DENTAL CARIES PROGRESSION AMONG U.S. MARINE CORPS PERSONNEL FOLLOWING OPERATIONAL DEPLOYMENT

by

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

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has been approved by the Examining Committee for the thesis requirement for the Master of Science degree in Oral Biology at the June 2012 graduation.

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ABSTRACT

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MASTER OF SCIENCE, COMPREHENSIVE DENTISTRY, 2012

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Introduction: Dental caries remains a major problem in the US military. Incipient lesions progress slowly, taking 3-4 years to progress from the enamel surface into dentin. For lesions in dentin, measurable radiographic progression occurs within 1-3 years. Although anecdotal evidence suggests that military personnel exhibit increased caries activity during operational deployments, no studies have specifically evaluated caries incidence or lesion progression among deployed personnel.

Objectives: To assess: (1) the overall incidence of new dental caries lesions, and (2) the frequency of caries progression among US Marine Corps personnel following operational deployment.

Methods: For this retrospective study, three standardized examiners analyzed dental record entries and serial bitewing radiographs of 280 USMC personnel who deployed to Afghanistan between February 2010 and January 2012. Baseline caries risk status was determined from the initial dental examination. Caries incidence and lesion progression during consecutive in-garrison and deployment periods were compared via Repeated Measures ANOVA.

Results: The mean in-garrison and deployment periods were 14 months. 53% of personnel developed new caries lesions during deployment. Of the pre-existing lesions, 64% progressed, 35.5% remained static, and 0.5% reversed during deployment. In-garrison, 52% of personnel developed new lesions. 54.5% of lesions progressed; 45.5% remained static. Mean caries incidence was significantly higher during deployment than in-garrison (2.91 vs. 2.38 lesions/patient) ($p=0.033$); significantly more lesions progressed during

deployment (1.86) than in-garrison (1.30) (p=0.005). Compared to those at low risk, high caries-risk personnel exhibited nearly threefold greater caries incidence and progression during deployment.

Conclusions: Caries experience increased during operational deployment, but primarily for personnel identified as high-risk. Approximal caries lesions in dentin progressed more quickly during deployment than previously reported; incipient (enamel) lesions progressed slowly during both in-garrison and deployed periods. Therefore, a risk-based approach that includes appropriate use of remineralization therapy, rather than aggressive restorative treatment, seems appropriate.

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CHAPTER 1: REVIEW OF LITERATURE

Dental Emergencies

Military dentistry has often focused its mission on preventing the occurrence of dental emergencies while in theatre. The loss of a member due to time spent in the dental chair while on deployment is a sacrifice towards mission objectives. Dental classification guidelines are used by dental officers of the U.S. armed forces to categorize the severity of oral disease in military personnel to prevent this sacrifice and ensure combat readiness. The classifications are based on the probability of experiencing a dental emergency within the next 12 months. Personnel identified as class 1 or 2 meet the criteria for readiness and are considered deployable and ready for operational assignment. Dental Class 1 (worldwide deployable) is assigned to patients having a current dental examination who require no dental treatment. Dental Class 2 (worldwide deployable) is assigned to patients who have a current dental examination and require only non-urgent dental treatment or re-evaluation. This would include asymptomatic caries lesions in the enamel or minimally into dentin [less than 0.5mm, radiographically, beyond the dentinoenamel junction (DEJ)], and/or lesions for which remineralization therapy, rather than restoration, is indicated. Dental Class 3 patients require urgent or emergent dental treatment for dental conditions that are symptomatic or are judged likely to result in a dental emergency within a 12-month period. Dental Class 4 patients require a dental

examination, or their dental status is unknown. Dental Class 3 and Class 4 patients are not considered worldwide deployable.[1]

While the goals of the Department of Defense Oral Health and Readiness Classification System are to standardize dental readiness, assess oral health, prioritize dental care, and, most importantly, to minimize the number of dental emergencies (DE), predicting which individuals will experience a DE remains problematic. In a 2003-2006 study of 906 Marine Corps personnel dental records, Simecek found that 64% of DE could not be prevented even if all urgent needs were completed in a timely manner. He defined DE as "any unscheduled dental attendance for which a chief complaint was noted in the progress notes."[2] He estimated a range of 77 to 92 dental emergencies per 1,000 personnel per year were non-preventable. Providers were only able to adequately classify, predict, and prevent urgent oral surgery-, endodontic-, and restorative-related emergencies 57, 51, and 45 percent of the time, respectively.

In 1981, Payne and Posey reported data from 360 dental emergency visits among 24,000 active duty Army personnel who participated in a simulated combat exercise for 39 days. Dental caries accounted for 38.6% of the total number of emergency visits, while periapical abscesses and defective restorations accounted for 10.3% and 3.3%, respectively. [3] Of the 360 dental emergency visits documented, caries and endodontic problems were attributed to 188 (52.2%) of the total. Teweles and King reported a total of 39 dental

emergencies, out of 602 troops, during a 6-month noncombat deployment to the Sinai Peninsula. Prior to this deployment, an intensive program was conducted to improve the dental health of deploying troops. Soldiers were examined and classified into one of three categories: Category A - no dental treatment needed (n = 247; 41%); Category B - needs routine dental treatment (n = 260; 43%); and Category PE - high potential for dental emergency within one year (n = 72; 12%). During the deployment, seven (18%) of the 39 dental emergencies occurred in group A, and 16 (41%) occurred in each of groups B and C. The authors reported that eight (20.5%) of the 39 dental emergencies were attributed to dental caries, five (12.7%) to periapical abscess, three (7.7%) to defective restorations, three (7.7%) to endodontic complication, and one (2.6%) to occlusal trauma. The total percentage due to caries and endodontic problems was 51.2% (n = 20). The remaining 48.8% (n = 19) of dental emergencies included: pericoronitis (n = 8; 20.5%), fractured teeth (n = 4; 10.2%), periodontal abscess (n = 3; 7.7%), and one case (2.6%) each of traumatic ulcer, sialadenitis, soft tissue laceration, and suture removal; the reasons for the remaining three emergencies were not reported.[4]

In 1993, Chisick and King reviewed seven studies that had been conducted on the epidemiology of oral, dental, and maxillofacial conditions during military deployments. They found that caries was the leading cause of dental emergenices.[5] In a more recent study, Dunn reported an emergency rate of 137 emergencies per 1,000 soldiers per year during a 6-month deployment to

Sultanate of Oman in support of Operation Enduring Freedom. Prior to this deployment, every effort was made to give deploying military personnel a dental examination to identify correctable conditions or disease before their arrival in theater (dental class 1 or 2). Most of the emergencies (34.8%) were due to dental caries, followed by pain from third molars (19.3%), and teeth requiring endodontic therapy (12.6%). Periodontal emergencies accounted for 9.6% of emergencies, and 7.4% of all emergencies could be attributed to teeth other than third molars that required extraction. The remaining six categories combined accounted for only 16.3% of all emergency visits.[6]

Although dental caries accounts for the majority of dental emergencies reported in many studies, it is important to note that, in general, the incidence of dental emergencies, both in garrison and in deployed settings, is low. Results from the dental emergency studies, from 1964 to present, show DE rates, as low as 65.8 (6.6%) and as high as 259 (25.9%) per 1000 troops per year.[7] Some authors have suggested that the lower rate may reflect pre-deployment efforts to provide necessary restorative or surgical care in order to prevent DE in personnel who are often without dental support while deployed.[7] However, the rate of DE has remained relatively unchanged since the 1960s, regardless of operational setting, and has not declined with either (1) the implementation of the Dental Classification System in the 1970s or (2) the increased emphasis on dental readiness during the 1980s through 2000s. In fact, implementation of a more stringent Dental Classification System in 2003 showed minimal improvement in predicting or reducing DE among U.S. Marine Corps personnel.[8] The literature

suggests that a certain baseline level between 77 and 92 DE (7.7% - 9.2%) per 1000 personnel per year appears to be constant and unavoidable.[8] Therefore, the prevention and treatment of dental disease to optimize oral health and minimize the potential for preventable DE have been, and continue to be, important factors in maintaining the combat readiness of our patient population.

Dental Caries Experience

Dental caries experience in the U.S. general population has been reported to be declining for the past three decades. Brown and Wall reported caries has decreased in all adult age groups from 18 to 45 years. Across the entire age range, total caries experience declined by 27% between the early 1970s and the early 1990s.[9] Similarly, using Australian Army recruits as a cross-sectional sample of society, Hopcraft and Morgan concluded that there had been a substantial decline in caries experience among Australian young adults (ages 17 to 35) over a very short time period. From 1996 to 2003, caries prevalence declined between 8 to 14%, and caries incidence declined between 22 to 32%, depending on age.[10]

The decline in caries prevalence during the last 30 years has been attributed to public water fluoridation and the nearly universal use of fluoride-containing products such as dentifrices, mouth rinses and topical gels applied in the dental office.[11, 12] A review of studies conducted during 1979 – 1989 found that a caries reduction between 8% to 37% among adolescents had resulted

from the fluoridation of public water supplies in many communities.[13] This decline, however, has not been distributed evenly across all population subgroups. Data from the National Health and Nutrition Examination Surveys (NHANES I, 1971 – 1974; NHANES III, 1988 – 1994; ongoing NHANES, 1999 - 2002) suggest that approximately 20% of U.S. children experience severe caries (decayed, missing, or filled teeth [DMFT] > 7), and among 5- to 17-year-olds, approximately 70% of total caries experience (DMFT) is concentrated in 30% of the population.14, 15 Moreover, there is evidence to suggest that, among at least some demographic groups, the decline in caries experience has slowed or stopped in recent years. Comparing data collected from NHANES 1988-1994 and 1999-2004, Dye and colleagues reported increased untreated caries experience among younger children, particularly among poor, non-Hispanic whites aged 6 to 8 years (8-22%) and poor, Mexican-Americans aged 9 to 11 years (38-55%).[16, 17] This increase in caries prevalence among children is alarming, since past caries experience has been shown to be the most significant predictor of future caries incidence.[18] A comparison of 11-12 year old children with > 1 DMFT and children with DMFT = 0-1 showed that children with DMFS > 1 had a significantly higher risk (2.5 times) of developing new enamel lesions during the subsequent 3 years than those than those with a DMFS = 0-1.[19] Although there has been a decline in overall caries experience, dental caries in adults continues to be a major problem. Beltran-Aguilar and colleagues noted approximately 91% of dentate adults aged 20 years and older had caries experience. Among those, 23% had untreated caries.[20]

In comparison to his earlier studies [10, 21] (conducted during 1996 and 2002-2003) which revealed a substantial decline in caries (22-32%), Hopcraft and colleagues found that caries experience increased 30% and 19%, respectively, among participants aged 17-20 years and 21-25 years between 2003 and 2008.[22] Furthermore, data from the Tri-Service Center for Oral Health Studies (TSCOHS) oral health surveys conducted in 1994, 2000, and 2008 revealed no decline in caries prevalence among incoming U.S. military recruits. In 1994, 79 percent of recruits had at least one untreated caries lesion, and 18.5 percent had seven or more lesions. In 2008, approximately 70 percent of recruits had at least one untreated caries lesion, and 18 percent of recruits had seven or more lesions.[23,24]

Rate of Caries Progression

Research suggests that progression of dental caries from the surface of the enamel into dentin is a relatively slow process. These studies[25, 26, 27] estimate that it takes approximately three to four years for a lesion to progress through enamel into dentin. Mejare and colleagues,[26] using annual bite-wing radiographs, examined 536 children at 11-13 years of age and continued up through 21-22 years of age. The authors assessed 2,012 proximal surfaces and concluded that 75% of enamel lesions had not reached the enamel-dentin border by 3.0-9.0 years (median value = 6.3 years). For lesions at the enamel-dentin border, the cumulative survival time before reaching into the outer half of the dentin ranged from 2.0 to 6.8 years (median value = 3.1 years). Hintze[27] also

assessed the prevalence and distribution of occlusal and approximal caries through radiographs. He initially examined 197 adolescents aged 14.5 years, and then re-examined them approximately three years later. Of the 2,794 occlusal surfaces assessed at both examinations, 93% remained unchanged, 1% developed new caries lesions, and 6% had been filled during the study period. Occlusal dentinal lesions found during the first examination, which remained unrestored during the study period, did not appear to have progressed. Of the 5,399 approximal surfaces, 86% remained unchanged, 9% developed caries, 2% showed caries progression, and 2.5% had been filled during the study period; only 22% of the approximal enamel lesions found during the first examination had progressed into the dentin during the study period.

Foster examined 62 caries lesions in adults (n= 65 adults; age range: 17-79 years) extending into dentin and found that the depth of an approximal dentin lesion was the main clinical marker to its progression. For lesions extending 0.5-1.0 mm beyond the dentin enamel junction (DEJ), 70% showed measurable radiographic progression within one year, and 92% showed progression within three years. In contrast, for more shallow lesions (< 0.5 mm into dentin), only 20% and 50% progressed within one year and three years, respectively.[28] Schwartz and colleagues analyzed changes in the depth of 1,584 unrestored incipient lesions in both the outer half and inner half of enamel, over time, in 342 patients; they concluded progression took 16 months through the outer half of the enamel and 27 months through the inner half.[29] Cook studied caries progression in approximal surfaces of premolars and molars among 95 dental students over a

period of three years. He found that 68 percent (n = 57) of the lesions confined to the enamel at the start of the observation were unchanged after 32 months.[30] Similarly, in a study of 307 subjects aged 12-14 years, Powell and colleagues reported that of the 555 proximal lesions detected at baseline, 51% were still in enamel after four years. The median time required for lesions to progress from outer enamel into the dentin was 38 months.[31]

Caries Risk Factors

Dental caries remains a major problem in the general population and especially in the military. Dental officers stationed at United States Marine Corps bases often report, anecdotally, of the deteriorating dental condition of Marines returning after deployment. Roberts-Thomson and Stewart[32] described risk indicators for dental caries in young adults to include: lack of lifetime exposure to water fluoridation, irregular toothbrushing at night, poor oral hygiene habits, socio-demographic indicators to include low socio-economic status, foreign-born mother, mother's education status, childhood socio-economic status, and poor general health behaviors including smoking and diet. Bartoloni and colleagues[33] examined annual data from 273,145 to 336,141 personnel dental records collected from the Air Force Dental Service (AFDS), Dental Population Health Metrics (DPHM) for the period October 2000 through September 2004. They concluded that higher percentages of people at high risk of developing caries were found in groups with younger age, lower rank, and less education. Higher risk was also identified in groups that included unmarried service members with

fewer years of service, users of tobacco, and non-flyers. Graves and Stamm[34] examined 14 studies of caries prevalence in young adult populations, and found that caries risk status was influenced heavily by the socioeconomic status (SES) of personnel before they enter the military service. SES had a strong influence on the tendency of populations to seek care, with increased SES inversely related to caries experience. Military personnel tend to possess many of these risk indicators, to include low childhood socio-economic status, low education of the mother, poor diet and lifestyle habits (smokeless tobacco, alcohol abuse, cigarettes). Further, stress and substandard living conditions experienced while in theatre place military personnel at increased risk for systemic disease and, undoubtedly, increase the caries risk for many individuals.

With military personnel possessing multiple risk factors for caries disease, then is it possible for these individuals to have a more accelerated rate of caries progression? If the possibility exists that caries progression is accelerated during deployment, then this should be addressed in the manner in which we classify and, ultimately, treat our military personnel. Although anecdotal evidence suggests that military personnel may exhibit increased caries experience during operational deployments, no studies have specifically evaluated caries incidence or rate of caries progression among deployed personnel. Therefore, the aims of this study were to assess (1) the overall incidence of new dental caries lesions and (2) the rate of incipient caries lesion progression among U.S. Marine Corps personnel following operational deployment.

CHAPTER II: MATERIAL AND METHODS

Subjects

For this retrospective study, we reviewed the dental records of 280 U.S. Marine Corps personnel assigned to Marine Corps Base (MCB) Camp LeJeune, NC who deployed to Afghanistan between January 2010 and March 2012. Records were randomly selected from nine USMC units, with a total of 7,040 personnel, which deployed during this timeframe. To obtain an accurate representation of the Marines deployed, a percentage of personnel from each unit were selected. To ensure the subjects' anonymity, no personally identifying information was recorded during the chart review process. Subject records were not linked in any way to the database.

Sample Size Determination and Random Selection

Sample size was calculated using an online database web survey software program (Raosoft®, Inc., 6645 NE Windermere Road, Seattle, WA 98115; www.Raosoft.com). Based on a population size of 7,040 deployed Marines, 5% margin of error, 90% confidence level, and a response distribution of 50%, the software calculated a sample size of 261. For ease in statistical calculations, we chose to increase the sample size to 280. Patient records were randomly selected from an alphabetical roster, based on a list of numbers produced by a random number generator (Dr. Mads Haahr, School of Computer Science and Statistics, Trinity College, Dublin 2, Ireland; www.random.org). The

alphabetical roster was destroyed immediately following selection of the patient records.

Data Collection

Three calibrated examiners (T.C.H., K.E.D., M.S.S.) traveled to MCB Camp LeJeune during April 2012 to complete data collection. Demographic data (age and gender), as well as tobacco use history, were recorded from information contained in the dental record. DMFS, DMFT, and caries risk status at in-processing and pre-deployment were determined from the in-processing and most recent pre-deployment examinations, respectively. We defined In-processing as the initial exam in the military. In-garrison was defined as the period when Marines are not deployed and located aboard station. Pre-deployment was defined as the annual exam received prior to deployment. Post-deployment was defined as the period when returning from deployment. We classified caries risk according to the 2010 U.S. Navy Oral Disease Risk Management guidelines,[35] as outlined in Table 1.

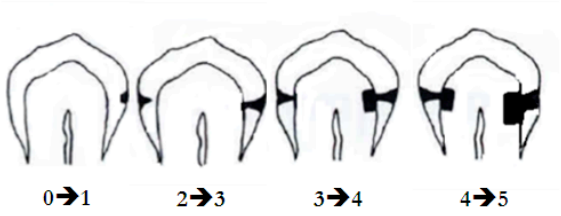
Table 1. Caries risk status.

Caries Risk Status	Criteria
Low	No new incipient or cavitated primary or secondary caries lesions during current exam; **AND** No factors that may increase caries risk.
Moderate	One or two new incipient or cavitated primary or secondary caries lesions during current exam; **OR** No incipient or cavitated primary or secondary caries lesions during current exam, but presence of at least one factor that may increase caries risk.
High	Three or more new incipient or cavitated primary or secondary caries lesions during current exam; **OR** Presence of multiple factors that may increase caries risk.
Source: BUMED Instruction 6600.16A, 23 August 2010.[35]	

Prior to deployment, all U.S. Marine Corps personnel at MCB Camp Lejeune undergo a routine dental health assessment comprised of clinical and radiographic examinations utilizing digital bitewing, periapical, and panoral radiographs as indicated. The posterior approximal surfaces (Teeth #2 - #5, #12 - #15, #18 - #21, #28 - #31; 16 possible teeth; 32 possible mesial and distal surfaces) were scored using the criteria of Mejare, Kallestal and Stenlund (1999) (Table 2; Figure 1).[36] Upon their first scheduled annual dental examination following deployment, Marine personnel are once again examined and new digital bitewing radiographs taken as indicated.

Table 2. Radiographic codings of approximal caries progression.

Codings of the Radiographs	Classification
0	No visible radiolucency
1	Radiolucency equal to or less than half-way through enamel
2	Radiolucency more than half-way through enamel, but not into dentin
3	Radiolucency with a broken enamel-dentin border but with no obvious progression in the dentin
4	Radiolucency with obvious spread in the outer half of the dentin
5	Radiolucency in the inner half of the dentin



Adapted from Mejare, Kallestal, & Stenlund

Figure 1. Illustrations of the five radiographic codings of approximal caries progression

Caries progression rates were assessed for all unrestored proximal surfaces. Each lesion was categorized on the basis of its radiographic appearance using the Kodak Dental Imaging software. For expression of the rate of progression, the incidence rate was used. The incidence rate expresses

the number of new caries lesions (transition from State 0 to State 1 or higher) or the number of lesions that progressed from one carious state to the next deeper one. Lesions that were restored between examination cycles were categorized separately (i.e., State 3– restored), but were considered progression in the final analysis.

Data were recorded on spreadsheets (Microsoft Excel) (Appendix B) and stored on password-protected laptop computers. To ensure the subjects' anonymity, we assigned a unique identification code to each subject. No personally identifiable subject information was recorded during the data collection process.

Outcome Measures and Statistical Analyses

For each caries risk category (Low, Moderate, High) and deployment status (deployed, in-garrison), we calculated the following:

1) Mean number of new approximal caries lesions (transition from State 0 to State 1 or higher);
2) Mean number of approximal caries lesions exhibiting progression (transition from State 1, 2, 3, or 4 to a higher State).
3) Correlations between caries lesion formation/progression and:
    a) Age
    b) Tobacco use

c) In-processing and pre-deployment DMFS, DMFT, and caries risk status.

We used a two-way analysis of variance (ANOVA) and Tukey post hoc tests, when indicated, to compare (1) the mean number of new approximal caries lesions, and (2) the mean number of approximal caries lesions exhibiting progression for each caries risk status and deployment status. For each caries risk category and deployment status, we used paired samples *t*-Tests to determine associations between both caries incidence and progression and age and tobacco use. All statistical significance levels were set at $\alpha = 0.05$. All data analyses were completed using SPSS Version 18 software.

Human Subject Use

The protocol for this study was reviewed and approved by the Institutional Review Boards (IRB) for the Naval Postgraduate Dental School, Walter Reed National Military Medical Center (WRNMMC), Bethesda, MD, and II Marine Expeditionary Force (II MEF), Camp Lejeune, NC. All investigators completed the "Collaborative IRB Training Initiative" (CITI) to ensure compliance with the requirement for protection of human research subjects.

CHAPTER III: RESULTS

We reviewed the dental records of 280 USMC personnel, retrospectively, through annual bitewings and examinations conducted during in-processing, in-garrison, pre-deployment, and post-deployment periods. The subjects ranged in age from 19 to 43 years (mean = 22.19 ±4.06 years), with an average of 3.95 years of active duty service. Our sample, which was randomly selected to represent a total population of 7,040 personnel, was comprised of 100% males. The study group average time in-garrison and pre-deployment to post-deployment period was 14 months.

At the beginning of the in-garrison period (non-deployment), of the 280 dental records examined, 139 of the personnel exhibited dental caries and 141 were caries-free (Figure 2). Of the 666 lesions identified in-garrison, 54.5% progressed from their initial state and 45.5% remained static (Figure 3) over 14 months. Of these same personnel examined at pre-deployment, 148 had caries and 132 were caries-free. Eight hundred fifteen caries lesions were identified at the pre-deployment examination; upon return from deployment, 64% progressed, 35% remained static, and 0.6% were not evident after deployment (Figure 3).

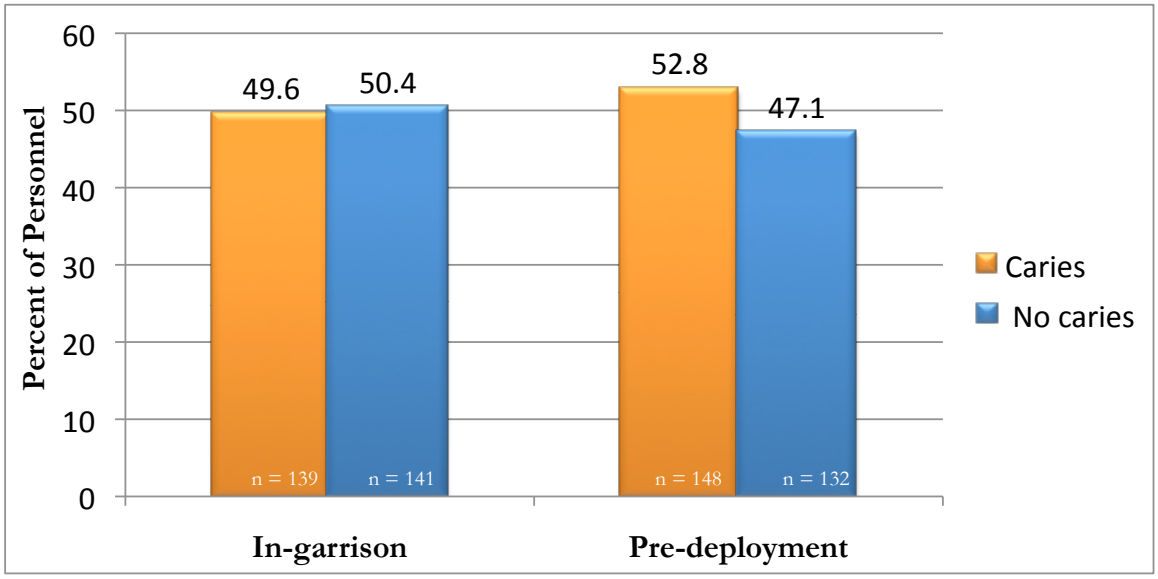


Figure 2. In-garrison and pre-deployment caries prevalence.

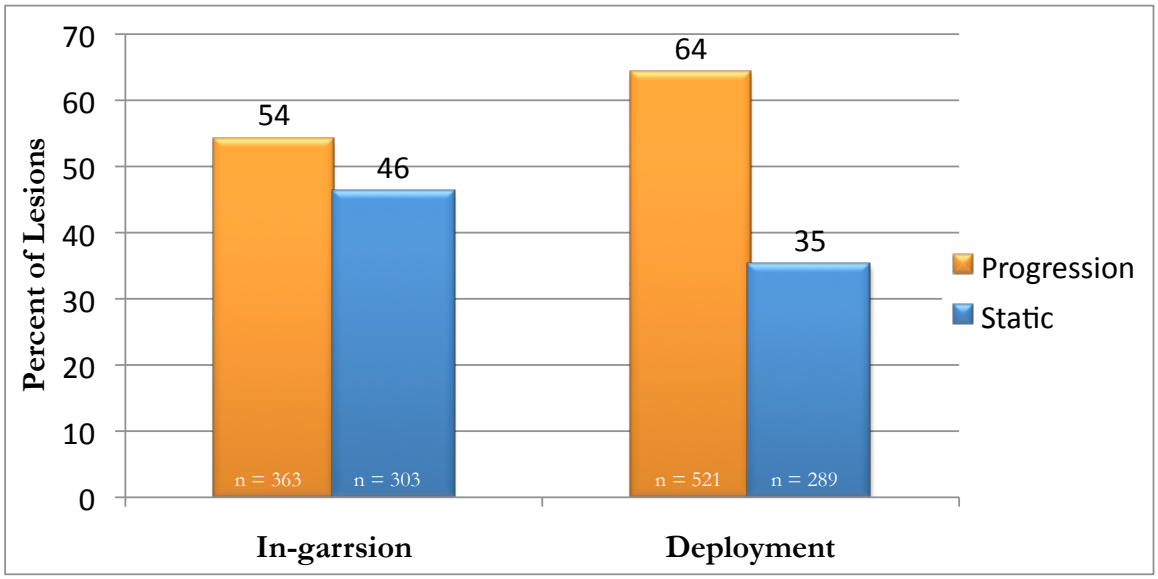


Figure 3. Caries lesion progression during in-garrison and deployment periods.

There were significant differences between in-garrison and deployment periods with respect to both caries incidence and caries progression (Figure 4). On average, personnel developed 2.38 new caries lesions while in-garrison and 2.91 new lesions during deployment (paired samples *t*-Test; p = 0.033).

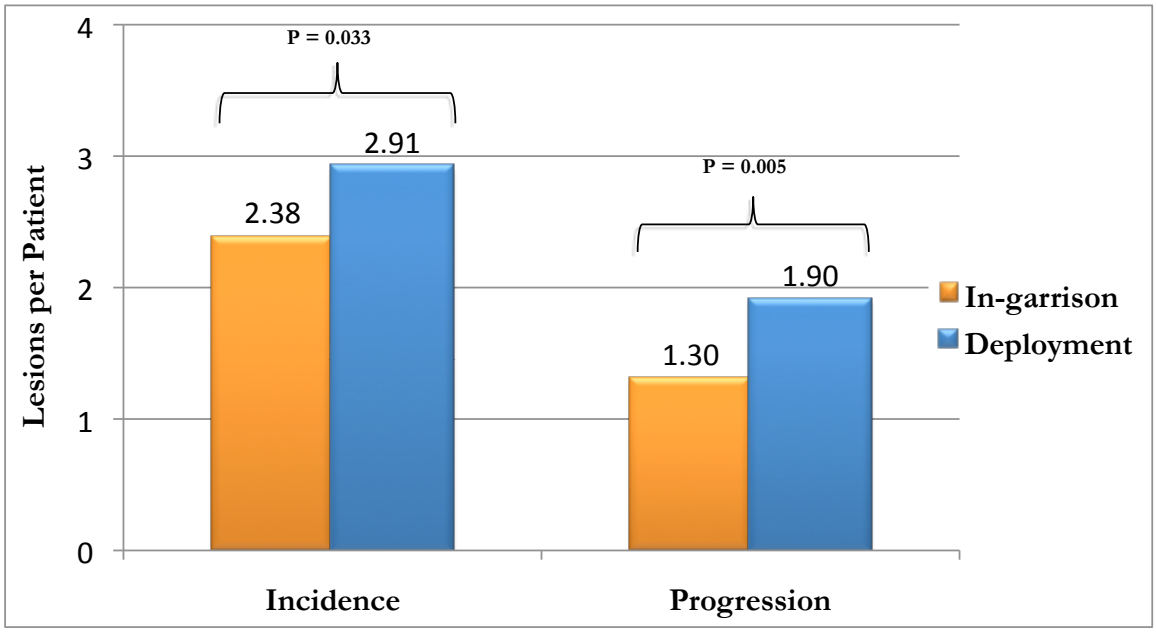


Figure 4. Caries incidence and progression during in-garrison and deployment periods.

With respect to caries progression, on average, 1.30 lesions per person progressed while in-garrison and 1.90 lesions progressed during deployment (paired samples *t*-Test; p = 0.005).

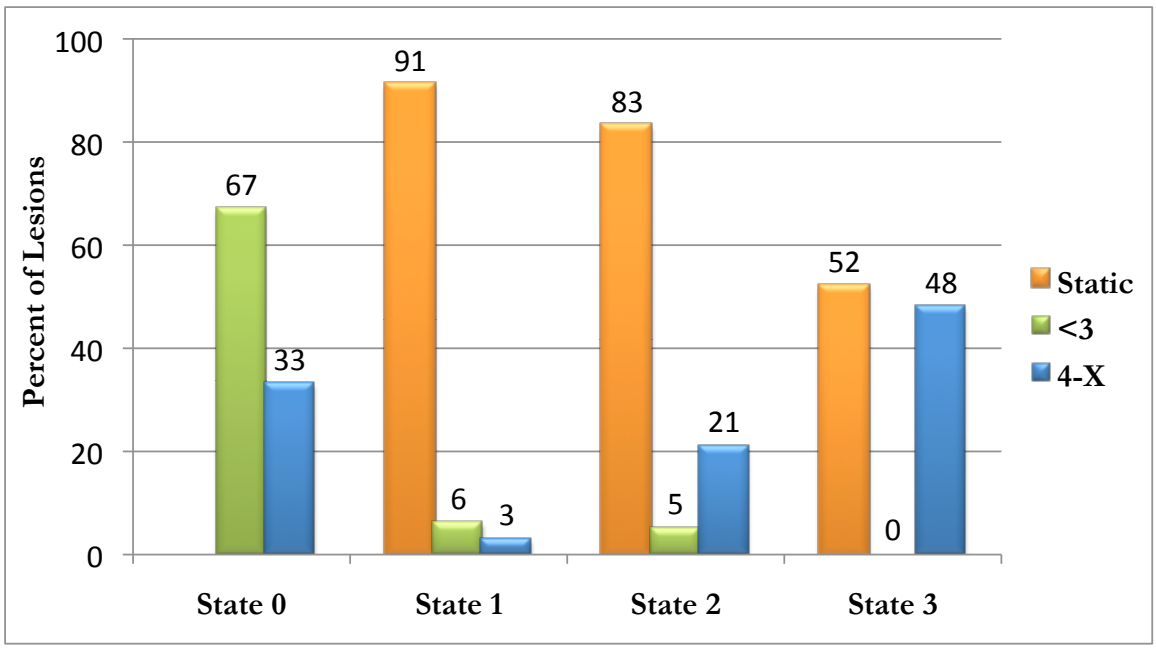


Figure 5. Caries progression during in-garrison period (as determined at pre-deployment examination).

Figures 5 and 6 show the proportions of caries lesions, initially in States 0 – 3, which progressed during in-garrison and deployment periods, respectively. While in-garrison (Figure 5), 52-91% of initial lesions (States 1 – 3) did not progress; 5-6% progressed no further than to the DEJ (< State 3); and 3-48% progressed beyond the DEJ or were restored (State 4 – X). State 0 lesions represent those teeth exhibiting no prior radiographic evidence of caries. Of 4,512 surfaces evaluated during in-garrison, 5% (n = 226) developed radiographically visible lesions by the subsequent examination, and therefore, reflect new caries lesions. Of 4,224 surfaces evaluated during pre-deployment, 6.7% (n = 284) developed visible lesions by subsequent examination.

While deployed (Figure 6), 43-84% of initial lesions in States 1 – 3 did not progress, while 1-13% progressed no further than to the DEJ. However, lesions at the DEJ (State 3) progressed beyond the DEJ 57% of the time. Incipient lesions in enamel (States 1 and 2) showed very little progression.

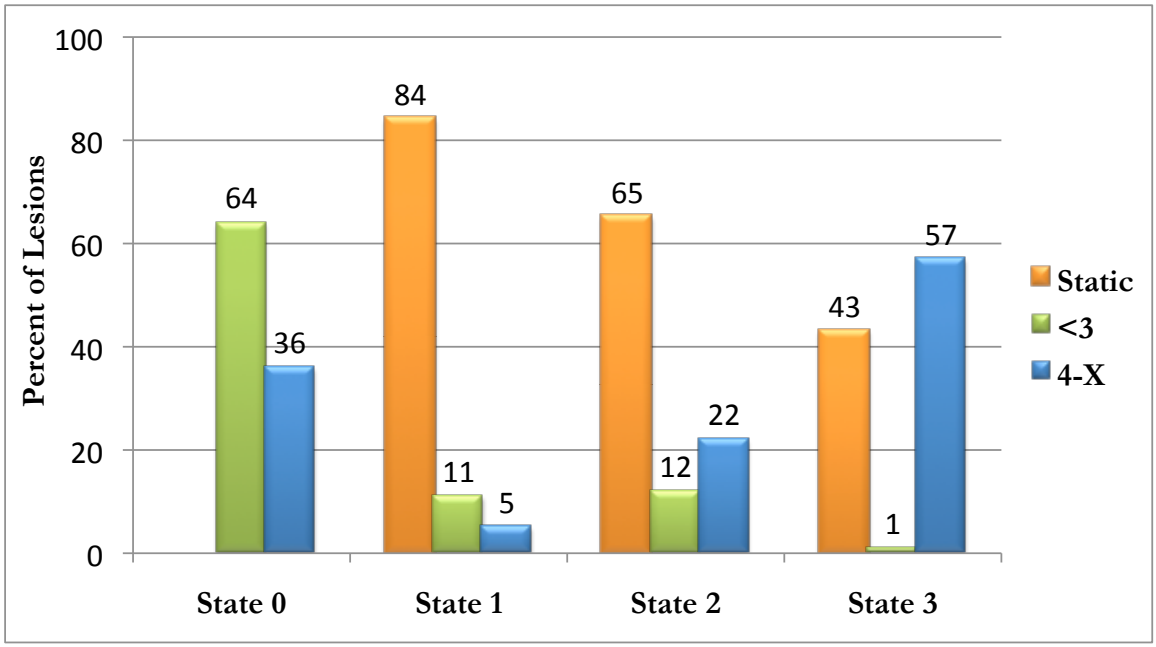


Figure 6. Caries progression during deployment period (as determined at post-deployment examination).

Based on our review of the patients' in-processing dental examinations (conducted at the time of initial entry into the military), we identified 42.5% (119) of our sample as low caries risk, 19.3% (54) as moderate caries risk, and 38.2% (107) as high caries risk group (Figure 7).

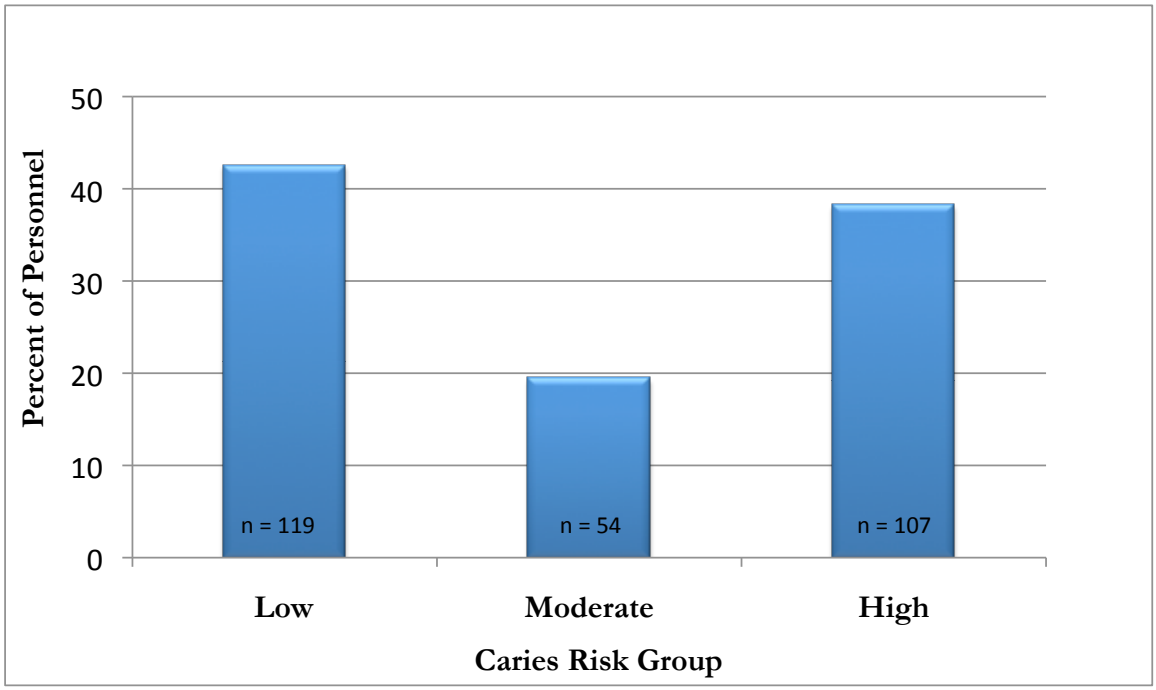


Figure 7. Caries risk status (as determined by caries prevalence at in-processing examination).

Figure 8 shows the distribution of caries incidence by caries risk status during in-garrison and deployment periods. Personnel in the High caries risk group had significantly higher caries incidence than those in the Low risk group during both periods (p = 0.021 in-garrison; p < 0.001 post-deployment). During deployment, High caries risk patients developed 2.6x more lesions (4.54) than those at low risk (1.74) and 2x more caries than those at moderate risk (2.26). There was no significant difference in caries incidence between the Low and Moderate caries risk groups either in-garrison (p = 0.758) or post-deployment (p = 0.656) (Figure 8).

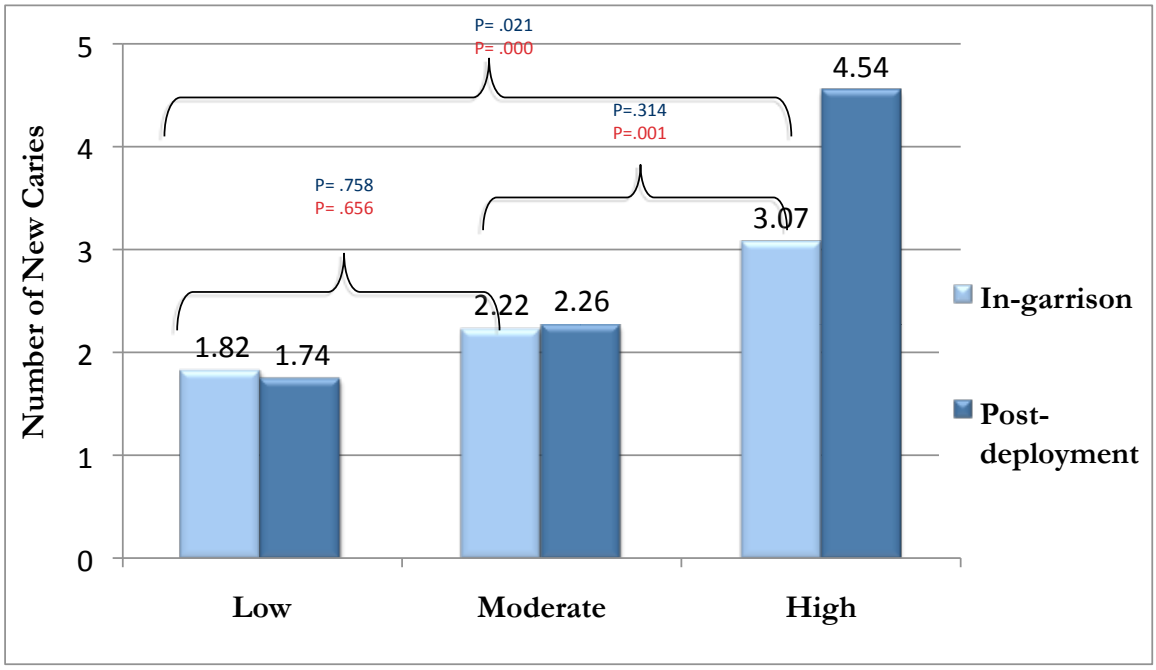


Figure 8. Distribution of caries incidence by caries risk status during in-garrison and deployment periods (two-way ANOVA; α = 0.05).

With respect to caries progression (Figure 9), there was a significant difference between those in the Low caries risk group and those in the High caries risk group during deployment ($p < 0.001$). Those in the High caries risk group had, on average, 2.78 lesions progress during deployment, while those in the Low caries risk group had 1.11 lesions progress. There were no significant differences in caries progression during deployment between the Low and Moderate caries risk groups ($p = 0.408$), or the Moderate and High caries risk groups ($p = 0.062$). There were no differences among the caries risk groups with respect to caries progression while in-garrison ($p = 0.267$) (Figure 9).

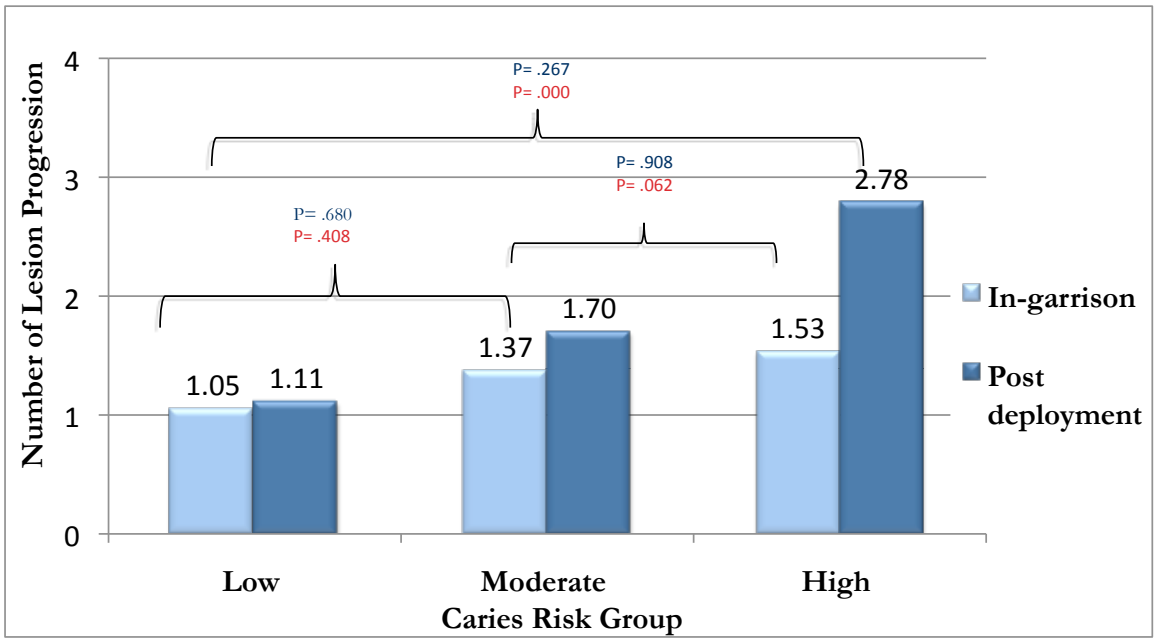


Figure 9. Distribution of caries progression by caries risk status during in-garrison and deployment periods (two-way ANOVA; $\alpha = 0.05$).

With respect to tobacco use and caries incidence, there was no association between tobacco use and caries incidence (p= 0.706) and caries progression (p= 0.743) during deployment. There was no association between tobacco use and caries incidence (p= 0.503) and caries progression (p= 0.868) in-garrison. However, there was a correlation between caries risk and tobacco use (p= .006).

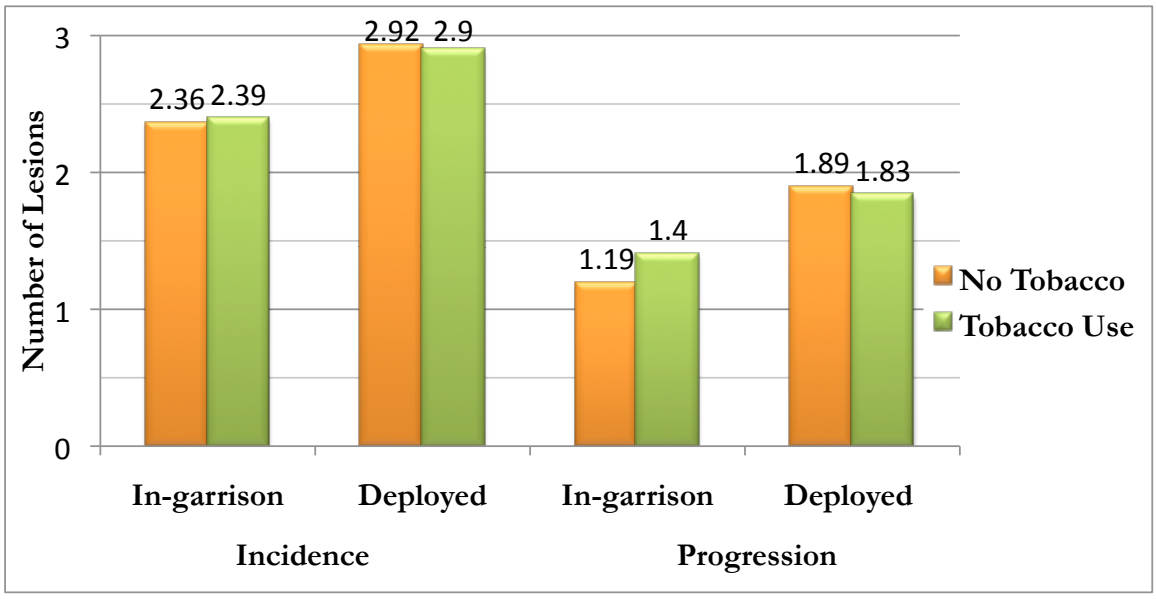


Figure 10. Distribution of caries incidence by tobacco and non-tobacco use (paired-samples *t*-Test; α = 0.05).

CHAPTER IV: DISCUSSION

Several limitations of the study should be noted first before commenting on the implications of these findings. First, this was a retrospective review of dental records and therefore, the diagnosis of dental caries was dependent on the documentation provided by previous practitioners. In busy clinics, failure by practitioners to diligently document all caries lesions may have occurred. It was agreed upon by the three examiners to not alter any records and to record only the caries documented by the practitioners.

Although practitioners are trained and calibrated in the U.S. Navy, disparities among dentists still exist concerning the restorative treatment threshold for approximal surfaces. For example, in a given stage of caries progression, one dentist might intervene via restorative treatment if he believes that caries lesions progress rapidly, while another may elect to perform remineralization therapy if he believes that the lesion may remain static. This disparity among practitioners is not unique to U.S. Navy dentistry. In a questionnaire of 86 dental faculty members at 16 French universities, Tubert-Jeannin and colleagues[37] found wide variation in restorative treatment thresholds. They found 55% of faculty members believed that not all teeth with caries needed to be restored, while 19% thought it was very important to fill all lesions, and 26% thought it was important to never fill sound teeth. The authors concluded that wide variability exists in diagnosis of caries lesions, assessment of restorations, and treatment decisions, which ultimately led to variation in their

students' treatment modalities. Bader and Shugars[38] examined differences in treatment recommendation for individual patients by analyzing 283 exams involving 43 patients and 51 dentists. The analysis data consisted of 7,822 assessments of 1,187 individual teeth, a mean of 6.6 assessments per tooth. The authors concluded the overall extent of agreement for treatment recommendation due to caries is only moderate, with disagreement among examining dentists occurring for almost one-third of all teeth. This substantial variation among practitioners is most likely due to differences in individual practitioners' criteria for intervention, diligence in the search for lesions, and criteria for identification of conditions as caries.

Second, although we were able to confirm, via radiographs, many of the caries lesions documented by the practitioners, the radiographs were not produced by the same provider or taken from the same reference point during in-processing, in-garrison, and post-deployment examinations. We did not consider it necessary or ethical to subject the patients to additional radiation by retaking bitewing radiographs solely for the purposes of this study. It should be noted that all radiographs of the study teeth were judged to be of adequate quality with minimal to no overlap, and the measurement of lesion depths could be calculated with the naked eye.

This study's results tend to confirm the anecdotal reports of deteriorating dental conditions among U. S. Marines returning from deployment. Sixty-four percent of all caries lesions progressed during the 14-month deployment period, as compared to the 54% that progressed while in-garrison (Figure 3). This

contrasts with previous studies[25, 26, 27] that found caries progression to be a relatively slow process. These studies estimated that it takes approximately three to four years for a lesion to progress through enamel into dentin. We found caries to progress at a faster rate in our study population. When examining caries lesions at the DEJ (State 3) before deployment, we found 57% of these lesions had progressed into the outer or inner half of dentin after deployment. While in-garrison, 48% of the lesions at the DEJ progressed. It should also be noted that enamel lesions (States 1 and 2) remained static, 84% and 65%, respectively, during deployment (Figure 6). Caries lesions at the DEJ showed the most progression.

Furthermore, U. S. Marines identified in the High caries risk group exhibited significantly increased caries incidence (2.6x or 260% more caries lesions) than those in the Low caries risk group while deployed. However, while in-garrison, these same Marines in the High caries risk group displayed 1.68x (168%) higher caries incidence than those in the Low risk group. There seems to be a 92% difference in caries incidence between the two groups while in-garrison and deployed. When analyzing just the High caries risk group, there was in increase in caries incidence of 1.47x (147%) while deployed, as compared to in-garrison (Figure 8). In summary, caries incidence and progression are unequally distributed between the caries risk groups. Caries management should therefore be tailored to allow for an appropriate level of prevention and treatment.[39]

This study's results confirmed that there are significant differences in both caries incidence and caries progression between deployment and in-garrison

periods. The primary causes of oral disease, which can be exacerbated during deployment, are attributed to poor diet, poor oral hygiene, stress, and dehydration. Dental caries is caused when oral bacteria such as mutans streptococci, lactobacilli, and many others produce acids that demineralize the inorganic mineral, mainly hydroxyapatite, following an individual's sugar consumption. Lactic acid diffuses through the dental calcified tissues and drops the local pH to below 5.5, which in turn leads to dissolution of the mineral crystals (demineralization). Demineralization occurs numerous times daily and is usually balanced by the properties of saliva, which allows remineralization to take place.[40, 41]

In addition, Lenora and colleagues[42] have shown that acid is only an initiator of enamel erosion and stimulator of an uncontrolled inflammatory response in the dentin. The tooth is nourished from the intradental fluids that flow from inside the pulp chamber out to the dentin and enamel. A high-sucrose diet could halt the fluid flow and cause the tooth to become susceptible to bacterial acids accumulating on its surface. This leads to a higher rate of caries incidence and progression in teeth. Chaussain-Miller and colleagues[43] proposed that acid produced by bacteria can potentially initiate an inflammatory response in the dentin. The body's own matrix metalloproteinases (MMP), mostly from the dentin, become activated and are able to digest demineralized dentin matrix. Tjaderhane and colleagues [44] by using Western blot analysis and gelatin zymography, were able to identify MMP2, MMP8, and MMP9 as the MMPs critical to the destruction of dentin by caries.

In the present study, there was no association between tobacco use and caries incidence (p= 0.706) and caries progression (p= 0.743) during deployment. There was no association between tobacco use and caries incidence (p= 0.503) and caries progression (p= 0.868) in-garrison. However, there was a correlation between caries risk and tobacco use (p= .006). This finding appears to be consistent with those reported by Bartoloni and colleagues [33] who noted that tobacco users had an elevated risk of developing caries. They also noted a higher percentage of people at high risk of developing caries were found in groups with younger age, lower rank, less education, and fewer years in military service. However, we found no association between tobacco use and age (p= 0.728) or caries risk and age category (p= 0.307). This is in agreement with other studies which found no association between age and caries risk.[45]

During deployment, self-care and hygiene habits are often lax when a Marine is placed in an austere environment combined with significantly increased operational tempo and environmental stress. Chronic stress has been shown, by Hugo and colleagues, [46] to reduce salivary flow rates. Corticosteroids released as a result of chronic stress cause atrophic changes in the major salivary glands, which may affect the total volume of saliva (quantity) and its composition (quality). Normal salivary function, which usually provides antimicrobial protection, lubricates the mucosa, maintains intraoral pH, and preserves the integrity of the dentition through its mineralizing potential, is reduced as a result. The loss or decrease of normal salivary production results in xerostomia, tooth demineralization, decreased clearance of food debris, and a shift in the mouth's

bacterial population that is characterized by an increase in cariogenic organisms (mutans streptococci and lactobacilli).[47] Therefore, individuals who suffer from hyposalivation are at even greater risk for caries.

In addition, to combat physical and mental fatigue and increase alertness, Marines often turn to energy drinks and sodas for replenishment. Increased intake of sucrose and other carbohydrates lowers the pH, causing a shift in the bacterial ecology of the mouth. This favors the proliferation of acid-tolerating (and acidogenic) bacteria, especially mutans streptococci and lactobacilli. Greater numbers of acidogenic and aciduric bacteria in plaque result in more acid being produced at even faster rates, thereby enhancing demineralization still further.[48]

Prevention and Treatment

Dental caries is a complex multifactorial biofilm disease. Successful treatment should not solely be focused on restorative procedures, but requires addressing all factors in the disease process. Consideration of the level of a patient's caries risk status may help determine the selection of the proper clinical treatment method.[39] As seen in this study, there are differences in caries incidence and caries progression based on caries risk status. Caries lesions found in individuals of moderate caries risk should be treated differently than those in individuals identified as high risk. For low caries risk patients, i.e., personnel with no new lesions during current exam and no factors that may increase caries risk,[35, 49] treatment plans should be centered on maintaining

primary oral health. Good dietary habits and oral hygiene are reinforced, along with daily use of fluoride toothpaste as preventive measures. Patients in this low caries risk group may not receive additional benefit from professional topical fluoride application (fluoridated water and fluoride toothpastes may provide adequate caries prevention).[50]

In dental caries, low pH and reduction in saliva flow appear to be primary mechanisms that disrupt microbial homeostasis.[51] An effective way to treat caries disease is to minimize or prevent plaque acid production, e.g. by use of fluoride-containing products. Bradshaw and colleagues[51] have shown fluoride can reduce the pH decrease following sugar metabolism in plaque biofilms, and in doing so, may prevent the establishment of conditions that favor growth of acid-tolerating cariogenic species. Featherstone[52] concluded that fluoride works primarily via topical mechanisms which include (1) inhibition of demineralization at the crystal surfaces inside the tooth, (2) enhancement of remineralization at the crystal surfaces (the resulting remineralized layer is very resistant to acid attack), and (3) inhibition of bacterial enzymes. Although different vehicles exist for fluoride delivery, the recommended method by the American Dental Association (ADA) is fluoride varnish or gel therapy for moderate and high risk caries therapy.[50] Fluoride varnish, however, demonstrates good substantivity, takes less time per application, creates less patient discomfort and achieves greater patient acceptability than does fluoride gel.[53] This is especially important in the military population where time or the environment for proper oral hygiene care may not always be available.

Treatment plans for moderate caries risk[35, 49] patients (those with one to two caries lesions during current exam, or presence of at least one factor that may increase caries risk) should focus on repairative strategies targeted at remineralizing and repairing lesions, in addition to strategies for preventing future lesions and encouraging a healthy biofilm. Fluoride varnish or gel treatments at six-month intervals in combination with daily use of fluoride rinse, patient education on proper dietary habits and oral hygiene, and restorative treatment for all cavitated lesions should be implemented.[35, 49, 50]

A high risk patient's[35, 49] (with three or more caries lesions during current exam, or multiple factors that may increase caries risk) treatment needs should first be addressed by repairing cavitations with cariostatic restorative materials, such as glass ionomer.[54] Based on the current study, Marines in the High caries risk group with a previous history of caries progression should have lesions that are at the DEJ restored prior to deployment. In addition, high risk patients should receive immediate fluoride varnish or gel treatment, with re-application planned at three month intervals, as well as daily prescription or OTC fluoride rinses.[50] Patients should also be educated on the importance of proper dietary habits, oral hygiene, and stress management.

Additional therapies directed at the caries disease process must include behavioral modification. Simply reducing the overall bacterial load in the mouth by brushing and flossing alone cannot effectively modify or control this disease.[55] Studies have shown that in tooth surfaces covered by salivary secretions immediately after cleaning, bacterial colonization of enamel surfaces soon

follows.[56, 57, 58] Therefore, alteration of the patient's dietary habits is important. Changes must center on reducing the frequency of refined carbohydrate consumption, and not just on temporary removal of cariogenic bacteria. Continual snacking or drinking can lead to repetitive acid attacks caused by a decrease in pH.[51]

The use of xylitol chewing gum or mints can stimulate salivary flow, increasing the clearance of fermentable carbohydrates from the oral cavity and increasing salivary buffering capacity. Xylitol has an antimicrobial and anticariogenic effect by reducing the amount of plaque and the number of mutans streptococci in both plaque and saliva. Further, users of clinically effective levels of xylitol exhibit mutans streptococci strains with reduced adhesion to the teeth and other reduced virulence properties such as less acid production.[59, 60] Gum-chewing also stimulates a protective salivary flow when used after an acidogenic stimulus and may enhance salivary function, especially in subjects with low salivary flow rates.[61]

Finally, stress management during and after deployment, and its effects on the oral environment should be addressed by military health care providers. As shown, stress can cause serious oral health problems such as increased caries incidence and progression. Military personnel should be trained in healthy coping strategies to relieve stress through exercise, balanced eating, proper hydration, plenty of sleep and maintaining a positive mental attitude. Patients who minimize stress may be at less risk for oral diseases.

CHAPTER V: CONCLUSION

Our study revealed that while the incidence of dental disease may be changing for the general population, caries incidence among U.S. Marine Corps personnel has remained consistently higher than the civilian population. The results provide evidence that caries incidence increases and lesions progress more rapidly during deployment than in-garrison. This may account for at least a portion of the caries-related dental emergencies reported in many studies. Based on our study, 57% of lesions currently classified as Dental Class 2--worldwide deployable (patients who have asymptomatic caries lesions in the enamel or minimally into dentin [less than 0.5 mm, radiographically, beyond the DEJ]), will progress and become Dental Class 3 within 14 months of deployment. This may explain why implementation of a more stringent Dental Classification System in 2003 showed minimal improvement in predicting or reducing DE among U.S. Marine Corps personnel.[2]

Considering the direct effects of dental emergencies on combat capability and operational readiness, as evidenced by historical DE rates in personnel during deployment, it may be reasonable to assume that the relatively low DE rate has negligible effects on the overall mission of deployed units during normal length deployment windows (six to nine months). However, based on the results of this study, which indicate a significant increase in caries incidence and progression rates while deployed, it may be concluded that post-deployment readiness is significantly affected due to the increased requirements for dental

visits and restoration/repair of lesions which either formed or progressed during the previous deployment cycle. Each post-deployment dental visit required will directly reduce the service member's availability for training and therefore, the unit's ability to carry out training with the limited time and resources available with the ever present increased operational tempo of today's Marine Corps. To prevent valuable time loss post-deployment, more concentrated efforts should be spent on identifying high risk personnel while in garrison. Strict adherence to BUMED Instruction 6600.16 (Oral Disease Risk Management protocol) may not only increase the overall operational dental readiness of Marine personnel but also prevent the accelerated caries incidence and progression seen on deployment. Ultimately, this will reduce the time lost to preventable dental operative procedures while in-garrison and during pre-deployment training.

APPENDIX A

CARIES RISK MANAGEMENT PROTOCOL FOR NAVY DENTISTRY

Low Caries Risk	Moderate Caries Risk	High Caries Risk
1. Oral hygiene instruction 2. Fluoride dentrifice	1. Oral hygiene instruction and oral education using BUMED-INST 6600.16, enclosure (7) as an outline. 2. Fluoride dentrifice 3. Caries elimination a. Sealants for pits and fissures judged at risk. b. Incipient caries remineralization. 4. Identification of patient specific dietary modification (nutritional counseling). 5. Professional topical fluoride treatment (four applications over 6-12 months; may be accomplished concurrently with restorative treatment). 6. Home fluoride rinses (OTC) and/or home fluoride treatments using prescription dentifrices/gels or prefabricated trays. 7. Discuss benefits of Xylitol chewing gum and provide a sample if available.	1. Oral hygiene instruction and oral education using BUMED-INST 6600.16, enclosure (7) as an outline. 2. Fluoride dentrifice 3. Caries elimination a. Sealants for pits and fissures judged at risk. b. Incipient caries remineralization. 4. Identification of patient specific dietary modification (nutritional counseling). 5. Professional topical fluoride treatment (four applications over 6-12 months; may be accomplished concurrently with restorative treatment). 6. Home fluoride rinses (OTC) and/or home fluoride treatments using prescription dentifrices/gels or prefabricated trays. 7. Discuss benefits of Xylitol chewing gum and provide a sample if available. 8. Antibacterial mouth rinses. 9. Bacterial testing. 10. Evaluation of salivary flow.
One Year Recall	6-12 Month Recall	3 Month Recall

APPENDIX B

CARIES PREVENTION MODALITITES BY RISK STATUS AND AGE GROUP
PREVENTENTIVE OPTIONS FOR RISK CATEGORIES

	AGE CATEGORY	
RISK CATEGORY	CHILD/ADOLESCENT	ADULT
LOW	Educational reinforcement re: good oral hygiene and use of fluoride dentifrice One year recall	Educational reinforcement re: good oral hygiene and use of fluoride dentifrice One year recall
MODERATE	Pit and Fissure Caries: Sealants Smooth Surface, Recurrent and Root Caries: Educational reinforcement Dietary counseling Fluoride mouthrinse* Professional topical fluoride Sealants Brush w/fluoride dentifrice Six month recall Fluoride supplements†	Pit and Fissure Caries: Sealants Smooth Surface, Recurrent and Root Caries: Educational reinforcement Dietary counseling Fluoride mouthrinse* Professional topical fluoride Sealants Brush w/fluoride dentifrice Six month recall Fluoride supplements†
HIGH	Pit and Fissure Caries: Sealants Smooth Surface, Recurrent and Root Caries: Educational reinforcement Brush w/fluoride dentifrice Sealants Home fluoride (mouthrinse/1.1 percent sodium fluoride gel*) Professional topical fluoride at each visit 3-6 month recall Dietary counseling Monitoring S. mutans count Antimicrobial agents Fluoride supplements†	Pit and Fissure Caries: Sealants Smooth Surface, Recurrent and Root Caries: Educational reinforcement Brush w/fluoride dentifrice Sealants Home fluoride (mouthrinse/1.1 percent sodium fluoride gel*) Professional topical fluoride at each visit 3-6 month recall Dietary counseling Monitoring S. mutans count Antimicrobial agents

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