

Firstly, the oral examination procedures during recruitment were assessed. It was found that dental screening for recruiting JARE members recorded only teeth present and DMFT scores. However, as periodontitis and endodontic problems have been reported on these expeditions, a more detailed examination during screening at recruitment is necessary. We developed a more detailed examination protocol which checks DMFT scores, periodontal pocket depths, bleeding, calculus and plaque scores, oral mucosal disease and temporomandibular joint dysfunction. Orthopantomogram radiographs are taken and assessed. From these inspection results, a diagnosis is made and observations are noted. For example, if endodontic therapy is necessary, the new recruit will be advised to visit a dental clinic or the TMDU team to receive treatment.

2) A dental training program for the attending doctor

A dental training program was developed for medical doctors that join the expedition. There are usually one or two physicians present at the Showa station. However, we observed that the dental equipment taken to the stations was inappropriate for use by the expedition physicians. We determined that simple instruments and materials should be made available to the physicians who should be trained in their use. At TMDU we developed a training program with input from various teams including periodontal, preventive dentistry, cariology and oral surgery, to provide instruction for medical doctors. In addition, a 10-page manual has been produced that physicians can refer to in an acute dental situation.

3) Construction of remote dental system

Finally, we developed a remote dental system, the intra-oral camera (Dental Eye\(^8\)), allowing attending physicians at the Antarctic location to examine members with the aid of dentists situated elsewhere. This technology has already been used in three situations: a debonded inlay, dental fracture and a periodontal draining sinus/fistula. The Dental Eye has also been used to perform routine examinations, record the gingival PMA index, tongue
coating etc., and to send this information to TMDU every three months. Our team can then provide relevant advice. Further tests to assess risk for oral disease include bacterial counts, perioscreen and more recently a salivary multi-test system which detects cariogenic bacteria, blood leukocytes and proteins and the oral presence of ammonia.

Conclusion

We hope the small steps we have taken in the development of remote dentistry will lead to giant leaps in oral and general health care provision in enclosed or isolated environments such as space and the Antarctic. Our oral health program of instruction and remote assessment may also help in other areas such as disaster medicine in times of natural disaster.

References

5) Lyndon B. Space Medicine Exploration Medical Condition List, NASA JSC-65722, Johnson Space Center 2012.