Occurrences of dental/oral diseases have been reported in the space environment and pre- or post-spaceflight and the deteriorations of oral defensive functions are evident in the space environment simulated experiments. NASA has identified 6 dental problems (Abscess, Avulsion/Tooth Loss, Caries, Crown Replacement, Exposed Pulp/Pulpitis and Filling Replacement) as the most important dental incidents to be dealt with in the long-term mission. To focus on the dental/oral health management for astronauts, dental examination and dental orthopantomogram are conducted as dental diagnosis. In addition, dental nerve block, dental prosthesis replacement and dental pain control are described in the treatment manual on the International Space Station (ISS). However, the systematic program to evaluate the risk of dental/oral problems in spacecraft and the manual to prevent the dental/oral problems in the space environment are still far from sufficient. To promote the dental/oral health of astronauts, the authors are going to launch “Space Oral Health Promotion (SOHP) project” which will tackle the research tasks and the operational countermeasures in space dentistry.

Key Words: Dentistry, Oral Hygiene, Oral Health

1. Introduction

There are several reports about the dental/oral diseases of astronauts during spaceflight. A Russian cosmonaut was reported to have suffered incapacitating dental pain during the last 2 weeks of his 96-day flight 1). Dental/oral symptoms such as caries, acute periodontitis and dental pulpitis can seriously affect on the performance of astronauts. Once the symptoms of the dental/oral problems occurred, it is hard for astronauts to concentrate on his/her tasks and to make a daily living on the ISS. To focus on the medical operation for astronauts in spacecrafts, NASA has identified 6 dental problems such as “Abscess”, “Avulsion/Tooth Loss”, “Caries”, “Crown Replacement”, “Exposed Pulp/Pulpitis” and “Filling Replacement” in Design Reference Missions (DRMs), the proposed future missions for lunar and Mars explorations 2).

However, the present condition to manage the dental/oral health of astronauts is far from sufficient and development of a process which allows appropriate diagnosis, treatment and prevention of the dental/oral diseases in astronauts is urgently needed.

To take appropriate countermeasures of “diagnosis”, “treatment” and “prevention” of the dental/oral problems during spaceflight, it would be highly valuable to review and summarize the possible dental/oral problems in astronauts and the countermeasures against them.

In this paper, the possible dental/oral problems in the space environment and the current dental management of astronauts by NASA are described and the countermeasures will be discussed.

2. Oral Symptom

2.1. Space environment

A Russian cosmonaut was reported to have suffered incapacitating dental pain during the last 2 weeks of his 96-day flight on Salut6 in 1978 1). A crown displacement in-flight occurred on the Space Station MIR from 1995 to 1998. Totally, dental events comprised 1% of the medical events in spaceflight on the Space Station MIR 3). In addition, Lee et. al. has reported the increase of dental plaque and dental calculus, and aggravation of gingivitis in Skylab Oral Health Studies conducted in 1974 4).

It was reported that an astronaut suffered from pulpitis within 90 days before his launch and the another at post-flight. Displacements of crown and tooth fractures were also reported 3).

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 6 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 5). These 6 dental problems are listed also in the Space Medicine Exploration Medical Condition List (SMEMCL) 6).
of motivation during the project\(^7\).

Rai et al. have reported the deterioration of periodontal status, the decrease of salivary flow and the aggravation of stress markers (Cortisol, C\(_g\)A and amylase) in saliva, within HDT bed rest study for 6 weeks\(^8,9\). The results of these reports strongly suggest that the deterioration of oral defensive functions occurs in the simulated space environments\(^11\).

Thus, it is possible that the dental/oral problems get worse in the space environment. Moreover, some of the dental/oral symptoms have not been investigated both in the space environment and in the simulated space environments, although they are expected to occur in spaceflight. For the longer period staying in the space environment in the future, further investigations of the dental/oral symptoms are to be conducted, such as the amount of jawbone, oral malodor, the state of occlusion, and taste sensation. Investigations of the amount and the properties of saliva of astronauts especially during the early phase of spaceflight are also highly valuable, since the deterioration of conditions of saliva is a negative impact factor to induce caries and periodontal disease aggravation.

### 3. Diagnosis

Dental check on astronauts is conducted both in the annual medical examination and the medical certification for spaceflight\(^2\). In the astronaut medical certification for spaceflight, dental examination and dental orthopantomogram are conducted to make clear the potential dental/oral problems in the astronauts before their flight.

In the dental examination, baseline measurements (brief dental history, unusual oral symptoms, periodontal evaluation, oral cancer screening exam, odontal evaluation) are conducted to generally assess the dental/oral health conditions of the astronauts and to confirm their readiness for flight. The medical certification for spaceflight are conducted 30-90 days before the launch and his/her dental health risks will be identified and mitigated if necessary\(^12\).

A dental orthopantomogram is a panoramic x-ray scanning of the maxilla and mandible. A full dental orthopantomogram of the astronaut is taken 18-21 months before his/her launch to assess the dental/oral health conditions of the astronauts in order to deal with any potential problems.

As described above, dental/oral health conditions of astronauts are carefully accessed before mission launch, however, there are no systematic programs to evaluate the risk of dental/oral problems, to diagnose and treat the dental/oral diseases in spacecraft. When we consider the dental/oral health management of astronauts during the prolonged spaceflight in the coming near future, the tailor-made dentistry for each astronaut should be developed and incorporated within the health management program in the mission.

Properties of saliva are good markers of dental/oral diseases, so that practical salivary kits are highly useful to evaluate the risks of dental/oral diseases of the astronauts. In addition, construction of the remote diagnostic system would be useful for regular oral health examination of astronauts in spacecraft. The photographs of the oral cavity of astronaut would be taken with an oral camera and transferred to the control room in the ground in future.

### 4. Treatment

Emergency dental treatment in spacecraft is currently targeting the 6 dental problems described in “chapter 2, Oral symptom”. The Dental Pack on the ISS CHECS Hardware Catalog is the medical manual for astronauts in space environment and is composed of handling of “Mouth anatomy”, “Mouth Exam”, “Nerve Block”, “Temporary Dental Filling”, “Dental Crown Replacement”, “Exposed dental Pulp”, “Loss of tooth” and “Tooth Pain"\(^13\).

“Mouth anatomy” is aimed to demonstrate the anatomy of mouth and teeth containing some pictures to help dental/oral treatment by astronaut. “Mouth exam” is designed to perform an examination of the mouth and teeth with a digital camera. “Nerve block” provides the technique to place a nerve block with lidocaine injection prior to dental treatment procedures. “Temporary Dental Filling” and “Dental Crown Replacement” describe the techniques to repair dental filling and to replace dental crowns on the ISS. “Exposed dental Pulp” describes the technique to treat the fractured tooth with exposed pulp with medicine (analgescics and antibiotic) and eugenol. “Loss of tooth” contains instructions to stop bleeding with gauze and to control pain with medicine. “Tooth pain” contains instructions to use of the medicines (analgescics and antibiotic).

The dental treatment technology/protocols in space environment are urgently expected to be developed and must be adapted to the restrictions to use water, and sharpen instruments in spacecraft. The protocols must be operated without difficulties. It is noteworthy that body fixation of the patient astronaut and the dentist astronaut in treatment room of spacecraft should be conducted, since precise control of astronaut movements is more difficult than on the ground.

### 5. Prevention

As described in “chapter 2, Oral symptom”, prevention of oral disease in the space environment is most important. Caries and periodontal disease in space flight are mainly caused by the poor oral hygiene. The manuals for astronaut practices in the space environment are prerequisite for the appropriate oral hygiene in spacecraft. However, such a manual has not been developed as yet.

Currently, tooth brushing is the only practical prophylaxis of dental/oral diseases of astronauts on the ISS. The authors propose to introduce the use of dental-cleaning tools, such as interdental brush, dental floss or fluoride application for more effective prevention on the ISS. Furthermore, improvement and optimization of the oral self-defense functions (salivary functions, tongue movement, etc.) would be highly effective to prevent oral diseases, such as xerostomia, in the space environment. The programs to improve oral functions of astronauts and chewing dental gum would be also effective to promote the oral self-defense functions of astronauts, especially in the long period spaceflight expected in the near future.
6. Conclusion and Perspectives

Several symptoms of dental/oral problems occur on astronauts in the space environment to date and the current countermeasure is only the dental examination before mission launch and treatment manual for some dental emergency in spacecraft. To deal with the possible dental/oral problems in future long-term stay in space, revising of the systems of “diagnosis”, “treatment”, and “prevention” of dental/oral problems for astronauts should be requested. For example, examination of salivary conditions and programs promoting oral hygiene of astronauts in spacecraft are to be urgently prepared for the prolonged spaceflight for lunar and Mars exploration.

For the purpose of the astronaut's oral health promotion, the authors are going to launch “Space Oral Health Promotion (SOHP) project” which tackles the urgent research tasks and the operational countermeasures in space dentistry. In SOHP project, the dental department of Tokyo Medical and Dental University and the research and the health management teams of JAXA cooperate to develop the countermeasures against the current and the possible dental/oral problems in the future long-term space flight (Table 1).

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<th>Problems</th>
<th>Countermeasures</th>
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| **Space Medical Basic Research** | - Investigations of caries and periodontal disease have not been conducted after the SKYLAB studies.  
- Oral malodor, occlusion, salivary functions have not been studied.  
- Promotion of investigations with more detailed approach and wider area.  
- Studies in the simulated space environment experiences (Bed rest studies, isolation experiments, Antarctic expeditions, etc). |
| **Diagnosis** | - Practical diagnosis protocols and kits have not been developed.  
- Dental/oral diagnosis and risk assessment cannot be performed in spacecraft.  
- Determination of inspection items and development of practical diagnosis protocol/kits.  
- Operation of the dental diagnosis protocols/kits in spaceflight and development of dental telediagnosis system. |
| **Health Management** | - Protocols and instruments are insufficient in spacecraft.  
- Development of the dental/oral treatment protocols/manuals and suitable instruments for use in spacecrafts. |
| **Treatment** | - Dental/oral disease prevention manuals are not established.  
- Prevention methods other than tooth brushing are not provided for the space environment.  
- Development of a practical manual for astronauts for use in the space environment.  
- Development of the effective tools (toothpaste, gel, dental guns, etc) and introduction of oral function promotion programs. |
| **Prevention** | |