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Aerospace Dentistry: Exploring an Innovative Frontier in Oral Health and its Relevance as an Emerging Speciality

Heinrich Jhased Morales Tecsi[1]*, Giovanna Gutiérrez-Gayoso[2], Annushka Malpartida-Caviedes[3]

Summary

The aim of the study is to expose the need to implement a new speciality within Stomatology, such as "aerospace dentistry," for which an exhaustive search was carried out of existing bibliographical sources in the literature since 1949. Under equations with the use of Bolen terms, which were selected under specific criteria of inclusion and exclusion, the document exposes the various situations of dental emergencies experienced in many missions carried out by NASA. This study shows, as a result, alterations produced in the stomatognathic system and their repercussion on the different dental treatments due to the variation in atmospheric pressure experienced by the crews on space flights. It concludes that there is a need for an aerospace dentist to adequately prepare the stomatognathic conditions for those chosen on a mission, to intervene in dental emergencies directly or indirectly, to study the variations and adaptations of dental materials, to investigate in depth the changes coming from the response of the stomatognathic system and to propose alternatives of prevention, intervention and solution of the problems in another atmospheric plane.

Keywords: *Aerodontalgia; barodontalgia space dentistry; NASA; aerospace medicine; barodontalgia. Dental specialty.*

Introduction

A little considered discipline emerges in the unexplored vastness of space, where weightlessness challenges conventional notions of health care, aerospace dentistry, this new frontier shows a unique panorama of dental challenges that claims its own section of specialised knowledge beyond terrestrial limits, reasons why it deserves prominent recognition as a pioneering and essential speciality.

To understand this innovative field, the question arises: what exactly is aerospace dentistry? First, we must emphasise the fundamentals of aerospace medicine and aviation dentistry, differentiating them from the term "aeronautics", a medical branch of medicine that provides health care on flights, whether sporting, military or commercial. Aerospace dentistry is now conceived of as a speciality committed to safeguarding, preserving and promoting the oral and dental health of those individuals involved in space missions, as well as that of non-mission-

[1] Universidad Andina del Cusco. School of Stomatology. Cusco, Peru
Orcid Id: https://orcid.org/0000-0002-9237-7838, Email: 019201497k@uandina.edu.pe
[2] Universidad Andina del Cusco. School of Stomatology. Cusco, Peru
Orcid Id: https://orcid.org/0000-0002-2007-0407 Email: ggutierrezg@uandina.edu.pe
[3] Universidad Andina del Cusco. School of Stomatology. Cusco, Peru
ORCID Id: https://orcid.org/0000-0003-1940-3195, Email: amalpartida@uandina.edu.pe
*Author for correspondence. Email: ggutierrezg@uandina.edu.pe

specific travellers participating in these space flights. Ensuring quality and productivity during these missions. In addition to studying the effects of flight through the atmosphere and the impacts of space on the human oral cavity. [1-5]

Taking these essential aspects into account, the oral health risks associated with space travel are assessed. Starting from the effects of microgravity, which during space missions has a significant impact on the oral cavity, triggering events such as bone demineralisation, developing the likelihood of periodontal diseases, caries and fractures as evidenced by Wolffe law, which predicts a loss of bone mass of 1-2% per month and the well established relationship between spaceflight and osteoporosis, are relevant aspects that highlight the importance of effectively addressing these problems during manned space missions, thus supporting the active presence of a dentist, in this context the task goes beyond prevention and extends to assessing, understanding and safeguarding changes in the oral health of crew members, which is crucial as conditions such as periodontitis, caries or fractures could compromise the success of a space mission. [6]

NASA has recorded some rare cases of dental emergencies during spaceflight, a notable example being the displacement of a dental crown during a spaceflight, where the astronaut provided a temporary solution using supplies available on board. This incident justifies the importance of conducting an assessment of the effects caused by the incorrect placement of a crown during flight, as it could affect an astronaut's ability to concentrate. In addition, cosmonauts have reported losing fillings and crowns during flights, attributing these effects to the vibrations experienced during launch. In 1978, a Russian cosmonaut suffered disabling dental pain during the last two weeks of a 96-day flight aboard the Salut 6 spacecraft. It is notable that this mission made no mention of a contingency plan, which would undoubtedly have a positive impact on his ability to carry out his activities regularly, as well as a case of caries treatment on the MIR space station, where a temporary filling was used to treat caries, and a case of pulpitis on pre-Apollo flights: one in the 90 days before launch and one after the flight. [7,8]

Finally, it is important to note that astronauts are exposed to hazards caused by changes in atmospheric pressure, as evidence shows, causing various disorders, such as tooth pain known as barodontalgia, a condition first diagnosed in aircrew members during World War II, The pressure variations that occur during flights and dives can cause pain in the dental area, and in more severe cases could evolve into acute dental pulpitis that could even incapacitate the affected person. [9]

Although it is possible to prevent these situations through thorough pre-flight examinations and preventive measures during crew training, it is relevant to note that as the duration of space flight lengthens, the probability of facing dental emergencies during these missions also increases. Additionally, the mass and velocity of moving objects can cause impacts resulting in cracked teeth, inflammation, dental pulp infections, temporomandibular disorders, periodontal abscesses and dental caries, due to the microgravity environment in which space crew members work. [10]

Literature Review

During the early years of aviation, in 1923, the first observations on aeronautical dentistry were made, however, with the advent of subsonic flight during World War II, research in this area intensified, with evidence of a significant increase in emergency dental visits by aircrew

members during this period, especially as aircraft began to fly at altitudes above 25,000 feet. This context marked a crucial milestone in the history of aviation dentistry. [11,12]

Historical Overview of the Emergencies Encountered in Different Aerospace Missions

1941 - 1944: Spanish pilots of the Blue Squadron, who were sent to the Russian front, were the first to report a dental problem characterised by a brief pain that could disappear on return to the ground. Thus the term "aerodontalgia" was born. [11]
1945: A dental research post is established at the Army Aviation Medical School at Randolph Field, Texas, USA. [12]
1950: As part of the Air Force Dental Service, pilots receive comprehensive dental care. [12]
1957: The General Office develops the original guidelines for dentistry in space medicine (Air Force Handbook 160-13). [12]
1960: Start of astronautical dental training programme. [12]
1966: To maintain the oral health of astronauts, the Air Force assigns dental officer Major William Frome to work full-time at the National Aeronautics and Space Administration (NASA) in Houston. [12]
1967: An emergency dental kit for use on space missions called SAM-TR-67-53 was developed. [13]
1970: The term barodontalgia is introduced to refer to the phenomenon previously known as aerodontalgia. [12]
• 1970: Colonel William Frome continues to serve at NASA during the Skylab programme.[12]
1978: A Russian cosmonaut's dental pain is recorded lasting two weeks, becoming the first dental incident in space, according to a record published by NASA. [7]
1980: NASA appointed Colonel Johan Young of the University of Texas at San Antonio as a medical operations consultant to work on dental instruments and guidelines for preventive and emergency procedures in zero-gravity environments. [12]
1991: NASA performs dental equipment test during zero gravity flight [14]
2000: The Space Medicine Committee of the Institute of Medicine of the National Academy of Sciences discusses how to maintain astronauts' oral health on long missions. [12]
2007: Dr. Balwant Rai introduces the term aeronautical dentistry. [12]
2009: Dr Balwant Rai is the first dentist to be appointed Health and Safety Officer of the Mars Desert Research Station. [12]
2009: Dr. Balwant Rai and Jasdeep Kaur conduct the first study on the effect of simulated microgravity on the oral cavity. [12]
2010: Dr. Balwant Rai offers the first course in aeronautical dentistry at Kepler Space University. [12]
2011: NASA proposes an Astronaut Medical and Dental Observation Care and Study Programme. [13]
2012: Dong Haibo and colleagues conduct studies on human dental pulp stem cell microfilaments change in a simulated microgravity environment. [14]
2014: Takashi ZAITSU, Toshiko OHTA et al. highlight the importance and necessity of space dentistry in their article published in The Japan Society for Aeronautical and Space Sciences. [15]
2023: NASA is developing portable emergency dental care that treats cavities and performs dental repairs without drilling, using focused microwave energy to modulate acid-producing bacteria in situ. [16]
2023: Morales H. et al. define the term "Space Dentistry" separately from the term "Aeronautical Dentistry" and publish an article promoting space dentistry, as well as proposing a new curriculum for this science. [16]

Increased Spaceflight

Over more than six decades, space exploration has undergone a remarkable transformation, characterised by a significant growth in spaceflight and the expansion of cosmic activity. This development began in 1961 with Yuri Gagarin, the first human to orbit the Earth, followed by the historic-manned flight of the US "Project Mercury". Since

then, the United States and Russia have led space exploration, marking milestones such as the missions to the Moon between 1968 and 1972, and the construction of the International Space Station (ISS). [17]

NASA, as a leader in this quest, has continued to drive scientific and technological advances over more than four decades. Collaboration with the private sector, such as SpaceX, Orbital, ATK and Sierra Nevada Corporation, has led to the rise of industry in low-Earth orbit, evidencing the increase in space activity. [18]

The construction and continued occupation of the ISS since 2000 underscores its crucial role as an epicentre of global collaboration and scientific progress. NASA, with its vision of sustainable human expansion in the solar system, is preparing to return to the Moon in 2024, establishing a more enduring presence with the development of the Space Launch System, the Orion spacecraft and the Gateway Lunar Module. [19]

The Artemis programme, unveiled in 2017, reflects NASA's continued ambition, planning a return to the Moon in 2024. With key milestones such as Artemis 1, Artemis 2 and Artemis 3, this project underlines the drive towards further space exploration and activity. [20]

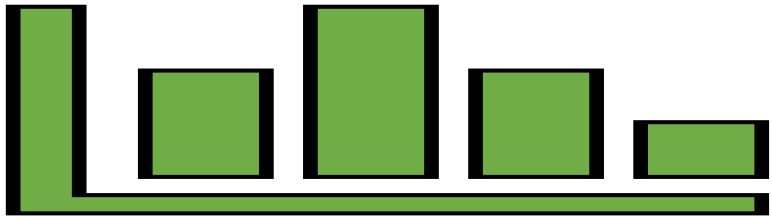
Technological advancement is paving the way for future missions, such as the planned mission to Mars in 2030. Even beyond that, NASA is actively working on crucial capabilities to send humans to an asteroid by 2025, cementing an ongoing commitment to expanding cosmic exploration. [21,22]

In an exciting future, spaceflight is projected to increase dramatically, with the planned transport of crew and cargo to Earth orbit, the Moon, Mars and beyond. The Starship spacecraft, among other vehicles, will play a prominent role in this cosmic expansion, marking a new era in space exploration. [23]

Virgin Galactic has burst onto the scene with commercial spaceflight, as evidenced by the successful private flight (Galactic 02) in August 2023, this event not only marked historic milestones as the first mother and daughter duo to go into space, but also highlighted the growing importance of commercial spaceflight in today's cosmic narrative. [24]

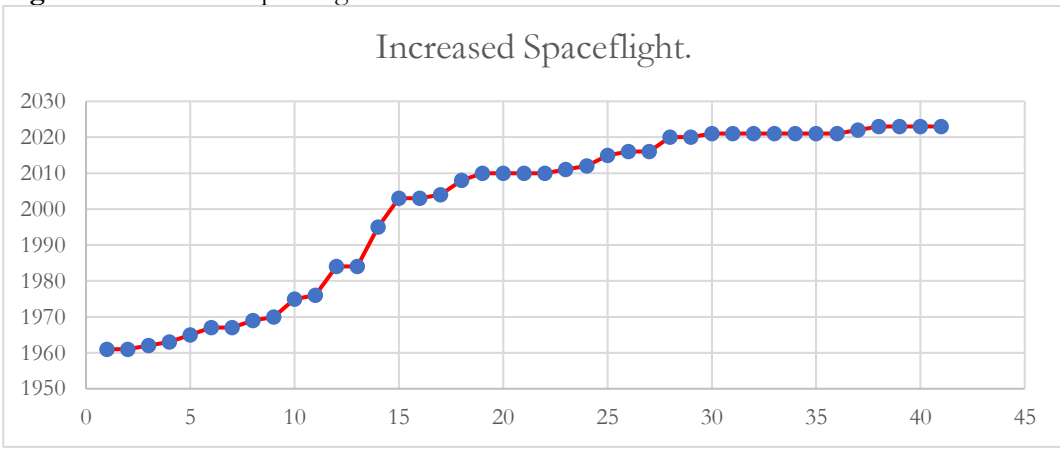
It is important not only to pay attention to the missions planned for the future, but also to analyse the space missions already carried out, which revealed their importance to support this statement, an exhaustive table was elaborated by consulting various bibliographic sources (Table 1). https://docs.google.com/spreadsheets/d/141ndBQYCLi3TuaU7TNOhCCAIaYjK-uUDfTqcj6pUIRU/edit?usp=sharing showing the annual growth of spaceflight (Fig. 1), this analysis provides an opportunity to develop medical specialities and advances in health sciences adapted to the evolution of space exploration, highlighting the importance of space dentistry and adaptability in our medical practices. 1), this analysis provides the opportunity to develop medical specialities and advances in health sciences adapted to the evolution of space exploration, highlighting the importance of space dentistry and adaptability in our medical and scientific practices, which is essential to capitalise on these opportunities and move towards a future where health in space environments is a solidly grounded priority and an emerging speciality.

Table 1: Data Collection Table.



Source: Own Elaboration.

Figure 1: Increase in spaceflight from 1960 to 2024.



Source: Own Elaboration.

The data collected consistently indicates a significant increase in the number of space flights performed annually, and when examining data from various sources, an upward trend can be seen, supporting a steady growth each year. [25-28]

It is worth mentioning that there is limited information in the literature on the subject, demonstrating the need to delve more deeply into this study, with the aim of giving rise to the emergence of a new speciality that is applied in a specific way, enhancing the fulfilment of the missions entrusted to it.

Importance of Implementing the Speciality of Space Dentistry

NASA applies strict dental standards for astronauts, with examinations six months before the flight and treatments performed three months before, minimising problems during the space mission and underlining the importance of space dentistry. (29)

However, microgravity in space missions presents significant oral health challenges, especially when these missions extend into space, causing periodontitis, dental caries, bone loss, jaw fractures, pain and numbness, despite limited scientific evidence. (12)

The increase in spaceflight recently and future exploration missions to the Moon, Mars and beyond will mean an increase in dental emergencies, although crews operate in weightlessness, the impact forces generated by the mass and velocity of moving objects can cause disturbances already manifested, with the projection of human travel and colonisation of distant planets in the future, exploration mission crews must be versatile and well-trained in medical and dental

emergencies, Dental emergencies in space can evolve into real medical crises, as infections in this area could be severe, since veins in facial areas lack valves to prevent backflow into the cavernous sinus area of the brain. It is essential to continue research in space dentistry to provide effective and simplified care to crews, thus contributing to human survival in space. (10)

This analysis provides a unique context for exploring human physiology, offering new insights and a more profound understanding of complex processes within the oral cavity. This knowledge can be applied extensively in conventional laboratories, while technologies derived from the space programme improve everyday aspects of human life, and continued research in simulated microgravity environments, supported by the medical community, will open new cycles of discovery and innovation and the creation of new specialities in dentistry. (17)

Proposed Curriculum Guidelines for Aerospace Dentistry

The implementation of an innovative postgraduate curriculum in Aerospace dentistry is an imperative need in the context of increasing spaceflight and future missions to explore the Moon, Mars and beyond. This educational approach would not be limited to theory, but would encompass practical aspects and physical training, transforming dentists into integral and active professionals within space crews.

In this new paradigm, dentists would not simply be passive observers, but essential members of the missions, trained to deal proactively and efficiently with dental emergencies. The relevance of this programme lies in the need for experts who not only understand the complexities of dentistry in space, but are also physically and mentally prepared to deal with any eventuality.

Mission of the Speciality: To train dentists specialised in space dentistry, providing them with advanced theoretical knowledge, practical skills specific to the space environment and comprehensive physical preparation, transforming dental professionals into active and essential members of space crews.

Vision of the speciality: To be noted for academic excellence and decisive contribution to the well-being of space crews during exploration missions, becoming influential leaders in dentistry adapted to the space environment.

The Graduate Profile of the Future Specialist in Aerospace Dentistry

- ✓ Excellence: Pursue exceptional quality in education, research and clinical practice in space dentistry.
- ✓ Innovation: Encourage creativity and the adoption of cutting-edge approaches to address the unique challenges of oral care in space.
- ✓ Integration: Valuing holistic training, encompassing theoretical knowledge, practical skills and physical preparation.
- ✓ Collaboration: Fostering cooperation between professionals from various disciplines to achieve a significant impact on astronaut health.

Objectives of the Implementation of the Speciality

- ✓ Develop Advanced Competencies: To train dentists with advanced theoretical and practical skills specific to the space environment, ensuring optimal oral care during extended missions.
- ✓ Active Integration in Space Missions: To facilitate the active participation of space dentists

as essential crew members, contributing significantly to the physical and emotional well-being of astronauts.

- ✓ Research and Innovation: To foster ongoing research in space dentistry to advance scientific knowledge, develop new technologies and improve oral care practices in extraterrestrial environments.
- ✓ Multidisciplinary Collaboration: Establish strategic alliances with space, health and research institutions to enrich training and create a collaborative environment to drive progress in the field of space dentistry.
- ✓ Global Leadership: To graduate specialised dentists who will emerge as influential leaders in space-adapted dentistry, actively contributing to the advancement and expansion of human space exploration.

	Proposed outlines for the speciality: Aerospace Dentistry
Basic introductory course	1. Introduction 2. History of aerospace dentistry 3. Fundamentals of aerospace physics 4. Effect of the aviation environment on teeth and oral cavity 5. Infection control 6. Barodontalgia. 7. Physical conditioning for aerospace dentists 8. Use and handling of communication devices in space environments 9. Use and handling of cosmonaut equipment 10. Emergency procedures during space flight 11. Emergency treatment during or before travel 12. Prevention and promotion of oral health in space 13. Prevention of pain and bleeding 14. Dental emergencies and emergencies 15. Indication and contraindication for treatment 16. Medico-legal and forensic aspects 17. Post-test examination and final physical examination
Intermediate course with clinical practice	1. Introduction 2. Self-qualifying pre-test (Mandatory visit) 3. Fundamentals of aerospace physics (Short) 4. Infection control 5. Barodontalgia and its implications 6. Physical conditioning for aerospace dentists 7. Use and Handling of Communication Devices in Space Environments 8. Use and handling of cosmonaut equipment (simulators) 9. Emergency procedures during space flight 10. Use of emergency and safety equipment in aerospace dentistry 11. Prevention and promotion of oral health in space 12. Prevention or management of dental emergencies 13. Biosafety in dental treatment 14. Effect of the aerospace environment on teeth and oral cavity 15. Differences in aerospace processing modalities 16. Pain and bleeding: prevention and management of dental emergencies 17. Indication or contraindication for dental treatment on board and complications 18. Precautionary measures: during, after, before the journey
Advanced course	1. medico-legal and forensic aspects: dental record keeping, creation and maintenance of dental databases 2. Current research and development programmes, as well as reports of experiences, based on the problems encountered 3. Development of a research project (on any topic in aerospace dentistry) 4. Post-test evaluations: • Evaluation of clinical application • Clinical case studies • Post-written tests • Defence of research work

Source: Own Elaboration Based On *(30).*

Note: The Proposal is Based on What Was First Proposed by Rai Balwant, Adding Aspects That Are Indispensable for This New Emerging Speciality.

Discussion

In 2011, Balwant Rai and Jasdeep Kaur [12] , noted that microgravity leads to an increase in the prevalence of dental problems such as periodontitis, dental caries, bone loss, jaw fractures, dental pain and numbness, as well as the occurrence of salivary duct calculus and oral cancer, They also highlight that aerospace dentistry being an emerging field, requires further research on the effects of microgravity, coinciding with the perspective that cosmonauts face these risks without the specialised care needed to prevent or treat these conditions. For this reason, there is a crucial importance of implementing this new speciality to efficiently address the dental challenges associated with spaceflight.

The same author, in 2006, Balwant Rai [30] proposed tentative academic guidelines for the implementation of the speciality of aeronautical dentistry, this branch focuses on the application of dentistry in the aerospace field, considering specific indications and contraindications, evidencing the need for practical knowledge in basic, applied and clinical dental science in this area. Rai advocates the establishment of curricular standards and guidelines, proposing two educational levels: introductory courses for general information and advanced courses with a practical focus and clinical case studies. Highlighting in this analysis a projection that differs slightly by seeking to make the aerospace dentist an active participant in the crew, requiring additional skills to those proposed by Rai. Focusing more on aeronautical dentistry which, as mentioned at the beginning of the article, addresses different aspects of aerospace dentistry.

Conclusions

- The significant increase in spaceflight that has occurred recently is a sign of a steady advance towards a new era of space exploration with new destinations in the future, characterised by more ambitious and longer duration missions, which is why the specialised integration of a Dentist is required.
- The creation of specific curricular guidelines and standards for aerospace dentistry training is required to prepare professionals capable of addressing the unique challenges of oral health in space environments.
- Aerospace dentistry is crucial not only for its ability to address dental emergencies during spaceflight, but also for its contribution to the development of medical and scientific practices that adapt to the continuing evolution of space exploration.

Statement

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