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## **THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY**

**Title of Thesis:** "Assessing the Use of Radiographs Alone to Determine Air Force Dental Readiness Classification"

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# Assessing the Use of Radiographs Alone to Determine Air Force Dental Readiness Classification

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## ABSTRACT

As a cost savings, it has been suggested that an examination of radiograph-only may be used to determine a military member's readiness classification in lieu of a clinical examination plus radiographs. **Objective:** The primary aim of this study was to determine how sensitive the use of radiographs alone were in diagnosing Dental Readiness Classification (DRC) 3 based on caries, periodontal conditions, and other conditions separately. A secondary aim was to determine the ability to diagnose caries using radiographs alone compared to a clinical exam which included radiographs. **Methods:** Twelve months after completion of the 2018 Air Force Recruit Oral Health Study (AFROHS), five of the original 10 dentists reviewed only radiographs from 535 of the original 1362 subjects. The DRC for caries, periodontal conditions, and for conditions other than caries and periodontal conditions from the radiograph-only examination were compared to those from the AFROHS examination. Sensitivity and specificity were calculated for each DRC to assess the ability of the radiograph-only examination to detect DRC 3 conditions. Total number of caries per patient were also compared. Secondary analyses examined the mean confidence level of providers for each variable recorded using a 5-point Likert scale. **Results:** The sensitivity of using radiographs alone to identify DRC 3 based on caries = 58.4%, periodontal conditions = 8.3% and other conditions = 55.9%. For caries count, radiograph-only scores were significantly lower than a clinical exam with radiographs scores,  $p < 0.05$ . Overall, the provider confidence levels were within the "somewhat not confident" level of the 5-point Likert scale. **Conclusions:** Radiographs alone can detect true DRC 3 for caries or other approximately one-half of the time and periodontal conditions less than 10% of the time.

## BACKGROUND

Budgetary concerns involving manning have been a long-standing balancing act that has generated underlying ramifications on military medical personnel.<sup>1</sup> When considering cost-saving options in military health care, suggestions have included the possibility that radiograph-only examinations could accurately determine a member's dental readiness classification in lieu of a comprehensive clinical examination which would normally include radiographs.<sup>2, 3</sup> Using radiograph-only examinations could challenge healthcare's Quadruple Aim of better outcomes, lower costs, improved patient experience, and improved clinician experience.<sup>4</sup> Entertaining this effort to lower costs may challenge the improvement of the clinician experience thereby leading to an adverse impact on the aims of patient experience and better outcomes.

A thorough examination of the oral cavity includes evaluation of the color, contour, and consistency of nearly all of the hard and soft tissues. Typical clinical dental examinations consist of visual inspection of the oral cavity aided by instruments such as a mirror and dental explorer, the latter facilitating tactile assessment. They can also enhance their visualization by increasing narrow-field lighting and/or the use of magnification. However, there are other areas where direct vision is not sufficient, such as interproximally between teeth or within the underlying alveolar bone. Radiographs therefore are an essential tool for the dental provider when providing a dental examination. They are utilized as adjunctive diagnostic tools for detection of caries, periodontal diseases, and other dental pathology such as tumors or cysts where direct vision cannot be used. Not only are they beneficial for immediate diagnostics, radiographs can serve as documentation as well as baseline information for monitoring suspicious oral lesions over time. Radiographs alone do have their limitations. For example, the standard panoramic and bitewing radiographs present as only two-dimensional images. This could be significant in the instance of a cavitated lesion developing on the occlusal, facial, lingual surface of a tooth; clinically it could be visualized, whereas radiographically it may not be easily observed or be overlapped and misinterpreted.<sup>5</sup> Dental findings are used to assign members' dental readiness classification.

The Department of Defense (DoD) uses Dental Readiness Classification (DRC) to identify the status of members' oral health, thereby directly informing dental readiness. DRC 1 is assigned to service members with a current dental exam with no dental needs. DRC 2 is for service members with a current dental examination who require non-urgent dental treatment or reevaluation for oral conditions that are unlikely to result in dental emergencies within 12 months. DRC 3 is assigned to service members who require urgent or emergent dental treatment. DRC 4 is assigned to service members who require a periodic dental examination or have an unknown dental readiness classification.<sup>6</sup> The standard use of digital radiography in Tri-service dentistry has allowed dental providers to better screen and diagnose critical dental-related issues that could affect its members and their dental readiness.<sup>7</sup> In the United States Air Force for example, the use of radiograph-only and examination with radiographs are both practiced. Recruit in-processing begins with an off-site dental panoramic radiograph screening by a dental provider for any major dental concerns and the member is classified at Dental Readiness Classification (DRC) 3 or 4. After a recruit graduates and arrives at his first duty station, a different dental provider will capture four bitewing radiographs, as well as review the panoramic radiograph, and then perform a comprehensive dental examination. This examination includes TMJ screening, oral cancer screening, soft and hard tissue examination, and Periodontal Screening and Recording (PSR) documentation. From this information, the dental provider makes a definitive diagnosis, categorizes the level of diagnosis as DRC 1, 2, or 3, and then establishes a prioritized treatment plan. The DRC 3 is the primary focus of our study since this classification threatens individual readiness status as well as the mission. Deploying troops who are miscategorized as DRC 1 or DRC 2 could eventually cost the military tens of thousands of dollars *per troop*, and furthermore misuse valuable manpower hours on unnecessary non-mission transport to get that troop proper care.<sup>8</sup>

Two past studies have compared the detection of caries using only radiographs versus clinical examination with radiographs. In 2005, Hopcraft and Morgan reported that the use of bitewing radiographs helped in the detection of carious lesions compared to clinical examination alone.<sup>9</sup>

Another study from 2004 explored the validity of using only panoramic radiographs to classify initial dental classifications of United State Army Recruits. They concluded that panoramic radiographs were sufficient enough to classify DRC 3s, but not specific enough to identify specific problem teeth.<sup>2</sup> Our updated study evaluated the ability to accurately classify Air Force enlisted recruits diagnoses using only radiographs versus a clinical examination plus radiographs. In contrast to earlier studies, we analyzed data from a study using digital radiographs instead of analog radiographs.

This study aimed to determine the sensitivity and specificity of using radiographs alone (test method) in diagnosing DRC 3 based on caries, periodontal conditions and conditions other than caries and periodontal disease separately compared to a clinical examination which included radiographs (gold standard). A secondary aim was to determine the ability to diagnose number of caries using radiographs alone compared to the gold standard. The null hypothesis is that the sensitivity of radiographs alone to detect DRC 3 versus DRC 2 or DRC 1  $< 0.90$  and the specificity  $< 0.90$ . The second null hypothesis was that there will be no statistically significant difference in number of caries identified per patient between the test method and the gold standard.

## **MATERIALS AND METHODS**

Data from the 2018 Air Force Recruit Oral Health Study (AFROHS) were used for this study. Typically in the first two weeks of enlisted recruits' training, they will receive a panoramic radiograph which will be read and interpreted asynchronously by a credentialed dental provider to determine DRC 3 or DRC 4. However, for the 2018 AFROHS, 1,362 enlisted recruits received panoramic and bitewing radiographs and a comprehensive clinical examination to determine DRC 1, 2, or 3. The AFROHS used 10 licensed and credentialed civilian and military dentists who underwent standardization training and clinical calibration to accomplish these examinations. These data were collected from February 2018 to January 2019. For the purpose of the AFROHS study and for this radiograph only evaluation, lesions were considered carious if they were clinically cavitated or extended past the dentino-enamel junction on a radiograph. To assess DRC based on periodontal conditions, the presence/absence/extent of calculus, in addition to assessments of horizontal and vertical bone loss were considered. In the determination of DRC based on conditions other than caries or periodontal conditions, radiographic findings that suggested hard or soft tissue pathology and malposed teeth and third molars were considered. In the AFROHS study, clinical considerations were also incorporated into DRC determinations including visual-tactile findings and patient communication, among others.

### *Data Collection*

Twelve months from the completion of the AFROHS, five of the dentists who performed the AFROHS examination reviewed only the panoramic and bitewing radiographs together from a random sample of the participants, described in Table 1. They did not have access to the original AFROHS examination findings or DRC. Using these providers helped minimize variation since they all underwent the same standardization and calibration training for the diagnosis and categorization of dental lesions and DRC assignment. All of the examiners were licensed dentists who possessed credentials to practice, at a minimum, full-scope general dentistry. The time period

of 12 months was used to allow enough time to pass to minimize the possibility of recall bias on the part of the providers. The images were read and interpreted from the software used by the Air Force (Medicor Imaging Picture Archive Communication System (MiPACS), Medicor Imaging, Charlotte, NC, USA) using the same viewing and filter settings that were used during the AFROHS and the findings were recorded on an electronic spreadsheet. Data recorded were the DRC (1, 2, or 3) based on caries severity, the DRC based on periodontal conditions, the DRC based on conditions other than caries and periodontal disease (1, 2, or 3), total number of caries identified per participant ( $\geq$  zero), and the provider's confidence level for each recording. The confidence level was assessed using a 5-point Likert scale (1 = not at all confident, 2 = somewhat not confident, 3 = neutral, 4 = somewhat confident, 5 = very confident). All measurements and determinations were conducted independently.

### *Sample Size Calculations*

With the prevalence of DRC 3 in the sample population being 23.2%, a minimum sample size of 535 subjects was required to achieve a minimum power of 80% in order to detect a change in the percentage value of sensitivity from 0.80 to 0.90, based on a target significance level of 0.05.

### *Data Analysis*

In this study, the AFROHS clinical examination accompanied by panoramic and bitewing radiographs was used as the "gold standard". While it is understood that the gold standard in this study is not perfect because it did not go so far as to include histologic examination of routine lesions (which is not typically performed in routine dentistry), it was still the most comprehensive, standardized and calibrated examination performed on active duty Air Force members. Thus, the findings from the AFROHS were assumed to be the gold standard to which the test method (radiographs alone) was compared. The DRC for caries, the DRC for periodontal conditions, the DRC for conditions other than caries and periodontal conditions, and the total number of caries per patient, from the radiograph-only examination were compared to those from the AFROHS examination. Sensitivity and specificity were calculated for each DRC (caries, periodontal, and "other") to assess the ability of the radiograph-only examination to detect DRC 3 versus DRC 2 or DRC 1. Wilcoxon Signed-Rank Test was used to compare caries counts between the two methods, and median confidence scores were calculated for each type of recording.

**Table 1. Characteristics of study population (n=535)**

	<u>n</u>	<u>%</u>
<u>Age</u>		
17-20	367	68.6
21-25	133	24.9
26-30	27	5.1
31-35	6	1.1
36-40	2	0.4
<u>Sex</u>		
Male	351	65.6
Female	184	34.4
<u>Race</u>		

White	312	58.3
Black	105	19.7
Asian	16	3.0
Hispanic	78	14.6
Other	24	4.5

Education

< High School	1	0.2
High School	317	59.3
Some College	169	31.4
College Grad	44	8.2
Beyond College	4	0.8

## RESULTS

**Sensitivity and Specificity.** The sensitivities and specificities for each parameter studied are presented in Table 2. The sensitivity of the radiographs alone examinations to detect DRC 3 based on caries severity and conditions other than caries or periodontal findings were similar, with 58% and 60% respectively. The sensitivity for DRC 3 based on periodontal conditions was much lower at 8%. Specificities for DRC 3 based on caries severity and periodontal conditions were 95% and 93% respectively, while the specificity for DRC 3 based on “other” conditions was 73%.

**Table 2. Sensitivity and Specificity of Studies Parameters**

Parameter Studied	Sensitivity	Specificity	AUC*
DRC 3 based on Caries Severity	58%	95%	0.77
DRC 3 based on Periodontal Conditions	8%	93%	0.51
DRC 3 based on “Other” Conditions	56%	73%	0.65

\*AUC = Receiver Operating Characteristic Area Under the Curve

**Total Caries Count.** The total caries count per recruit determined from each of the methods was compared. From the gold standard examination, the median = 1, IQR 0 - 3. From the test method, the median = 0, IQR 0 - 3. The Wilcoxon Signed-Rank Test indicated that the test method scores were statistically significantly lower than gold standard examination scores,  $Z=2.86$ ,  $p<0.05$ .

**Provider Confidence Levels.** Median provider confidence scores and associated inter-quartile ranges for each recording are summarized in Table 3. These represented how confident the provider was in determining the specific parameter (DRCs or total caries count). The Likert scale for satisfaction ranged from 1 = Not at all confident to 5 = Very confident. Overall, all provider confidence levels were "somewhat not confident."

**Table 3. Summary Statistics for Provider Confidence Level**

	Median	IQR
DRC Caries	2	1 - 4
DRC Periodontal conditions	2	2 - 4
DRC “Other”	2	1 - 4

## DISCUSSION

Our study focused on the ability of Air Force dental providers using radiographs alone to correctly assign DRC 3 versus DRC 1 and DRC 2 among Air Force enlisted recruits. This is because DRC 3 carries a more significant risk for dental morbidity, often necessitating a greater number of dental appointments and more complex and/or costly care. It also has negative implications for military readiness, since DRC 3 conditions generally render an airman non-deployable and threaten mission success. In contrast, DRC 1 and DRC 2 are considered "Mission Ready" and deployable. The sensitivity of the test method (radiographs alone) compared to the gold standard method (clinical visual and tactile examination accompanied by radiographs) for each DRC parameter was unacceptably low.

For DRC 3 based on caries severity, the sensitivity was 58.3%. Other studies report sensitivities of radiography alone to diagnose caries of approximately 0.6 and higher.<sup>10-13</sup> However, there is wide variation in the literature about the sensitivity of using radiographs to detect caries due to inconsistent disease cut-offs, clinical studies vs *in vitro* studies, the tooth surfaces studied, and digital radiography versus analog radiography. Dental radiography has been reported to be inadequate for detecting occlusal surface caries until the lesion is well advanced into the dentin.<sup>14</sup> In a meta-analysis, sensitivity for proximal dentine lesions in clinical studies was 0.60 with specificities above 0.90.<sup>12</sup> In a study comparing caries status assessment of posterior teeth of young Chinese adults by using clinical examination alone and with the supplemental use of bitewing radiographs, more than one third of the caries found in the posterior teeth was not detected from reading the radiographs but was detected by clinical examination.<sup>15</sup> It is important to note that our study asked examiners to identify carious lesions (lesions that cross the dentino-enamel junction) on all tooth surfaces of all teeth using radiographs alone. Because occlusal surfaces were included, this may partly explain slightly lower sensitivity in our study. Additionally, anterior teeth are not visualized with bitewing radiographs and panoramic radiographs alone will not capture interproximal caries in the entire dentition.<sup>16</sup> Consistent with current evidence, the specificity of radiographs alone to rule out caries in our study was 95%<sup>17</sup>, but this does not align with the needs and requirements of the DoD, which prioritizes readiness, thus requiring the identification and treatment of DRC 3 members to return them to DRC 1 or DRC 2. Although the consequence of a false positive may be treating an otherwise healthy tooth, the prioritization of dental readiness would favor this approach versus false negatives which would allow a lesion to progress until it causes pain, disruption in job performance, and potentially loss of a tooth.<sup>17</sup> Failing to identify DRC 3 service members, especially those with job duties that make them susceptible to deployment to geographically separated or austere environments can have significant negative impacts on the mission. Studies in this area have indicated a dental emergency rate in deployed locations of 120 – 185 per 100,000 per year.<sup>8, 18</sup> Severe cases may require aeromedical evacuation out of theater to a higher echelon of care, putting additional service members in harm's way.<sup>8</sup>

The sensitivity of radiographs alone to detect DRC 3 periodontal conditions was 8%. This is not unexpected since a significant amount of information needed to diagnose periodontal disease

comes from a visual-tactile examination. Periodontal probing depths must be accomplished with a periodontal explorer and measured to the millimeter and an examiner must visually assess tissue color, contour and consistency, the anatomic location of the gingival margin (soft tissue), bleeding from the gingival sulcus, and the presence or absence of extenuating factors such as calculus deposits, tooth crowding, angulation, and position, among others. Tactile examination also assesses the texture of tooth surfaces, subgingival calculus, and restorative influences such as overhanging restorations or open margins. The Area under the Curve (AUC) for this analysis was 0.51, reinforcing the low value this measure of sensitivity provides for DRC 3 periodontal conditions.

The sensitivity of radiographs alone to detect DRC 3 conditions other than caries and periodontal conditions was also relatively low at 56% with a specificity of 73%. This is also not surprising, considering the criteria set forth in the original AFROHS. Aside from suggestions of pathology that may be noted on the radiographs, such as suspicious radiopacities or radiolucencies, this category included assessment of third molars. While the debate about whether or not to extract impacted third molars continues<sup>19</sup>, and is often highly dependent clinical presentation (e.g. occlusal considerations, tissue quality and morphology, presence or absence of pathology or symptoms), the military must also consider the impact of retaining third molars on military deployment. In the AFROHS, aside from obviously diseased (e.g. pericoronitis) third molars, examiners were standardized and calibrated to exercise judicious use of recommending extraction while also asking patients, when indicated, whether or not they experienced and pain or other symptoms with their third molars. In our study, examiners using the radiographs alone correctly identified DRC 3 third molars or other pathology only 56% of the time, reinforcing the importance of the findings obtained from the clinical examination, including patient communication.

Providers' confidence in their ability to correctly assign DRC based on the different categories and determining the total number of caries per recruit were consistently low. This is not necessarily surprising since dentists are trained to use all information from both a clinical examination and radiographs before arriving at an accurate diagnosis. Understanding the gravity of an accurate Dental Readiness Classification and its impact on military readiness and dental workload, it would be expected that providers would have lower confidence arriving at a definitive DRC without having all available information to consider. Consequently, when a provider is required to make an official dental readiness classification without the aid of a clinical examination, they may question their own professional judgement or their ability to perform the task accurately. This may lead to degradation of self-efficacy, which is associated with higher degrees of burnout<sup>20</sup>,<sup>21</sup> and in turn, lower patient safety<sup>22</sup>.

## **CONCLUSIONS**

Using radiographs alone versus a clinical examination plus radiographs detected true DRC 3 for caries or other conditions approximately 58 and 56%% of the time, respectively, and correctly detected DRC 3 periodontal conditions 8% of the time. It underestimated the number of caries, and caused providers to feel less confident in their ability to identify DRC 3 conditions. Using radiographs alone is not a viable option for accurately determining DRC of military members.

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