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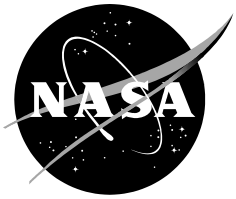

Dental Working Group Meeting Summary Report

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September 2012

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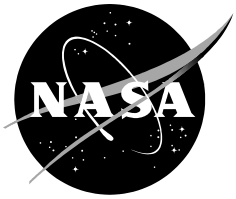

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TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

CAMBRA	Caries Management by Risk Assessment
CBCT	Conical Beam Computed Tomography
CMO	Crew Medical Officer
ExMC	Exploration Medical Capability
HRP	Human Research Program
IMM	Integrated Medical Model
ISS	International Space Station
JSC	Johnson Space Center
NASA	National Aeronautics and Space Administration
NSAIDS	nonsteroidal anti-inflammatory drugs
SMEMCL	Space Medicine Exploration Medical Condition List
UTMB	University of Texas Medical Branch

1. INTRODUCTION

1.1. Background

The Human Research Program (HRP) has assigned the Exploration Medical Capability (ExMC) Element the responsibility of addressing the risk associated with the "the inability to adequately recognize or treat an ill or injured crewmember." The dental working group meeting was held on March 23, 2012, to address this risk as it applies to dental risks. Specifically, the ExMC gap addressed by this document is *ExMC 4.11: Limited dental care capabilities*.

The Space Medicine Exploration Medical Condition List (SMEMCL) was created to define the set of medical conditions that are most likely to occur during a distinct mission profile, as the first step in addressing the aforementioned risk. According to the SMEMCL, the in-flight dental system shall address caries, crown replacement, filling replacement, pulpitis, abscess, and tooth avulsion and loss. Additional conditions of concern, as suggested by dental experts during a 2004 NASA dental summit, include acute necrotizing ulcerative gingivitis, temporomandibular joint dislocation or subluxation, temporomandibular disorder, oral laceration, facial fracture, cracked, split teeth or fractured cusps affecting enamel and dentin only, hygiene and periodontal issues, dental abscess, failing root canal, fractured, cracked, or split teeth affecting the pulp, trauma causing subluxation where the pulp could eventually die, and hidden caries under preexisting crown or filling (missed on radiograph because of crown obscuration).

The Integrated Medical Model (IMM) is a stochastic model that uses Monte Carlo methodology to simulate medical events and estimate the impact of these medical events for a given design reference mission, such as the consequence of losing a tooth at a Lunar Outpost. Outcomes that are calculated by IMM include Crew Health Index, probability of evacuation, and probability of loss of crew life.

Current data from the IMM estimate the following incidences (in events per person-year):

Condition	**Incidence**
Caries	0.39
Abscess	0.02
Exposed Pulp/Pulpitis	0.02
Avulsion/Tooth Loss	0.003
Crown Replacement	0.005
Filling Replacement	0.005

Cracked, split teeth, and fractured cusps and other conditions were not addressed. Models of near-Earth asteroid and Mars missions predict dental emergencies to be one of the top five conditions to impact mission objectives. Anecdotal observations by NASA flight surgeons have noted dental emergencies requiring root canal happening as close as 2 weeks before a launch. If such an emergency was missed on screening and occurred in flight, the likelihood of adversely affecting mission objectives is high.

1.2. Participants

The following is a list of Participants included local and external dentists, members of medical operations, the astronaut office, advanced projects, and the HRP.

Meeting Participants, External
Kyle Aaron, D.D.S. – Private Practice
Philip Bales, D.M.D. – Private Practice
Arthur Jeske, D.M.D., Ph.D. – University of Texas Dental Branch at Houston
Michael Hodapp, D.D.S. – Private Practice
Robert Harrington, D.M.D. – U.S. Army Special Forces
John Hatcher, D.D.S. – Private Practice

Meeting Participants, Internal
Dickey Arndt, Ph.D. – NASA Johnson Space Center (JSC)
Serena Aunon, M.D. – NASA JSC
Patricia Bahr – NASA JSC
Yael Barr, M.D. – University of Texas Medical Branch (UTMB)/Wyle
Peter Bauer, M.D. – NASA JSC
Kristina Barsten – Enterprise Advisory Services, Inc./Wyle
Duane Chin – Wyle
John Dusl – Jacobs
Melinda Hailey, R.N. – Wyle
Eric Kerstman, M.D. – UTMB/Wyle
Craig Kundrot, Ph.D. – NASA JSC
Kjell Lindgren, M.D. – NASA JSC
Tammie McGrath – NASA JSC
Shannon Melton – Wyle
Anil Menon, M.D. – UTMB/Wyle
Marguerite Sonier, Ph.D. – Universities Space Research Association
Sharmi Watkins, M.D. – UTMB/Wyle

Meeting Support
Holly Williams – JES Tech/Wyle

1.3. Plan

Given the longer duration and reduced possibility for evacuation during an exploration mission, a reassessment of dental evaluation and treatment was initiated. The goal of the dental working group meeting was to inform the dental operational concept for exploration missions. This document contains consensus statements and background information recorded during the meeting. The information in this document will be used in the development of the operational concept for dental care on exploration missions.

2. CONSENSUS STATEMENTS

2.1. Conditions

Objectives:

- *Define dental emergencies not considered by the SMEMCL that are likely to occur and manifest into mission impact consequences during an exploration mission using data from analogous populations and subject matter expert opinion.*

In regards to dental conditions, the SMEMCL contains caries, crown replacement, filling replacement, exposed pulp/pulpitis, abscess, and avulsion/tooth loss. The current list includes conditions most likely to occur based on predicted in-flight incidence or known ground-based incidence of the disease. It also prioritizes those conditions based on the ability to treat the disease and the consequence of not treating the disease. The SMEMCL is not a final list but, instead, an iterative process that can be updated annually. Risk modeling has determined that if the crewmembers develop the dental conditions described by the SMEMCL, then mission objectives are likely to be impacted. Additional conditions considered were tooth fracture, cracked or splitting of teeth, and fractures above the neck such as a mandibular fracture. Tooth fractures are expected to be more common than mandibular fractures or other fractures above the neck. In addition, there are alternative treatments, which make some conditions unnecessary to include and analyze further. For example, dry socket, though painful, can be treated with a combination of clove oil, ibuprofen, and acetaminophen until pain resolves in 1 week. Mandibular fractures can be stabilized with head wrapping until adequate healing takes place, since this can make food consumption more difficult. A fabricated temporomandibular splint that can double as a fixation device and has an anterior opening may be appropriate.

Consensus: Tooth fractures are captured by the SMEMCL under exposed pulp but may warrant a further delineation.

Consensus: Fractures such as mandibular or maxillary fractures are unlikely to occur in spaceflight but can be considered for the SMEMCL with further research into incidence.

2.2. Prevention

Objectives:

- *Define best practice for prevention of dental emergencies before exploration missions*
- *Define ground-based, routine, preventive care necessary for exploration missions*
- *Define daily and periodic dental care capabilities required in flight for exploration missions*

Longer duration missions without the possibility of evacuation drive dental planning towards more stringent prevention standards. Efforts to prevent dental emergencies can be focused on preflight screening, preflight prophylactic treatment, in-flight care, and routine examinations. Although current screening includes routine x-rays, examination, and annual prophylaxis at launch minus 90 days to 30 days, a longer mission duration increases the probability of a dental emergency and increases the time since last dental exam, which could be years on longer

missions. Class I exam status, which is required for current International Space Station (ISS) mission candidates, addresses expected dental health over a 1-year period only. There are three classes used to grade a dental exam where class I describes a patient with good oral health and a low likelihood of requiring dental care within 12 months. Class II might require minor treatment but no dental emergencies are expected within 12 months. And, class III has oral conditions that require treatment and are likely to result in emergencies within 12 months.

Increasing the standards and methods used for screening can help to identify dormant lesions such as cracked or splitting teeth underneath fillings that are greater than 1/3 the width of the coronal isthmus of the tooth, failing root canals or hidden abscesses. Newer technologies such as high definition (minimum 229 um) three-dimensional conical beam computed tomography (CBCT) are not currently in use. However, CBCT offers the ability to slice through sections of teeth with prior endodontic treatment to determine whether any canals or anomalies have been missed that potentially could lead to a future abscess. In addition, large amalgams, silicates, and composites that are greater than 1/3 the isthmus of a tooth are susceptible to fracture and hidden decay and should be considered for full coronal coverage restoration. Other tools exist to quantify the risk of dental decay including caries management by risk assessment (CAMBRA). CAMBRA uses multiple indicators to assess risk of caries such as frequency of radiographs, frequency of dental exams, saliva flow rate and buffering capacity, fluoride use, sealants, pH control, calcium supplements, and antibacterial adjuncts (www.ada.org/5157.aspx).

Consensus: Prevention should be the primary focus of exploration missions and include expanded screening efforts.

Consensus: Mouth guards that can double as a TM splint should be provided for all crewmembers to be worn at night to prevent tooth trauma.

Consensus: Large amalgams and concerning fillings should be removed and the tooth should be transilluminated and evaluated for cracks and decay, after which a buildup and full coronal coverage restoration should be placed. Cracked or splitting teeth should be pulp tested at a follow-up visit without local anesthetic to determine whether the pulp may be compromised.

Consensus: Ground-based dental examination should occur every 6 months for all astronauts.

Consensus: Screening technologies should be employed to reduce the chance of preflight and in-flight disease (e.g. probing, palpation, heat and cold testing, percussion testing, electric pulp testing, cone beam computed tomography) for teeth that have a questionable prognosis.

Consensus: In-flight preventive dental care should be expanded beyond twice daily brushing and once daily flossing to include an examination and cleaning every 6 months by the crew medical officers (CMOs).

Consensus: In-flight prevention can be supplemented by higher fluoride content in toothpaste such as Prevident 5000 or by fluoride varnish applied by the CMO.

2.3. Diagnosis

Objectives:

- *Define best practice for diagnosis of dental emergencies during exploration missions*
- *Define in-flight capabilities necessary for diagnosis*
- *Define adjunctive measures to assist in diagnosis such as telemedicine requirements*

Many dental tools are becoming increasingly more portable such as handheld x-ray devices (http://www.aribex.com/). In addition, the diagnosis of dental disease can be augmented by technologies likely to be manifested for an exploration mission such as ultrasound, video transmission, or electronic medical records. Ultrasound can detect an easily accessible abscess but would require a smaller probe to reach intraoral abscesses and, also, might be obscured by surrounding bone. Further evaluation of ultrasound capabilities might permit fracture diagnosis or apical abscess. An electronic medical record should provide pictures of previous dental exams for comparison. Preflight x-rays and ultrasound images of teeth would be an important part of dental records to inform decisions about tooth extractions where roots might complicate the process. Dental history, medical history, dental photos, and previous exam findings would also aid in diagnosis. A camera capable of an effective oral exam would help with ground-based telemedicine assistance and diagnosis.

Consensus: Ultrasound should be explored as an adjunct to dental diagnosis.

Consensus: Video-assisted examinations are critical to examination on dental exams.

Consensus: Electronic medical records should contain medical and dental history, dental photos, x-rays, and ultrasound images, as well past dental exams.

2.4. Treatment

Objectives:

- *Define best practice for treatment of dental emergencies during exploration missions*
- *Define changes in current practices and capabilities necessary for in-flight treatment of dental emergencies during an exploration mission*
- *Define likely avenues of research for developing treatment modalities to be used for exploration missions*

Much like diagnosis, treatment will be aided by telemedicine and ground-based guidance. Important techniques to master for exploration missions include tooth extractions, filling and crown replacement—in a more permanent fashion than currently exists—use of a dental hand piece after tooth repair or for improper seating of crown, and pain control. Novel techniques for tooth extraction might be particularly useful in exploration missions. One such technique for example is the O'gram method for single-root teeth. The O'gram recommends an initial gentle twisting motion to induce an inflammatory process within the periodontal ligament followed by a waiting period of 10 to 20 minutes to allow for tooth loosening before tooth extraction. In the case of a lost filling, crown, or fractured tooth—a likely outcome that could lead to significant pain and mission impact—a more permanent cement or restorative material will be needed than

current ISS materials permit. Current glass ionomer products can be applied without light curing and last several years. However, the majority of permanent repairs do not lead to immediate and proper seating of the teeth (ideal occlusion). To identify and correct improper seating, articulating paper is needed. Also, an electric dental drill that is capable of at least 25,000 revolutions per minute is needed. Such a drill can be handheld, portable, and use an alternative in-flight battery power source. Video assistance with the procedure would be possible if the telemedicine capability could transmit images of rear molars with adequate lighting during the procedure. Dedicated dental suction is not required to perform all emergency dental procedures. Drying of surgical or restorative treatment sites can be accomplished with compressed air from other sources in-flight, using a Venturi device. Additional tools could include a dental probe, scaler, condenser, burs such as #245 and #6 round, a 6856 .016 diamond bur, Wyman crown remover, and a good light source.

Consensus: A portable dental drill with more than 25,000 revolutions per minute capability is highly recommended for exploration missions.

Consensus: Exploration missions should provide the capability of fixing caries, crowns, and fillings with permanent cement that chemically adheres to teeth and does not require light fixation such as ChemFil Rock glass ionomer.

Consensus: Tooth extraction is an essential procedure for exploration missions.

Consensus: Video assistance is necessary for many dental procedures given the expected CMO training time allocated towards dental preparation.

Consensus: Redundant forceps are not necessary for long-duration missions if universal handle for alternate grasping ends of forceps is designed.

Consensus: Important tools for a dental kit include a dental probe, scaler, teeth cleaners (one to sterilize or one for each crewmember), Wyman crown remover, burs #245 6856 .016 diamond bur, and #6 round bur, forceps #151AS, #150, and elevator #12.

Consensus: Dental tools can be made with lightweight materials such as titanium, ceramic, and carbon fiber and with weight-saving holes drilled into them.

Pain control can be achieved with a dental block using tools similar to current ISS components. Articaine should be explored as a local anesthetic that is a more effective anesthetic when administered by simple infiltration, thereby reducing the need for more invasive block techniques. Acetaminophen and ibuprofen, alone or in combination, could substitute for longer-term pain control after the procedure. Tooth sensitivity due to loss of enamel or development of a cavity could be managed and be augmented with topical eugenol or fluoride. Two weeks of pain control should be sufficient.

Consensus: Dental pain can be treated with regional and local anesthesia for procedures.

Consensus: Articaine should be evaluated for non-dental procedures given its clear benefit in dental anesthesia.

Consensus: Long-term pain control can be managed with nonsteroidal anti-inflammatory drugs (NSAIDS), eugenol, clove oil, and fluoride.

Antibiotics need to cover a 1- to 2-week period at most. Penicillins are the drugs of choice. Azithromycin is also a well-tolerated antibiotic with sufficient spectrum for most intraoral infections. Other antibiotics of use are clindamycin, augmentin, amoxicillin, and amoxicillin with clavulanate, which can be used to treat abscess and cellulitis. A difficult to treat abscess can be controlled with a fistula if necessary. Ozone should also be followed as a novel treatment.

Consensus: Azithromycin should be an alternative medication for allergies or antibiotic failure and manifested to cover dental infections and should provide treatment for 2 weeks.

Consensus: First-line antibiotic choices should include augmentin, amoxicillin, or clindamycin.

2.5. Training

Objectives:

- *Define CMO training required for successful diagnosis and treatment given expected resources.*
- *Define preflight training and refresher requirements; define in-flight refresher specifications.*

Dental training for exploration missions can include ground-based training (e.g. field medical training given to newly selected astronauts or just-in-time training given during the training for an assigned mission), in-flight training through recorded procedures, and real-time training during a procedure through telemedicine guidance. Currently, field medical training includes one-half a day of dental training. This subset of dental training includes lectures, familiarization with common tools, and observation of dental procedures. Resources for telemedicine and stored medical procedures are under development. Just-in-time training is allocated 1 hour to teach local anesthesia, tooth extraction, and crown replacement on a plastic model.

A model training program designed for maximum field performance with minimal training hours is currently used by the US Army Special Forces Medical Sergeants (18D). Students at the Joint Special Operations Medical Training Center at Fort Bragg undergo similar limited initial dental training as well. Additional training is received in the field during overseas humanitarian assistance missions where extractions and fillings are performed. In 1 day of initial training for 18D, where patients are arranged to increase procedural exposure for the trainees, approximately 60 teeth are pulled after local anesthetic is given. Anesthesia experience includes local dental blocks. On the second day of this course, 10 to 15 fillings are placed using a portal dental drill and 60 dental emergencies are diagnosed.

Not only are dental procedures important to learn and practice, familiarity with dental terminology and anatomy will be beneficial for in-flight diagnosis and treatment. Important

concepts include an estimation of enamel depth, identifying dentin, identifying exposed pulp, determining the signs and symptoms of reversible and irreversible pulpitis, as well as pulpal necrosis, diagnosing periodontal disease and techniques for examination and treatment in microgravity.

Consensus: Ground-based training should be expanded to include 2 days of hands-on dental training in a high throughput environment such as demonstrated by special operations dental training.

Consensus: Ground-based procedural training should include actual tooth extractions, dental crown and filling replacement with the use of a dental drill to adjust the occlusal surface of teeth, and dental blocks (and include flight surgeon familiarity).

In-flight videos can be used to assist recall, examination, and procedures, thereby reducing ground-based training requirements. All dental procedures within the scope of existing resources would be important to include. Videos of procedures could serve as a just-in-time in-flight refresher and also provide diagnostic photos for examination. For example, http://www.toothiq.com/ provides dental tutorials through animations and videos. Videos can be used in-flight and also serve as a necessary preflight refresher and enhance familiarity with the material. Telemedicine and remote-assistance can serve as just-in-time training as well for dental examination, diagnostic aid, and preparation and training for procedures.

Consensus: An all-inclusive database of video procedures and dental findings should be integrated into training and serve as an in-flight repository for reference.

Consensus: Real-time telemedicine assistance for dental procedures can reduce ground-based training requirement.

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