Dental Considerations for Manned Missions to the Moon and Mars

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Abstract

Dental emergencies for long term space missions are not commonly considered for space missions. The health of the oral cavity in critical in the well-being of individuals in space. Human physiology is not well adapted to the harsh and isolated environment of space. Earth-based simulation of space have shown there to be many implications in these extreme conditions. The microgravity in space and the variation in barometric pressure may lead to xerostomia and barodontalgia, respectively. Other key issues include weight of dental equipment and hygiene kits, radiation, oral microbiota and immune response, skeletomuscular loss, and dental technology.

History of Space Dentistry

Aerospace-derived dental emergencies date back to the Space Race in the 1950s that marked the development of guidelines and protocols to ensure the health of individuals in space. Various dental issues arose amidst the harsh space environment including crown displacements caries, abscesses, and periodontal diseases.

Figure 1 NASAdent, an ingestible toothpaste developed in the 1960s.

Current Long Term Analogues

Simulations of the harsh and extreme conditions of space have been used to prepare astronauts, as well as to research those effects of such conditions on human physiology. It is found that opportunistic pathogens are more proliferative and complying to a routine oral hygiene routine was lacking. Furthermore, salivary function is decreased and stress markers are altered, both leading to a lower immune defense mechanisms.

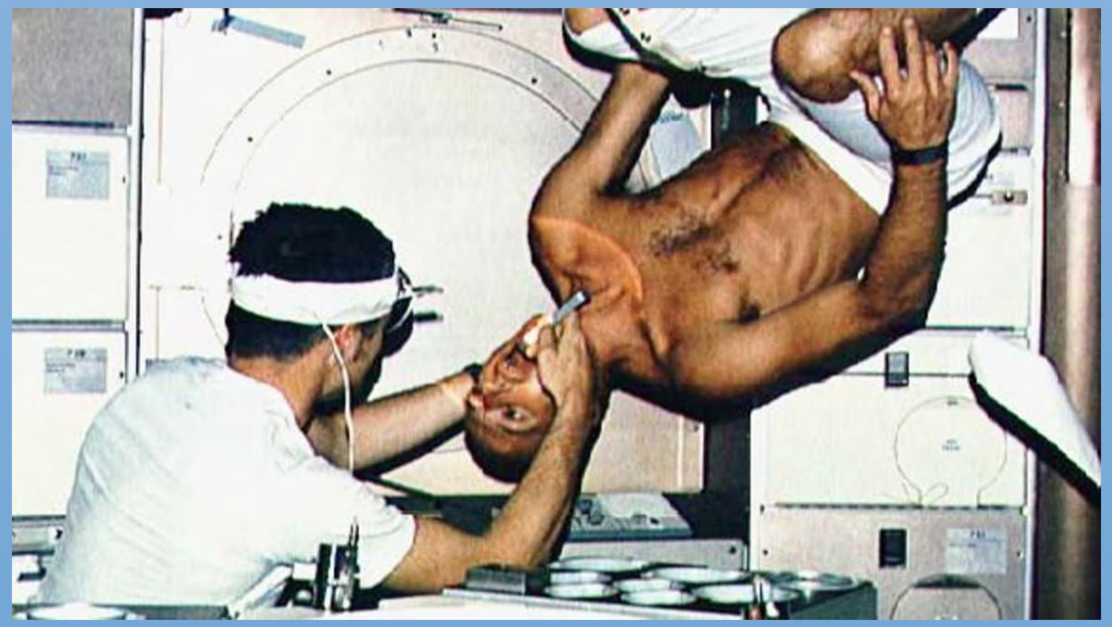

Figure 2 Dental exam performed by a crew medical officer in space

Xerostomia

Microgravity in space leads to water typically kept in legs flowing to the core of the body, triggering more release from kidneys. This can lead to xerostomia and increased chance of salivary duct stones. Due to the low salivary flow rate, there is a higher risk of caries and periodontal disease. Dryness of the mouth can also be attributed to breathing dry compressed gases.

Barodontalgia

Barodontalgia is a toothache caused by a variation in barometric pressure. It is due to the trapping of gases in a closed chamber such as in a leaky filling. Pain is sharp and can be related to periapical disease. Many of the cements used in crowns, such as glass ionomer or zinc phosphate, can be broken down. The air trapped in micropores expands and contracts as the pressure changes.

Weight

To take cargo to Mars, it has been estimated to cost roughly $45,000 per kilogram. This leads to extensive constraints on the items that can be brought related to dentistry. The ideal equipment has many other uses than simply dentistry, such as a 3D printer or milling machine.

Radiation

In outer space, there is no protection from Earth's Van Allen belts. Humans are at the mercy of radiation from various sources such as the sun and galactic cosmic rays. This significantly increases the astronaut's chances for a variety of abnormalities such as damage to the salivary and thyroid glands, as well as oral cancer.

Oral Microbiota and Immune Response

An environment of microgravity can impact an astronaut's ability to fight infection. Microgravity affects the virulence and growth of pathogens. The immune system undergoes impaired wound healing, altered cytokine production patterns, decreased T cell signaling, impaired leukocyte production and inhibited natural killer cell activity.

Figure 3 NASA/Mir-23 researcher Jerry Linenger brushes his teeth in the Spektr module. Note the floating Crest toothpaste. (NASA)

Skeletomuscular Loss

Short term studies of humans have shown an increase in mass of the non-weight bearing bones such as the mandible and bones of the calvaria. However, longer term studies of mice in microgravity have shown significant decreases in mandibular bone volume fraction compared to mice that stayed on the ground.

Technology

Using current technology such as 3D scanners, scans of the teeth and soft tissue can be transmitted to Earth. A dental technician on Earth can modify the splint, crown or prosthesis to the current needs and transmit the information to a 3D or milling machine on the spaceship. Medical robots can be controlled by doctors on the ground and assist with medical and dental procedures in space.

Kit

Currently, astronauts have toothbrushes and dry toothpaste in their hygiene kit. Additional tools such as interdental brushes, floss, or fluoride applicators should increase hygienic conditions. Each crewmember should use an occlusal splint during launch and re-entry to reduce damage to restorations.

Figure 4 & 5 - Medical and PPE kits provided on the ISS

Further Studies

There still are many questions involving the oral cavity in space such as oral microbiota, malodor in different environments, effects of weightlessness on occlusion, and how taste is altered in space.

Conclusion

With technology furthering the capability of humans to explore space for longer longevities, dental considerations become an even bigger priority in the success of space missions. The effects of space may lead to alterations in salivary function, barometric pressure, human weight and bone density, radiation dosage, oral microbiota, and immune response. 3D printing technology and autonomous medical equipment has helped paved initial steps to protocols to counteract dental issues that may arise, but further studies need to be made as there are more uncertainties that remain.