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Implant Risk Assessment Validation Study with One Year Follow-up

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Implant Risk Assessment Validation Study with One Year Follow-up

by
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CONTRIBUTIONS

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Implant Risk Assessment Validation Study with One Year Follow-up

Laura G. Aguilar-Fernandez

ABSTRACT

This short-term prospective pilot study aimed to assess the validation of the patient-centered implant risk assessment tool in patients recruited at the University of California, San Francisco School of Dentistry. Patients were enrolled in the study based on their eligibility for dental implant treatment. For each implant placed, dental surgeons completed a survey tool, called the Implant Risk Assessment Questionnaire (RAQ). After at least one year of loading with the implant final prosthesis, patients were seen for a recall visit at which point, the implant was diagnosed as healthy or having peri-implant disease. The peri-implant disease was further subcategorized as peri-implant mucositis and peri-implantitis. The survey output classifies the implant as low, medium, or high aggregate risk, which was correlated to diagnoses of healthy, peri-implant mucositis, or peri-implantitis respectively. The RAQ scores and diagnoses were used to compute sensitivity, specificity, and positive and negative predictive values to determine the tool's validity. In total, thirty-three patients, representing eighty-seven implants, participated in the one-year follow-up and were consequently included in the study results. Among these implants, fifty-four were diagnosed as healthy, ten as peri-implant mucositis, and six as peri-implantitis. Additionally, four implants experienced early failures before the delivery of the prosthesis. Initially, the sensitivity, specificity, and positive and negative predictive values of the RAQ tool were low, indicating a limited predictive value within this timeframe. However, these parameters were notably improved by omitting questions that were found to diminish the

predictive ability of the test. Specifically, questions related to treated periodontitis, smoking, tissue phenotype, maxillary posterior placement, clinician experience, and restoration emergence angle were removed to improve the validity parameters for this short-term study. Following the omission of these questions, sensitivity significantly increased from 22.22% to 74.07%, while specificity decreased from 100.0% to 62.5%. The positive predictive value declined from 100.0% to 86.96%, whereas the negative predictive value improved from 27.59% to 41.67%. When comparing the results before and after the exclusion of these questions, the predictive value also increased from 0% to 62.5%.

In a short-term context, the RAQ survey tool may have limited utility in its original form to identify cases of health and disease, but if modified to omit certain risk categories, its predictive capacity could be increased. A long-term follow-up study is necessary to evaluate the validity of the original RAQ survey tool across different risk categories.

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LIST OF ABBREVIATIONS

RAQ: Implant Risk Assessment Questionnaire

SAC: Straightforward, Advanced, Complex

IDRA: Implant Disease Risk Assessment

ITI: International Team for Implantology

INTRODUCTION

Dental implants have increasingly been used to restore edentulous areas. However, the high incidence of peri-implant disease has posed a challenge and limits the predictability of implant treatment. Dental implants are being used by over 5.6% of the general population, and that trend is increasing.[1] Notably, older age groups have seen a 13-fold increase in implant use from 1999-2000 to 2015-2016 compared to younger adults.[1] While implants represent a substantial advancement in restoring edentulous space, the prevalence of complications associated with implant treatment is also increasing.

Complications related to the implant fixture can be categorized as failure to either achieve or maintain osseointegration. Osseointegration, as defined by Branemark et al., refers to the direct structural and functional connection between living bone and the surface of a load-bearing implant.[2] Failure to establish initial osseointegration is deemed an early complication; failures that occur after established osseointegration are considered late complications, and can be further categorized as mechanical or biological. Biological complications may manifest either as inflammation around the implant without bone loss, termed peri-implant mucositis, or as pathologic bone loss beyond physiologic remodeling, known as peri-implantitis which can ultimately lead to implant loss.[2] A systematic review and meta-analysis by Atieh et al. in 2013 reported 63.4% frequency of peri-implant mucositis among participants and 30.7% of implants, and peri-implantitis in 18.8% of participants and 9.6% of implants.[3] More recently, Diaz et al. found that the prevalence of peri-implantitis had increased to 19.53% at the patient level and 12.53% at the implant level.

Numerous studies have delved into the possible causes of peri-implant disease, yet a consensus regarding the key risk factors and their relative significance remains uncertain. For instance, Atieh et al. discovered a notably higher prevalence of peri-implant diseases among smokers, with a recorded frequency of 36.3%. They also found that supportive periodontal therapy appeared to reduce the rate of occurrence.[3] Renvert et al. in 2013 completed a retrospective study of 172 patients receiving dental implants and found individuals with a history of cardiovascular disease had an odds ratio of 8.7 for developing peri-implantitis, and those with a history of periodontitis had an odds ratio of 4.5. However, no correlation was found between smoking and gender.[5] Monje et al. determined that the risk of peri-implantitis was 50% higher in patients with diabetes than those without diabetes.[7] Similarly, Daubert et al. conducted a cross-sectional study, identifying that patients with diabetes exhibited up to three times the relative risk of peri-implantitis compared to healthy individuals.[8] Additionally, Monje et al. reported that adherence to peri-implant maintenance protocols was associated with an 86% reduction in the incidence of peri-implantitis at the patient level, emphasizing the importance of maintenance in preventing peri-implant disease.[9]

Though there is considerable debate as to which risk factors are more heavily implicated in peri-implant diseases, it is imperative that the dental provider discuss the potential impact of these risks with patients who may be candidates for implant treatment. This necessitates a meticulous examination of the patient's medical history and clinical findings to assess and convey the overall risk associated with implant therapy. A study conducted by Insua et al. underscores the prevalent misperceptions among patients regarding implant therapy, revealing 74.1% of surveyed participants with no knowledge of peri-implantitis and 70.4% of patients under the false belief that ‘‘implants are a life-lasting treatment’’.[10]

In the realm of implant therapy, identifying risk factors contributing to unfavorable outcomes can be achieved through a thorough patient interview and examination. Currently, three primary tools for assessing implant risk have been developed. The first of these tools is the SAC, which stands for "straightforward, advanced, complex," assessment tool. It was introduced during the SAC Consensus Conference at the International Team for Implantology (ITI) conference in 2007.[11] The tool has evolved but is primarily meant to objectively classify the complexity and overall treatment risk of an implant rehabilitation case from surgical and restorative perspectives. Its purpose is to assist clinicians in gauging the perceived difficulty of treatment and to determine whether the case aligns with their skill level, thereby potentially mitigating risk, especially for less experienced practitioners. For the experienced clinician, it serves as a comprehensive checklist to ensure all pertinent risks for the patient have been thoroughly considered. Lastly, the tool is meant to facilitate patient education and improve communication between patient and provider.[12] The SAC tool has been validated regarding agreement between users of the tool but has not been validated in terms of implant outcomes.[11]

Another notable tool, introduced by Heitz-Mayfield in 2020, is the Implant Disease Risk Assessment (IDRA), specifically designed to assess the risk of peri-implantitis. This tool evaluates eight key factors: history of periodontitis, bleeding on probing, probing depths, bone loss relative to the patient's age, susceptibility to periodontitis, compliance with supportive periodontal therapy, distance from the prosthesis margin to the bone crest, and prosthesis-related factors such as cleansability and fit.[13] IDRA was evaluated in a retrospective study by De Ry et al.. This study found an odds ratio of 2.27 for developing peri-implantitis in patients identified as high risk. Although multiple study limitations were noted, including a small sample size and limited generalizability due to a patient pool from a university setting, this paper supports the

utility of such a tool to predict peri-implant disease and increase patient awareness of these risk factors.[14]

The focal point of this study is a risk assessment tool introduced in the publication "Patient-Centered Risk Assessment in Implant Treatment Planning" by Curtis et al. in 2019. This tool offers a comprehensive assessment of implant-related risks, aiding in clinical recommendations based on individual and aggregate risk factors (**Figure 1**).[16] The primary purpose of the risk assessment tool is to enhance communication between providers and patients during the planning stages of implant treatment, while also identifying pertinent risk factors, particularly those associated with late biological complications. The development of this tool involved a meticulous review of current literature on risk indicators, supplemented by the Delphi process, wherein experts in prosthodontics and periodontics deliberated on the inclusion of relevant risk indicators. The tool is primarily designed to assess any late biological complications of peri-implantitis, implant loss, and non-inflammatory processes of bone remodeling, especially in cases with minimal buccal bone. It incorporates subscales and weighting for 20 risk indicators categorized into three main areas: 1) patient history, 2) clinical findings, and 3) clinician decisions and post-implant placement findings. The output score of the tool classifies patients as low risk (less than 6 points), medium risk (6-10 points), or high risk (greater than 10 points), offering clinicians insights into the patient's aggregate risk score. Despite its development, this risk assessment tool has not undergone validation in a prospective clinical study. Therefore, this prospective study aims to validate the sensitivity, specificity, positive predictive value, and negative predictive value of this risk assessment tool over a one-year follow-up period.

MATERIALS AND METHODS

Participant recruitment involved identifying eligible patients for implant placement from the UCSF Post-Graduate and Faculty Periodontics and Prosthodontics Clinics. Upon recruitment, patients were provided consent forms to participate in the study, after which the provider completed the initial portion of the Implant Risk Assessment Questionnaire (RAQ) concerning patient history and clinical findings. Patient history details, including recent diabetes diagnosis and glycated hemoglobin (HbA1c) levels within the preceding three months, were meticulously verified to ensure accuracy for this survey segment. In appointments following implant restoration, the clinician answered the remaining questions on clinical decisions and post-implant placement findings to finalize the RAQ for each patient.

For this study, a follow-up period of at least one year following implant final restoration or final prosthesis loading was used to conclude a diagnosis of peri-implant health, peri-implant mucositis, or peri-implantitis. The 2017 World Workshop Criteria for diagnosis of implant health was utilized. Health was diagnosed as an asymptomatic implant without any thread exposure, bleeding on probing, suppuration, or bone loss beyond initial remodeling. Any implant with bone loss beyond 2mm from the time of final prosthesis delivery was deemed to have peri-implantitis, whereas implants without at least 2 mm of bone loss, bleeding, and suppuration were considered to have peri-implant mucositis.[17] Implants were clinically evaluated six months and one year after restoration. The final diagnosis was determined by the patient's surgeon and a faculty member and verified by an investigator at the time of chart and radiograph review. Additional information on the patient's gender, medical history, implant system used, bone or soft tissue grafting, and restoration type was retrieved from the patient chart. Exclusion criteria included patients not eligible for implant treatment in the UCSF Periodontal, General Dentistry, or

Prosthodontic clinics or those lost to follow-up. Implants that failed before the time of final prosthesis delivery or before the 1-year follow-up were not included in the final statistical calculations, but data from their chart review and survey questions were still included for qualitative analysis.

Statistical Analysis

RAQ scores underwent two conversions into corresponding disease categories. The first wherein a "Low" RAQ score of <6 points was designated as "Health," a "Medium" score between 6-10 points was categorized as "Peri-implant mucositis," and a "High" score >10 points was labeled as "Peri-implantitis." In the second conversion, both a "Low" RAQ score of <6 points and a "Medium" score between 6-10 points were was considered to be "Health," and a "High" score of>10 points was deemed as "Peri-implantitis. These classifications were then compared with implant diagnoses of health, peri-implant mucositis, and peri-implantitis that were determined at the one-year (minimum) post-implant final prosthesis delivery and loading follow-up appointment to ascertain sensitivity, specificity, positive predictive value, and negative predictive value. Given that these computations necessitate a binary outcome, the diagnosis categories of peri-implant mucositis and peri-implantitis were combined into a singular "disease" category for the first conversion. For the second conversion, the diagnosis of peri-implantitis was the "disease" category and the diagnosis categories of peri-implant mucositis and implant health were combined into a singular "health" category. Additional chart information, including patient medical history, medications, implant specifications, implant brand, and bone or soft tissue augmentation, were evaluated by average scores corresponding to disease outcome categories to identify trends in these risk factors.

To improve the predictive value of the RAQ for short-term usage, a monothetic analysis approach was conducted to increase sensitivity and positive predictive value. Additionally, averages for each survey question within health, peri-implant mucositis, and peri-implantitis diagnosis groups were computed. Questions with higher mean scores in health compared to peri-implant mucositis, and peri-implantitis were taken out of the survey output calculation. By removing questions concerning treated periodontitis, smoking, tissue phenotype, maxillary posterior placement, restoration emergence angle, and clinician experience, an adjusted survey output was computed, as illustrated in **Figure 2**.

RESULTS

The study enrolled patients before dental implant placement, comprising 73 patients with 187 implants. Before implant placement, each patient consented to the study and the surgeon answered survey questions regarding patient factors and clinical findings. Following implant placement, the surgeon completed survey questions regarding perioperative clinician decisions. 35 patients totaling 87 implants, participated in the one-year follow-up and were consequently included in the results of this study. Of the final study pool, 24 were male (68.57%) and 11 were female (31.43%). Demographic information was collected from the patient's chart and survey responses then compiled for both patient and implant-level data as shown in **Table 1**.

RAQ scores were translated into predicted one-year diagnosis outcomes, such that a "Low" score of <6 points was "Health," a "Medium" score of 6-10 points was "Peri-implant mucositis," and a "High" score of >10 points was "Peri-implantitis." Initial RAQ outputs from the survey questionnaire were skewed towards Medium and High scores, indicating a propensity for disease around implants. This was not representative of the sample diagnosis outcomes,

resulting in an initially poor sensitivity and negative predictive value as seen in **Table 2** and **Figure 2**. Our statistical analysis revealed that by removing the categories of treated periodontitis, smoking, tissue phenotype, maxillary posterior placement, clinician experience, and restoration emergence angle we were able to improve the short-term predictive accuracy of the RAQ. Subsequently, sensitivity increased from 22.58% to 75.81%, while specificity decreased from 100.0% to 52.00%. The positive predictive value shifted from 100.0% to 79.66%, whereas the negative predictive value improved from 34.25% to 46.43% (**Table 7**).

When comparing the predictive efficacy of the RAQ at the six-month and one-year intervals, a noticeable improvement in its predictive value preceding any alterations was observed. At the six-month diagnosis, the unadjusted sensitivity was recorded at 18.18%, with a corresponding specificity of 80.7%. The positive predictive value and negative predictive value were 61.54% and 36.4% respectively. Over the subsequent one-year period, all metrics exhibited improvement, as demonstrated in **Table 3.** This trend underscores the increasing accuracy of RAQ in disease identification over time. This is further demonstrated by excluding identical categories in the six-month diagnosis as in the one-year follow-up. In doing so there was a notable surge in sensitivity from 18.18% to 65.91%, in negative predictive value from 36.4% to 44.44%, and in positive predictive value from 61.54% to 67.44%.

In the second data conversion, “Peri-implant Mucositis” was combined with the “Health” category to shift the survey focus away from mucosal implant inflammation and towards implant bone loss. The results in the raw data experienced an increase in sensitivity from 22.58% to 45.57%. When the data was adjusted to exclude the same categories (i.e. treated periodontitis, smoking, tissue phenotype, maxillary posterior placement, clinician experience, and restoration emergence angle) the sensitivity continued to increase from 75.81% to 94.9% (**Table 4**).

Data on four early implant failures was compiled to review potential risk factors that lead to failures and was not included in the final results. All failures occurred in males with a history of bone grafting and bruxism – among them, one patient was a smoker, one had diabetes, two had hypertension, one had a history of cancer, 50% of implants were bone level, 50% were tissue level, and two of the implants were placed in the maxillary posterior location (**Table 5**). The sample size was not sufficient to run additional analysis.

DISCUSSION

Throughout the study, the advantages of utilizing the RAQ tool became apparent through increased communication between healthcare providers and patients regarding implant-related risks and preventive measures. The outcomes of this study provide preliminary validation of the RAQ tool in the short term. However, it is important to note that this validation is not exhaustive, as certain risk indicators may require a longer timeframe to manifest fully. Notably, refining the tool by omitting six questions led to improved predictive capacity for short-term applications. Nevertheless, more extensive follow-up studies are imperative to fully validate these findings.

The decision to exclude certain questions from the patient history and clinical findings sections regarding smoking, treated periodontitis, clinician experience, restoration emergence angle, maxillary posterior placement, and tissue phenotype as short-term risk indicators is aimed at improving the RAQ predictive capability regarding implant-related diseases. While the removal of these factors was made on speculative grounds, the observed effects could be attributed to inadequate follow-up, given that many of these risk indicators have been documented to correlate with peri-implant disease in published literature.

Several factors contributed to the inconclusive effect of smoking as a predictive factor for peri-implantitis. Firstly, it is possible that smoking may not reliably predict peri-implantitis. Current literature shows mixed results on the effects of smoking on peri-implant health. For example, Berglundh et al. found the relationship between smoking and peri-implants to be inconclusive.[18] In addition, Aguirre-Zorzano et al. showed no significant association between smoking and peri-implantitis.[19] Confounding variables, like a history of periodontitis, as noted by Schwarz et al., may obscure the true relationship between smoking and implant health.[20] Conversely, several prospective studies show an association between smoking and peri-implantitis. Bain et al. revealed a significantly higher failure rate among smokers compared to non-smokers, suggesting a link between smoking and peri-implantitis outcomes.[21] Furthermore, Chrcanovic et al., Bergstrom et al., Strietzel et al., and Heitz-Mayfield et al. all conclude that smokers experience more implant complications than non-smokers.[22-25] Another factor that could explain the lower predictive value of smoking is that the relatively short duration of our one-year follow-up period may have limited our ability to capture the downstream impact of smoking on implant health. Lambert et al. reported that the effects of smoking become more pronounced over time, particularly around the three-year mark.[26] Extending the follow-up period could potentially reveal a higher incidence of implant failure in the smoking group.

The proportion of smoking patients within our sample cohort (4.84%) may also be insufficient to draw definitive conclusions regarding the relationship between smoking and peri-implantitis. However, despite the small cohort size, notable patterns emerge, such as all cases of smoking patients with peri-implantitis occurring in the maxilla. Lambert's findings also support this, indicating that implant failure rates in the maxilla among smokers are twice as

likely compared to non-smokers.[26] While smoking did not improve the sensitivity of the RAQ, more research needs to be done to determine the long-term effects of smoking on implant health.

There exists substantial evidence supporting a correlation between a history of treated periodontitis and peri-implantitis. For instance, Souza et al. discovered that implants placed in patients with a history of treated periodontal disease exhibited a heightened incidence of biological complications, lower success rates, and diminished survival rates compared to those in healthy patients without a history of periodontal disease.[27] More recently, Ferreira et al. found that patients with a history of periodontitis were at a 2.29 times greater risk of developing peri-implantitis.[28] Nevertheless, this correlation is nuanced, as the risk of peri-implantitis is related to the severity of periodontal disease. In a prospective study, Swierkot et al. observed that partially edentulous patients with treated Stage III grade C molar incisor pattern exhibited a five-fold greater risk of implant failure, a three-fold greater risk of mucositis, and a fourteen-fold greater risk of peri-implantitis compared to periodontally healthy patients.[29]

A potential explanation for the lack of predictive value found in our study regarding treated periodontal disease and peri-implant disease may be the result of peri-implant disease associated with treated periodontitis not manifesting within the one-year follow-up period. It is conceivable that with a longer duration of follow-up, the predictive significance of a history of periodontitis could become more apparent. Additionally, our approach to evaluating predictive value may have overlooked the influence of other factors on the history of periodontitis. Specifically, there could be a correlation between a history of periodontitis and patient compliance. Research conducted by Costa et al. has indicated that patients with a history of periodontitis who adhere well to maintenance care tend to have a reduced risk of peri-implantitis compared to those with a history of periodontitis who have erratic maintenance.[30] Subsequent

analyses could investigate whether the predictive value of treated periodontitis diminishes in cases where patients demonstrate full compliance with maintenance care.

The omission of clinician experience in our study was decided due to a disproportionate skew towards inexperienced clinicians in the survey population, with the majority of implants being placed by residents rather than by faculty providers in the Postgraduate Periodontics Residency Clinic. It is worth noting that a 2017 systematic review and meta-analysis conducted by Sendyk et al. found that surgeon inexperience, defined as those who had placed fewer than 50 implants, significantly impacted implant failure rates. The odds ratio for inexperienced surgeons was 2.18.[31] In our study, 85% of patients had implants placed by clinicians classified as inexperienced. This aspect is likely to gain more relevance with a more diverse study population, as it could better elucidate the impact of clinician experience on implant outcomes.

Despite significant evidence correlating an emergence angle greater than 30 degrees to an elevated risk of peri-implantitis, the exclusion of this risk factor surprisingly improved predictive capability. Serino et al. revealed that 48% of implants diagnosed with peri-implantitis lacked accessibility for oral hygiene, contrasting with only 4% of implants that did possess such access.[32] This finding was corroborated by Katafuchi et al., who observed a higher incidence of peri-implantitis (31.3%) in bone-level implants with a restoration emergence angle exceeding 30 degrees, compared to bone-level implants with an angle below 30 degrees (15.1%).[33] Again, the absence of a significant impact of a 30-degree emergence angle on the predictive capability of the RAQ study could be attributed to the limited one-year timeframe, which may not have allowed sufficient time for peri-implantitis to manifest in this particular population. Moreover, it is plausible that patients with implants featuring significant emergence angles were able to maintain their implants through regular recall visits.

Literature that examines the location of implant placement as a predictor for peri-implantitis exhibits inconsistency. In the original RAQ paper by Curtis et al., a survey question regarding implant placement in the maxillary posterior was employed as a proxy for Type IV bone density – known to be the least dense bone in the oral cavity. This choice was based on a 2014 systematic review by Goiato et al., which indicated lower survival rates for implants inserted into Type IV bone (88.8%) compared to Types I, II, and III (97.6%, 96.2%, and 96.5% respectively).[35] However, a more recent systematic review and meta-analysis conducted by Song et al. in 2020 revealed a higher prevalence of peri-implantitis in the maxillary and mandibular anterior regions compared to the maxillary posterior region.[36] In our pilot study, the utilization of the maxillary posterior site as a predictor may not have been effective for several potential reasons: the one-year follow-up period may not have been adequate to detect significant bone destruction in this region for diagnosing peri-implantitis or this risk indicator might not strongly predict bone loss or implant failure. Studies by Goiato et al. also suggested that the survival rate of implants placed in the posterior region may be higher if they are surface-treated implants rather than machine-treated implants.[35] It is plausible that the relationship between implant type and the location of implant placement could modify the effect of the risk factor, thereby making its predictive value less straightforward. Notably, among the four early failures observed in our patient sample, two occurred in the maxillary posterior region.

The exclusion of tissue phenotype from the adjusted statistics warrants consideration given the substantial evidence supporting its influence on implant health. One potential explanation for its limited predictability is that the tissue phenotype characteristic noted during examination likely occurred before any augmentation procedures were undertaken. A systematic review and meta-analysis conducted by Tavelli et al. in 2020 revealed that tissue phenotype

modification techniques, such as soft tissue augmentation affecting keratinized mucosa width, mucosal thickness, and supracrestal tissue height, were associated with favorable outcomes including reduced probing depth, decreased incidence of soft tissue dehiscence, and improved plaque control compared to non-augmented sites.[38] Importantly, these parameters could significantly impact the final implant diagnosis. Given that these augmentation techniques may have been performed after the completion of the survey, the timing of tissue phenotype evaluation is not specified. Consequently, the utility of this survey question may be limited short term, and its predictive capacity could be improved with longer study follow-up or clearer specification of the timing of tissue phenotype assessment relative to implant treatment.

Although the RAQ survey exhibits limited predictive capacity during one year, there is a possibility of its accuracy improving with time. This notion is evidenced by comparing the predictive values of the RAQ at six months and one year. Despite the relatively short six-month difference, there was a significant increase in sensitivity from 18.18% to 22.95% (**Table 3**) . It is conceivable that without any modifications to the RAQ, sensitivity may further improve as the follow-up duration extends. Subsequent research on the RAQ could explore its predictive value at various time intervals to ascertain if this upward trend persists. The observed increase in sensitivity supports the notion that risk indicators previously excluded from consideration may become more discernible at later time points.

Additionally, the RAQ survey offers increased sensitivity for identifying implant disease with bone loss rather than implant disease with mucosal inflammation. The increase in sensitivity was observed when patients were divided into “Health” or “Peri-Implantitis” after “Peri-implant Mucositis” was removed as a disease category. Adjusting the use of the RAQ survey levels (i.e. “Low”, “Medium”, and “High”) to measure correlation of level with the risk of peri-implantitis

instead of the initial analysis correlating with disease progression, resulted in sensitivity increases in the raw data from 22.57% to 45.57%. This demonstrates that the RAQ survey has increased accuracy for detecting complications at the bone-level rather than at the implant mucosal level. The RAQ survey may be best suited for long-term implant complications rather than short-term complications as bone-level complications manifest more slowly than implant mucosal complications.

One potential focus for a new RAQ survey could be on early pre-prosthesis delivery, failures, or implant loss. This subset of the study population, including four failures in four different individuals, could only complete the first part of the survey, thus their RAQ scores were not usable. **Table 5** highlights the different risk factors found in this group as collected from chart reviews and survey responses. A new survey for early implant loss could include a different scale that correlates to different peri-implant outcomes based on scoring from only the first part of the survey. The inclusion of cancer history and cardiovascular disease as risk indicators, as was seen in this population subset, for the early implant loss survey may also be indicated, though larger-scale studies would be necessary to verify this.

As the study progressed through patient recruitment and follow-up, several limitations in the study design became apparent. One notable drawback is the potential inadequacy of a one-year implant follow-up period to reliably establish an implant diagnosis. Moreover, there was a lack of calibration amongst providers regarding specific time points to which each question in the survey pertained or how to address modifiable risks. Survey and recall biases emerged as significant concerns, as providers were inclined to subjectively report their work, potentially favoring their outcomes compared to an impartial evaluator. Investigators were not blinded to patient and implant history during follow-up, which may have introduced bias in the

final diagnosis determination. Furthermore, there was a lack of standardization in radiograph acquisition for bone level comparison at the various stages of implant placement, prosthesis delivery, and follow-up. These limitations emphasize the need for caution in interpreting study findings and highlight areas for improvement in future research endeavors.

In the original paper by Curtis et al., the RAQ tool was introduced as an initial survey and conceptualized as a dynamic document subject to refinement over time. Since its publication, a significant body of research has developed, contributing to ongoing debates and enhancing our understanding of factors pertinent to the RAQ tool. Amongst these factors, the RAQ survey focuses primarily on the current usage of selective serotonin reuptake inhibitors (SSRIs), and recent studies have identified specific SSRIs such as Sertraline as potential contributors to implant failure. Other investigations have explored the impact of various classes of antidepressants beyond SSRIs on implant outcomes.[44,45] Emerging studies, such as that of Wu et al., have started to examine new potential risk factors, specifically proton pump inhibitors and their impacts on implant failure.[40] As novel evidence continues to provide insights into various risk factors and their respective influences on peri-implant disease, it is inevitable that the RAQ tool will undergo continuous modification and refinement to align with the evolving understanding of implant treatment risk assessment.

CONCLUSION

The RAQ may have limited utility in its original form to identify cases of health and disease on a short-term basis; however, if modified to omit certain risk categories, its predictive capacity may be clinically acceptable. A long-term follow-up study is necessary to evaluate the validity of the original RAQ survey tool across different risk categories. While the clinical

significance of correlating RAQ scores to short-term implant health may be constrained, the RAQ retains its importance as a tool for heightening clinician awareness about the risk indicators associated with implant therapy. Significantly, this study initiates discussions about implant risk among patients and other providers, thereby facilitating informed decision-making in the clinical setting.

Part 1: Risk Indicators Based on Patient History		
Risk Indicators		**Points**
Smoking		
	≤5 cigarettes/day	1
	6-20 cigarettes/day	3
	>20 cigarettes/day	6
Diabetes at the Time of Implant Placement		
	Controlled or prediabetic Hb1AC <6.5%	0
	Hb1AC levels above >6.5%-8%	3
	Hb1AC levels above >8%	6
Implant Placement Site		
	Site of Previous Implant Loss	2
Use of Antiresorptive Agents		
	Oral antiresorptive	0
	Currently using IV antiresorptive agents for treatment of osteoporosis without MRONJ history	4
	Currently using IV antiresorptive agents for cancer treatment	Red Flag
	Patients with any stage of MRONJ	Red Flag
SSRI usage		
	Current use of SSRI	1
PPI usage		
	Current use of PPI	1
Irradiation		
	History of irradiation to the head and neck	Red Flag

Figure 1a. Implant Risk Assessment Questionnaire (RAQ) Part 1: Risk Indicators Based on Patient History

Part 1: Risk Indicators Based on Clinical Findings			
Risk Indicators		**Points**	
Periodontal Disease		**Treated/Inactive**	**Untreated/Active**
	Aggressive Periodontitis	6	Red Flag
	Moderate/Severe Periodontitis	4	6
	Slight Chronic Periodontitis	2	4
Plaque levels (Plaque Index)			
	Moderate Plaque PI >20% to 50%	2	
	Heavy Plaque PI >50%	4	
Tissue Biotype/Phenotype			
	Thin	2	
Parafunctional Habits			
	Bruxism	3	
Implant Location			
	Maxillary Posterior	2	
Clinician Experience			
	Inexperienced Clinician	3	

Figure 1b. Implant Risk Assessment Questionnaire (RAQ) Part 1b: Risk Indicators Based on Clinical Findings

Part 2: Risk Indicators Based on Clinical Decisions and Post-Implant Findings		
Risk Indicators		**Points**
Soft Tissue		
	Lack of 2mm attached tissue around the implant	2
	Distance <3mm from peri-implant tissue margin to the bone crest	2
Bone		
	<2 mm of buccal bone at implant site	4
Implant Position		
	<3mm to adjacent implant	4
	<1.5 mm to adjacent tooth	4
Prosthesis Design		
	Prosthesis limits access for cleaning resulting in an increase in bacterial load	6
Cemented Restorations		
	Cemented at or above the gingival margin	2
	Cemented and subgingival	4
Recall Compliance		
	Poor compliance	3
Biologic Width		
	Not accommodating for biological width with the implant/prosthesis design	2

Figure 1c: Implant Risk Assessment Questionnaire (RAQ). Part 2: Risk Indicators Based on Clinical Decisions and Post-Implant Findings.

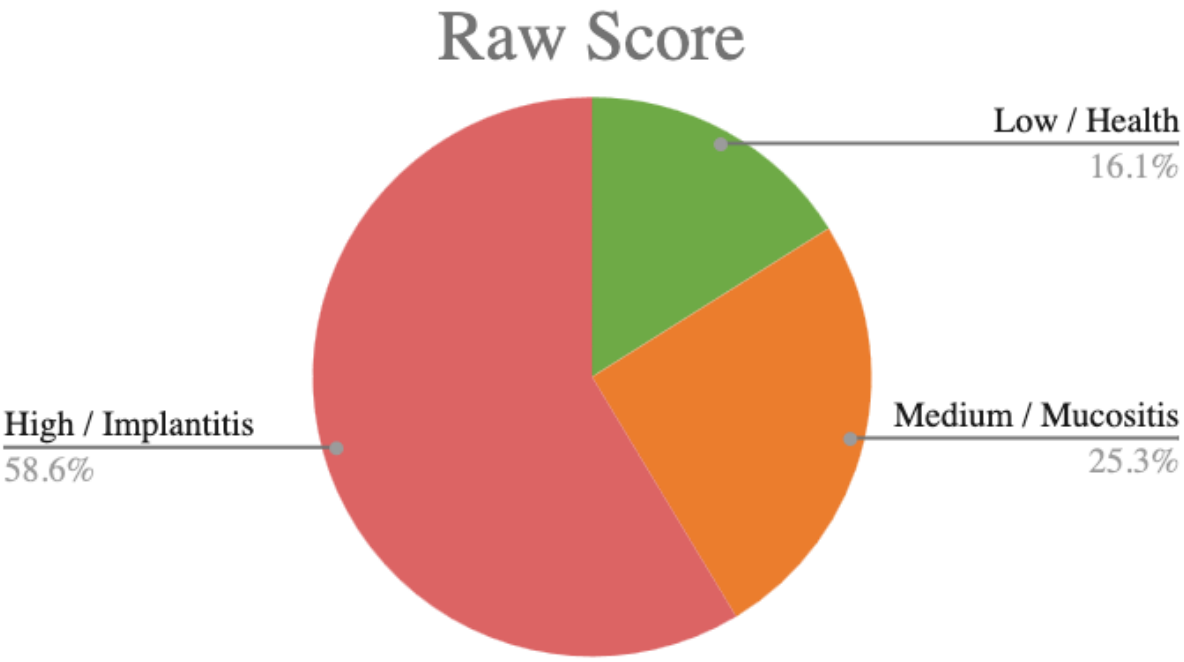

Figure 2a: Pie Charts of Raw and Adjusted RAQ Scores versus 1-Year Diagnoses Percentiles

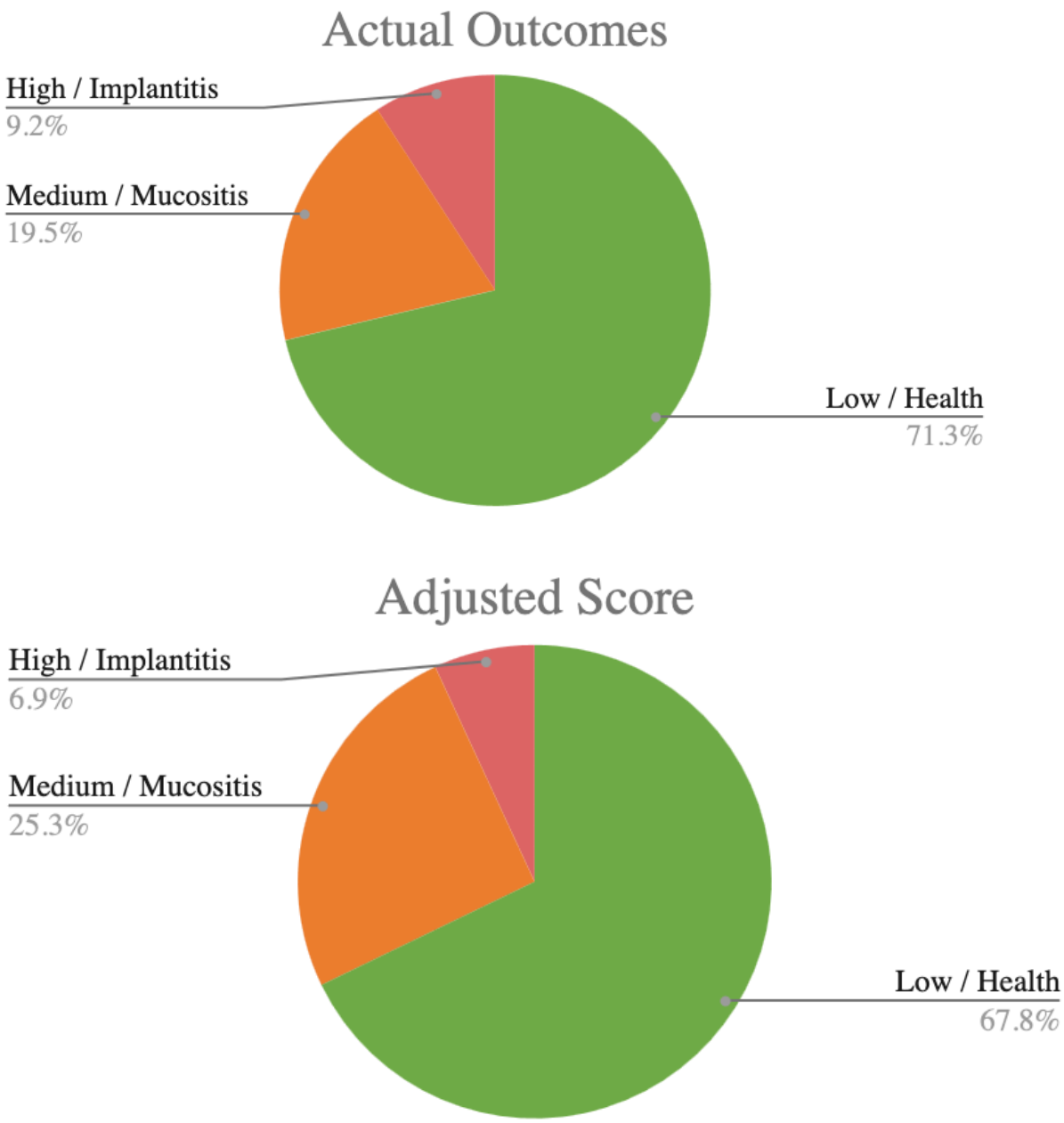

Figure 2b: Pie Charts of Raw and Adjusted RAQ Scores versus 1-Year Diagnoses Percentile**:** continued

Table 1a: Survey Responses. Demographic Data from Chart and Survey Questions

Chart Review			
Patient Level		**Implant Level**	
Gender		**Implant Company**	
Male	68.57%	Straumann	47.73%
Female	31.43%	Nobel	52.27%
Antidepressant Medication		**Implant Platform**	
Yes	14.29%	Bone Level	89.77%
No	85.71%	Tissue Level	10.23%
Diabetes Mellitus		**Bone Graft**	
Yes	5.71%	Yes	55.68%
No	94.29%	No	44.32%
Cardiovascular Disease		**Sinus Lift**	
Yes	22.86%	Vertical Lift	7.95%
No	77.14%	Lateral Lift	4.55%
Cancer History		No	87.50%
Yes	11.43%	**Soft Tissue Augmentation**	
No	88.57%	Yes	10.23%
Smoking History		No	89.77%
Previous Smoker	25.71%	**Restoration Type**	
Current Smoker	11.43%	Screw-retained Crown	94.32%
Total Smokers	34.29%	Cement-retained Crown	5.68%

Table 1b: Survey Responses. Implant and Patient Data from Chart and Survey Questions

Survey Questions			
Part 1 Survey Questions (Patient Level)		**Part 2 Survey Questions (Implant Level)**	
Smoking Status (cigarettes/day)		**Previous Implant Site Failure**	
Not smoking	93.65%	No	96.40%
<5	0.00%	Yes	4.60%
6-20	3.17%	**Maxillary Posterior**	
>20	3.17%	No	70.11%
Diabetic Status (HbA1c)		Yes	29.89%
Not diabetic	90.63%	**2mm Attached Tissue**	
5.7-7%	7.81%	Yes	91.79%
7-8%	1.56%	No	8.21%
>8%	0.00%	**3mm Coronal Tissue**	
Antiresorptive Use		Yes	93.85%
None	98.41%	No	6.15%
Oral	1.59%	**2mm Buccal Bone**	
Intravenous for osteoporosis	0.00%	Yes	91.97%
Intravenous for cancer	0.00%	No	8.03%
SSRI Use		**Mesio-distal Space Adequate**	
Yes	6.25%	Not from implant	5.11%
None	93.75%	Not from tooth	2.19%
PPI Use		Yes	92.70%
Yes	7.81%	**Cement-Retained Restoration**	
None	92.19%	Yes, supragingival margin	5.74%
H&N Radiation (55Greys)		Yes, subgingival margin	1.64%
Yes	1.59%	No	92.62%
None	98.41%	**Compliant with Recall**	
Treated Periodontitis		Yes	71.76%
No	51.56%	No	28.24%
Yes, slight chronic	14.06%	**Biologic Width Acceptable**	
Yes, moderate/severe chronic	34.38%	Yes	94.44%
Yes, aggressive	0.00%	No	5.56%

Table 1c: Survey Responses. Implant Data from Chart and Survey Questions Post Loading

Survey Questions			
Part 1 Survey Questions (Patient Level)		**Part 2 Survey Questions (Implant Level)**	
Active Untreated Periodontitis		**Limited Hygiene Access: "30 degree Emergence Angle"**	
No	95.31%	Yes	32.28%
Yes, slight chronic	1.56%	No	67.72%
Yes, moderate/severe chronic	3.13%		
Yes, aggressive	0.00%		
Plaque Levels			
Light	67.19%		
Moderate	31.25%		
Heavy	1.56%		
Bruxer			
Yes	43.08%		
No	56.92%		
Clinician (# of Implants Placed)			
<50	85.94%		
50+	14.06%		

Table 2: Final Diagnosis from within the Survey Question Scores Counts

1 Year Diagnosis		
	Counts	% of Total
Low - Health	62	71.06%
Medium - Mucositis	17	19.54%
High - Peri-Implantitis	8	9.20%
Total	87	100.00%

Table 3: 6 month and 1 year RAQ Validity Metrics

6-Month Validity Measurements Raw			
PPV	NPV	Sensitivity	Specificity
61.54%	37.29%	17.78%	81.48%
Total patients:72			

1-Year Validity Measurements Raw			
PPV	NPV	Sensitivity	Specificity
100.00%	15.69%	45.57%	100.00%
Total patients:87			

Table 4: Adjusted versus Raw Survey Validity Metrics without Peri-implant Mucositis

Raw		Adjusted	
PPV	100.00%	PPV	92.59%
NPV	15.69%	NPV	33.33%
Sensitivity	45.57%	Sensitivity	94.94%
Specificity	100.00%	Specificity	25.00%

Table 5: Early (Pre-prosthesis Delivery) Failures Risk Factor

Implant Failure Cases				
	Individual 1	**Individual 2**	**Individual 3**	**Individual 4**
Implant Failure Site #	28	3	23	14
Age	60	53	57	69
Gender	Male	Male	Male	Male
Bone Graft	Bone graft at implant placement	External Sinus	Bone graft at implant placement	Internal Sinus
Implant Platform	Bone Level	Tissue Level	Bone Level	Tissue Level
Implant Company	Straumann	Straumann	Nobel	Straumann
Antidepressant Medication	No	No	Yes	No
Diabetes Mellitus	No	No	Yes	No
Cardiovascular Disease	No	No	Yes	Yes
Current / Past Smoker	Yes	No	No	No
Treated Periodontitis	No	No	No	Yes, moderate-severe chronic periodontitis
Plaque Levels	Moderate	Low	Moderate	Low
Tissue Phenotype	Thick	Thin	Thick	Thick
Bruxer	Yes	Yes	Yes	Yes
Maxillary Posterior	No	Yes	No	Yes
Clinician Implant Experience #	<50	<50	<50	<50

Table 6: Raw and Adjusted Survey Output Compared to 1-Year Diagnosis Outcomes

Raw RAQ Outcome		
	Counts	% of Total
Low - Health	14	16.09%
Medium - Mucositis	22	25.29%
High - Peri-Implantitis	51	58.62%
Total	87	100.00%

Adjusted RAQ Outcome		
	Counts	% of Total
Low - Health	59	67.82%
Medium - Mucositis	22	25.29%
High - Peri-Implantitis	6	6.90%
Total	87	100.00%

Table 7: Adjusted versus Raw Survey Validity Metrics

Raw		Adjusted	
PPV	100.00%	PPV	79.66%
NPV	34.25%	NPV	46.43%
Sensitivity	22.58%	Sensitivity	75.81%
Specificity	100.00%	Specificity	52.00%

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