

Clinical assessment of malnutrition risk screening tools among individuals with dentures

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Research Article

Keywords: Malnutrition risk screening tools, complete dentures, nutrition screening initiative, mini nutritional assessment-short form, malnutrition screening tool

Posted Date: September 24th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10960887/v1>

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Additional Declarations: No competing interests reported.

Title: Clinical assessment of malnutrition risk screening tools among individuals with dentures

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Abstract:

Objective

Tooth loss impairs chewing efficiency, which in turn is associated with improper food intake and nutritional status. Therefore, monitoring the impact of dental treatments on patients' oral and nutritional health is essential. This study evaluated the relationship of malnutrition risk scores obtained from malnutrition-risk screening (MS) tools to select nutritional markers from laboratory tests and dietary intake in denture-wearing individuals. Further relationships between malnutrition risk scores and denture wearing characteristics were explored. The ease of use of these MS tools was also assessed.

Methods

We conducted a cross-sectional clinical observational study among individuals (N=93) aged 50 years and older who wear removable complete dentures, immediate, or overdentures. They completed three malnutrition-risk screening tools: Nutrition Screening Initiative (NSI), Mini Nutritional Assessment-Short Form (MNA-SF), and Malnutrition Screening Tool (MST), provided blood samples, reported their dietary intake using the automated self-administered (ASA24®) tool, and completed the System Usability Scale (SUS) questionnaire for each MS tool. Descriptive statistics and Spearman correlation were performed to summarize and assess associations among malnutrition risk scores, a panel of serological laboratory values, specific nutritional markers, 24-hour dietary intake, and SUS scores.

Results

The mean age of the 93 study participants was 71 years. The NSI, MNA-SF, and MST identified malnutrition risk in 74%, 37%, and 28% of participants, respectively. NSI risk scores were significantly lower with a longer denture-wearing period ($p=0.012$). Spearman's correlation revealed a higher risk of malnutrition with MST correlated with lower vitamin K1 and lower zinc. Spearman's correlation also revealed a higher risk of malnutrition with NSI and lower zinc. Less vegetables ($p=-0.223$, $p=0.031$) and potassium ($p=0.210$, $p=0.044$) intakes correlated with MST and MNA-SF, respectively. SUS scores were acceptable for the three MS tools (>68), with no significant differences ($p>0.05$) between tools.

Conclusion

The results demonstrate the potential of using these MS tools to detect individuals at risk of malnutrition during dental treatments that affect chewing efficiency.

Clinical relevance

The study demonstrates the significance of implementing malnutrition risk screening tools among denture wearing patients in a clinical dental setting.

Keywords: Malnutrition risk screening tools, complete dentures, nutrition screening initiative, mini nutritional assessment-short form, malnutrition screening tool

Introduction:

One of the fundamental principles of maintaining a healthy life is adhering to a balanced diet and nutrition, which promotes overall systemic health and, in turn, supports proper oral health. With public health advances such as the use of fluoride, there has been a decrease in edentulism among US adults; however, untreated dental diseases are on the rise among adults aged 50 years and above, accompanied by an increase in tooth loss [1–7]. Edentulism, or the absence of a minimum functional dentition or tooth loss, affects chewing efficiency, healthy food intake, and nutrient uptake, impacting nutritional status [3–10]. Even though tooth loss can be rehabilitated through dentures, there are consequences related to chewing inefficiency, which can lead to malnutrition and a decreased quality of life [11]. Therefore, monitoring the impact of dental treatments on patients' oral and nutritional healthcare is essential. Anecdotal evidence based on conversations with denture wearing individuals revealed adaptation to dentures with years of experience. Dental professionals can be an additional resource for assessing patients at risk of malnutrition, either before or after receiving dentures or while undergoing treatments that affect chewing efficiency.

Malnutrition screening (MS) tools provide an opportunity to identify individuals wearing complete dentures or who have undergone maxillofacial prosthetic surgeries who are at risk for malnutrition. However, MS tools are seldom used in dental settings or practices. Since there are no current standard clinical guidelines to select an MS tool for denture wearing patients, there is more flexibility in choosing the most appropriate MS tool to identify risk for malnutrition among denture wearing patients through evidence based findings [12] [13]. Although validated MS tools, such as the Mini Nutritional Assessment (MNA) form [14–16], Subjective Global Assessment (SGA) [17], Malnutrition Screening Tool (MST) [18], and Malnutrition Universal Screening Tool (MUST) exist [19]; they are seldom used in dental practices, even to screen malnutrition risk among denture-wearing patients [20]. The MNA-short form (SF) [21] has excellent validity and sensitivity, is comparable to the full version MNA, and is recommended for use in dental clinics [22–25]. Also, the Nutrition Screening Initiative (NSI), developed for older Americans [26,27] as a risk appraisal questionnaire, has been proposed for use in dental practices [28,29]. The Academy of Nutrition and Dietetics recommends MST use in diverse populations and across different clinical settings based on the current grade 1 good/strong strength of evidence [30,31].

The Joint Commission recommends the use of validated screening tools for malnutrition risk. However, to enhance the acceptance and adoption of such tools, it is essential to validate their effectiveness in relevant clinical settings, such as dental care, given differences in patient characteristics across settings [32]. To the best of our knowledge, no studies have evaluated the contextual validity or effectiveness of MS tools among patients wearing dentures. This finding is not surprising because historically, dentistry has focused more on treating the outcomes of oral conditions than on routine screening for various risk factors [33,34]. As a result, although several screening tools, including artificial intelligence, exist to assess risk for caries, periodontal disease, and other oral and medical conditions, only limited studies have examined their deployment and effectiveness in improving preventive management in dentistry [35–41]. We have reported previously that diet quality of denture wearing participants from the current study was inadequate [42].

Therefore, this study aims to test the correlation between malnutrition risk scores obtained from MS tools, selected nutritional markers from serological tests, and dietary intake measured using two 24-hour dietary recalls in denture wearers. The ease of using these tools among denture-wearing patients was also assessed. The outcomes of this study provide evidence to identify an appropriate MS tool for detecting malnutrition risk among patients wearing dentures.

Thus, the successful implementation of the MS tool would help improve patient care outcomes and quality of care by identifying individuals at risk of malnutrition.

Materials and Methods:

Study design, recruitment, and population

This cross-sectional, observational study included an in-person clinical visit and a follow-up phone call and was conducted at the Indiana University School of Dentistry's (IUSD) Oral Health Research Institute (OHRI). Three recruitment approaches were used to identify study-eligible participants. Firstly, the following: 1) querying the electronic dental record (EDR) database to identify patients who received dentures between 2014 and 2023 (Codes on Dental Procedures and Nomenclature (CDT codes): D5110; D5120, D5130, D5140, D5860, D5863, D5865, D6110, D6111) and consented to be contacted for research; 2) recruiting participants from prior denture-related studies at OHRI by phone; and 3) posting study recruitment fliers in IUSD clinics and public places in and around Indianapolis, such as libraries, hospitals, and ambulatory clinics. The study participants and recruitment have already been described and published.

Study-eligible IUSD patients were contacted by postal mail, which included a flier and a study information sheet with a contact number. Interested patients and participants who saw the posted fliers called the study recruitment line and left a voicemail expressing their interest in participating. Subsequently, a research coordinator contacted them, confirmed their eligibility, and scheduled the study appointment. In addition, participants from prior denture studies were screened for study eligibility by phone and scheduled for the study. The Institutional Review Board at Indiana University approved the clinical study as expedited (# 15766).

Study population:

The study population included adults aged 50 years and older who wore either maxillary or mandibular complete dentures or both. The inclusion criteria were those who received their dentures at age 18 or older. The exclusion criteria were individuals having terminal illness with cancer, chronic obstructive pulmonary disease, cystic fibrosis, inflammatory bowel disease, dementia, gastric bypass surgery, Crohn's disease, ulcerative colitis, end-stage renal disease (dialysis), or who were hospitalized for more than two days from the day of the clinical visit. Individuals who were enrolled in nutritional interventions or were receiving dietary counseling at the time of the study visit were also excluded.

Study data collection:

The study team collected demographic information (age, race, sex), anthropometrics (height, weight, BMI), denture wearing characteristics (e.g., type, years of wearing current denture, total years of wearing denture, age at the time of receiving their first denture), medical history, medication use, two 24-hour dietary recalls including supplement use, and performed a blood draw. Study participants were instructed to fast for 12 hours and abstain from alcohol for 24 hours prior to blood collection. Blood samples were sent immediately to the lab on ice for analysis.

Malnutrition risk screening using the three MS tools:

We used the following three MS tools to screen for malnutrition risk in denture wearers: the NSI's DETERMINE,[26,27,29], the MNA-SF,[43] and the MST [30]. The NSI DETERMINE checklist (Disease, Eating poorly, Tooth loss/mouth pain, Economic hardship, Reduced social contact, Multiple medications, Involuntary weight loss or gain, Needs assistance in self-care, and Elderly), developed by the American Academy of Family Physicians and the National Institute on Aging (NIA), and validated among older adults, is a 10-item self-administered questionnaire with a score of 0-21 for each question [27]. Higher NSI scores ranging from 6-21 indicate high nutritional risk; scores 3-5 indicate moderate nutritional risk; and scores <3 indicate good nutritional status.

The second tool, MNA-SF, designed for older adults, is used extensively in various clinical settings[43–48]. This tool has six questions, can be administered in about 3 minutes, and has a high overall diagnostic accuracy (98.7%) [43]. A maximum score of 14 indicates normal nutritional status, whereas a score below 7 indicates malnutrition. The questions allow the provider to assess a patient's BMI (calculated based on the height and weight) measured at the time of the clinical study visit; collect information on any weight loss over the past 3-months; and any decline in food intake due to loss of appetite, digestive problems, chewing or swallowing difficulties; mobility level; psychological stress or acute disease in past 3 months; and neuropsychological problems such as dementia or depression.

Finally, the third tool, MST [30] is a 2-question screening questionnaire that asks patients about unintentional weight loss in the past 6 months and whether they have been eating poorly due to decreased appetite. MST scores range from 0 to 5, with a score of 0 or 1 indicating no risk of malnutrition, and a score of more than two indicating malnutrition. Levels of malnutrition risk among the three MS tools are provided in Table 1. In summary, higher scores on the NSI and MST indicate an increased risk for malnutrition, while lower scores on the MNA-SF indicate an increased risk for malnutrition.

24-hour Dietary recall assessment

Dietary intake of study participants was collected using the web-based automated self-administered (ASA24[®]) dietary recall system during two non-consecutive periods: first, during the in-person clinical study visit, and second, over the phone within seven days after the in-person study visit. The findings from the dietary assessment and the methodology are provided in our publication [42] on the diet quality of adults wearing dentures using the Healthy Eating Index (HEI) [49,50].

Serology tests

A trained phlebotomist performed venipuncture for 12 serology tests: complete blood count (CBC), comprehensive metabolic panel (CMP), which includes basic metabolic panel (BMP), thyroid-stimulating hormone (TSH), parathyroid hormone (PTH), vitamin A, vitamin B12, total vitamin D (25-hydroxy), vitamin K1, magnesium, zinc, and lipids. Peripheral blood (< 20ml) was collected, and the labeled blood samples were immediately transferred to Indiana University (IU) Health Pathology and Lab Services for analysis. Samples were processed at IU Pathology and analyzed either at IU Path and/or in ARUP laboratories. Blood samples were not collected for six participants because either the participants had not fasted or the blood could not be drawn. In addition, some of the labs, such as zinc and vitamin K1, are unavailable for 9 study participants because of unknown interfering substances in the specimens and failure to centrifuge within 2 hours of collection.

System usability scale (SUS) to evaluate usability

A validated 10-item SUS questionnaire [51] was administered to participants to assess their perceptions and satisfaction with these MS tools. The scores for the 10-items are based on a 5-point Likert scale, ranging from 0 to 100. Higher questionnaire scores indicate greater usability of an MS tool, with scores of 68 or higher considered acceptable.

Statistical analysis:

Summary statistics included frequencies and counts for categorical variables, as well as means (M) and standard deviations (SD), or medians and interquartile ranges for continuous variables. Spearman's correlation was performed due to the ordinal nature of the MS score to evaluate the association between the nutritional risk scores from the three malnutrition risk screening tools, laboratory values obtained through basic and comprehensive metabolic panels, and complete blood counts. Spearman's correlation was performed due to the ordinal nature of the MS scores. The association between nutritional risk scores of the malnutrition risk screening tools and denture wearing characteristics, including type of denture, years of wearing current denture, years of wearing any dentures, and age at the time of receiving a denture, was evaluated using Kruskal-Wallis test. A mixed-effects model was used to evaluate and compare SUS scores for the three malnutrition screening tools while taking into consideration the correlation of the repeatedly measured SUS scores for the same participant. Multiple comparisons were not adjusted due to the exploratory nature of the study. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, North Carolina).

Results:

Study participant characteristics:

Demographics: Fifty-four of the 4,202 individuals whose information was retrieved from the EDR database and were contacted based on their recent dental visits (2014-Jun 5, 2023) were qualified to participate. Of the 56 study records obtained from previous denture studies conducted at OHRI, 27 individuals qualified for the study. We recruited 12 eligible study participants through advertisements posted at various community locations. A total of 93 adults participated in the study, with a mean (SD) age of 71 (8.8) years and a BMI of 31.1 (6.6) kg/m² (range: 13.8 to 55.5 kg/m²). Women comprised 57% (n = 53) of the total cohort. Regarding race, about 50% of the study population were African American and White, showing equal distribution (Table 2).

Denture wearing characteristics: About 54% (n = 50) of the study participants wore both upper and lower complete dentures. Approximately 51% (n = 47) of the study participants had worn complete dentures for more than 10 years, while 55% (n = 51) had worn their current dentures for 5 years or less. The majority (79%, n = 73) of the participants received their dentures between the ages of 50 and 69 years. Specifically, 43% (n = 40) had received their complete dentures between 50 and 59 years of age, and 36% (n = 33) received them between 60 and 69 years. A previous publication from this research also reports the denture-wearing characteristics of the study participants [42].

Nutritional status based on the scores of the three malnutrition screening tools

Table 3 summarizes the frequency distributions of scores for the study participants using the three malnutrition screening tools (NSI, MNA-SF, MST). Thirty-seven study participants (40%) scored 6 or above using the NSI, classifying them at high nutritional risk, while 32 study participants (34%) scored between 3 and 5, indicating moderate nutritional risk. Therefore, a total (n = 69; 74%) of the participants were at nutritional risk based on the NSI. Using the MNA-SF, one study participant with a score of 4 was found to be malnourished, and 33 (35%) study participants scoring between 8 and 11 were found to be at risk of malnutrition. Using the MST, (n = 26; 28%) of the study participants scored 2 or higher and were at risk of malnutrition. A greater number of study participants were found to be at low risk of malnutrition (n = 67; 72.0%) using the MST, while 63% (n = 59) were found to be at no risk of malnutrition using the MNA-SF, and 26% (n = 24) were at good nutrition based on the NSI. Table 4 displays MS risk scores from the three MS tools as at nutritional risk, at low nutritional risk, or not at risk. Thirty-six study participants (39%) had similar nutritional risk levels across the three MS tools. However, 33 (35.4%) participants were classified as at risk for malnutrition with the NSI, in contrast, these participants were classified as not at risk/low risk by the MNA-SF and MST.

Association of denture wearing characteristics and malnutrition screening tools scores

Results show that the malnutrition risk screening score from NSI was significantly correlated with the number of years of denture wearing by the participants (Table 5). As the number of years wearing current dentures increased, the risk for malnutrition decreased ($p=0.035$). In addition, the risk of malnutrition determined through the NSI increased among those who had worn their dentures for less than 10 years ($p = 0.12$). Further, MNA-SF showed a significant correlation ($p=0.024$) between years of wearing dentures and the risk score for malnutrition.

Frequency of denture wearers with low, normal, and high laboratory values

The number of study participants with low, normal, and high laboratory values is listed in Table 6. Six participants did not have any laboratory test values because blood samples could not be collected. Among the 40 lab tests evaluated, 25 (63%) lab tests were lower, and 29 lab tests (73%) had higher values than the reference ranges for at least one of the study participants. Specifically, total vitamin D (ng/mL), hemoglobin (Hgb, gm/dL), and calculated glomerular filtration rate (GFR, mL/min/1.73m²) were most frequently low among study participants, with low levels in 31% (n=27), 30% (n=26), and 27% (n=23) of the participants, respectively. In addition, hematocrit (Hct, %) and high-density lipoprotein (HDL, mg/dL) were low among 21 (24%) and 17 (20%) study participants. On the other hand, participants had higher than normal values in the following lab tests parathyroid hormone (pg/mL) (35%, n=30), glucose (mg/dL) (34%, n=29), low density lipoprotein (LDL, mg/dL) (34%, n=29), total cholesterol (mg/dL) (20%, n=18), triglycerides (mg/dL) (18%, n=16), and blood urea nitrogen (BUN) (17%, n=15). ALT was within the reference range for all study participants (n=86). Specific nutritional marker labs [hemoglobin, magnesium, vitamin A (Retinol), vitamin A (Retinyl Palmitate), vitamin D, vitamin K1, vitamin B12, and zinc] were analyzed for association with malnutrition risk scores using the three MS tools.

Association between nutritional risk scores and specific nutrition markers and lab values

Table 7 provides the association between the nutritional risk scores from the three MS tools and eight specific nutritional markers from the panel of serological laboratory values. From the 40 laboratory test values, hemoglobin, magnesium, vitamin A (Retinol), vitamin A (Retinyl Palmitate), vitamin D, vitamin K1, vitamin B12, and zinc were considered as specific nutritional

markers. Results for the NSI and MST show that higher scores, indicating higher risk for malnutrition, were significantly correlated with lower vitamin K1 ($\rho=-0.231$, $p=0.035$ with MST), and lower zinc levels ($\rho=-0.258$ with NSI, $p=0.019$; $\rho=-0.320$ with MST, $p=0.003$).

Association of nutritional risk scores and the panel of 32 serological laboratory values are provided in the supplementary file (Supplementary Table S1). Regarding the CBC panel, the NSI and MST higher scores indicating increased risk for malnutrition were correlated with lower MPV ($\rho = -0.299$, $p = 0.005$ with NSI) and lower RBC ($\rho = -0.278$, $p=0.01$ with MST). Lower MNA-SF scores, indicating higher malnutrition risk, were correlated with lower WBC values ($\rho=0.227$, $p=0.036$). Results showed that a higher risk for malnutrition determined using the NSI was associated with lower ALT ($\rho=-0.324$, $p=0.002$) and AST ($\rho=-0.225$, $p=0.038$). For the CMP laboratory tests, higher risk for malnutrition using the MNA-SF was associated with lower chloride ($\rho=-0.264$, $p=0.014$) and lower triglycerides ($\rho=0.267$, $p=0.013$). Higher risk for malnutrition using the MST was also associated with lower triglycerides ($\rho=-0.244$, $p=0.024$).

Correlation between malnutrition risk screening scores and ASA24® data

Table 8 provides the Spearman correlation between malnutrition risk scores and the ASA24 data. In the current analysis, there was no significant association between total diet quality as measured by the Healthy Eating Index (HEI) and the malnutrition risk scores from the three MS tools. However, lower vegetable consumption was significantly correlated with higher MST risk scores, which indicates malnutrition risk ($\rho = -0.223$, $p = 0.031$). We have previously reported that vegetable consumption was lower than recommendations per the Dietary Guidelines for Americans (DGA) in adults wearing dentures [42]. Additionally, lower potassium intake was significantly correlated with higher risk scores using the MNA-SF indicating malnutrition risk ($\rho=0.210$, $p=0.044$).

Comparison of SUS usability scores between three MS tools

The mean (SD) SUS scores for NSI (10-item), MNA-SF (6-item), and MST (2-item) were 70.2 (14.1), 70.1 (15), and 69.2 (15.6), respectively. There were no statistically significant differences among the three MS tools ($p = 0.25$; $F = 1.4$; $F_{crit} = 3.10$). There were also no significant differences for pairwise comparisons on SUS between tools. Figure 1 shows the boxplot of SUS scores of the three MS tools.

Discussion:

Among the three MS tools (NSI, MNA-SF, MST) evaluated in this study, NSI identified a greater proportion of the study population at high risk of malnutrition with about 74% of the study participants classified as having a moderate or high risk of malnutrition. Whereas MNA-SF and MST identified 36% and 28% of the study participants at risk for malnutrition, respectively, indicating variation in detecting those at risk across the three tools. In 39% of study participants, all three tools identified their malnutrition risk at the same level. The higher percentage of individuals identified as at risk of malnutrition using NSI is similar to that reported in a previous study using NSI [29].

Performance of NSI, MNA-SF and MST tools: The variability in the performance of the three MS tools in detecting individuals at risk of malnutrition may be attributed to differences in the questions included in these tools. For instance, NSI captures medical conditions, medication

use, intake frequency of specific foods and beverages, clinical, social, psychological, economic, and functional factors [26,27]. The tool, MNA-SF focuses more on weight loss, food intake, mobility, psychological factors, neuropsychological problems, and BMI [43]. The MST tool screens for weight loss and eating poorly [30]. While NSI captures whether an individual's weight has gained or lost in the last six months, the other two screening tools (MNA-SF and MST) capture only weight loss.

Evaluating MS tool use during denture treatment: In a clinical setting, nutritional assessments would be completed if the screening tool indicates a risk of malnutrition. The selection of the MS tool varies based on the health care setting (i.e., hospital, long-term care facility) and the population. The Academy of Nutrition and Dietetics recommends using the MST regardless of age, medical history, or setting [31]. Also, other studies have recommended using NSI and MNA-SF in dental practices [24,25,29]. However, a systematic review and meta-analysis on identifying a valid tool concluded that MS tools should be evaluated for their effectiveness in a specific patient population before deploying them [52]. Similarly, dental clinicians consider the absence of sufficient scientific evidence of a risk assessment tool's effectiveness in dental settings as a major barrier in adopting such tools for patient care [53].

Association between selected serology test results, ASA24 data and MS tools scores:

Hemoglobin (Hb) and hematocrit levels were lower among 30% and 24% of the study participants, which is consistent with results from our retrospective study for Hb levels. In addition, the malnutrition risk using the MST was higher for individuals with low vitamin K1 and zinc values, and the malnutrition risk using the NSI was higher for individuals with low zinc values. For other specific nutritional markers, such as hemoglobin, magnesium, vitamins A, D, and B12, weak correlations with malnutrition risk were observed but did not reach significance. Therefore, the clinical relevance of these nutritional markers remains inconclusive (see Table #7). A possible reason for this lack of a significant association could be the small sample size of 93 participants, compared with a retrospective study of 10,481 patients [54]. In addition, the retrospective study included all patients regardless of underlying medical conditions or living conditions of long-term care facilities, which increases the risk of malnutrition. In this study, we did not include people with certain medical conditions or those who lived in a long-term care facility. Finally, because 74% of these study participants were taking supplements, some of the serology test results may not be a good indicator of malnutrition risk [54]. Additional studies are warranted to determine the optimal laboratory tests and determine appropriate nutritional biomarkers to indicate malnutrition in denture wearing adults.

We previously reported inadequate diet quality among these denture-wearing participants.- Yet, the total diet quality measured by the Healthy Eating Index (HEI) score was not significantly associated with the malnutrition risk scores of the three MS tools [42]. More than 90% of these participants consumed less dietary fiber, vitamin D, E, and choline than recommended. In addition, poor diet quality was significantly associated with lower dietary fiber, magnesium, potassium, vitamins A, D, C, B-6 and K levels [42]. Dietary components such as greens and beans, total vegetables, total fruits, and whole grains were consumed at lower levels than the recommended dietary intake. These results, comparing the dietary data with the scores of the three MS tools, revealed that higher malnutrition risk using MST was associated with lower total vegetable intake and higher malnutrition risk using MNA-SF was associated with lower potassium intake. Fruits and vegetables are an abundant source of potassium and thus aligns well the lower vegetable consumption and lower potassium intake [55]. In summary, not having a balanced diet rich in protein, fiber, carbohydrate, and essential fats may result in high malnutrition risk scores.

Association of denture-specific variables and MS tools scores: Studies have shown a proportional relationship between the number of teeth lost and the nutritional status [56–60]. Although prosthodontic rehabilitation improves nutritional status by restoring some functional capacity, evidence indicates that an adequate prosthesis is required to maintain it. Those with higher number of missing functional teeth, the type of replacement, and the presence of an upper or lower denture, rather than both, are at higher risk of malnutrition [54]. However, the findings from the current clinical study did not show any differences between the scores of three MS tools based on wearing both upper and lower complete dentures or only one of them, specifically upper dentures. Further, the NSI scores showed a correlation: the longer they wore dentures, the lower the risk of malnutrition. This finding could be due to the time it takes participants to adapt to dentures and modify their food choices and cooking habits.

Usability of the three MS tools: Participants scored an average of 69-70 on the SUS questionnaire assessing the tools' ease of use. A score of 68 or higher is considered high, and therefore, the three tools are considered easy to use by participants. These results suggest that dental patients can complete the questions included in the three MS tools without difficulty.

Limitations and future work: As with any study, this research has limitations that should be considered when generalizing the results. First, this was a one-time cross-sectional study with 93 participants who wore dentures and were recruited from a single geographical location. Second, this study cohort did not have a control group of people who did not wear dentures and there were no participants with only lower dentures. Third, this study only evaluated the feasibility of identifying the risk of malnutrition among people who use dentures and the ease of using these tools. Fourth, the study is a descriptive exploratory study to identify which nutritional markers or laboratory values might be related to malnutrition risk identified through the MS tools in this specific study population of adults wearing dentures. Future research is needed to evaluate the performance of these three tools against a registered dietitian's evaluation of a person's risk of malnutrition. The results could inform how best to implement the screening tools to assess dental patients' risk of malnutrition and to manage it, possibly through referral to a dietitian.

Conclusion: Edentulism is increasing, especially among older adults, and even with the replacement of lost/missing teeth with dentures, their nutritional status remains affected. Therefore, dental professionals need to assess the risk of malnutrition among individuals undergoing dental treatments, including denture use and oral and maxillofacial surgical procedures that affect chewing efficiency. All three MS tools capture the risk of malnutrition at varying levels, with the NSI identifying most denture-wearing patients at risk of malnutrition, suggesting the potential of using these tools in dental settings. Moreover, specific serological test results and diet quality were associated with higher malnutrition risk scores (though not statistically significant) among individuals wearing dentures, underscoring the need to assess their nutritional risk status during treatment. The usability test results suggest that these tools are easy for dental patients to use, further enhancing their potential for use during dental care visits. Thus, the results of this study demonstrate that screening dental patients for malnutrition would enable dental professionals to appropriately refer them to a primary care provider or a registered dietitian.

Data availability: All data supporting the findings of this study are available within the paper and in the supplementary section. Any further interest in requesting the data used for this research will require submission of the specific purpose of the data access for review and will be

made available after approval through the Indiana University School of Dentistry Privacy and Compliance office.

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Acknowledgments:

Received support from Delta Dental Foundation Grant funding, GG-0000000807.

We thank the study participants who contributed their time to participate in this research study. We thank Dr. Daniel O. Clark, Ms. Mei Wang, Mr. Sandeep Gaddam, Mr. Satwik Inampudi, Mr. Kiran Burlakunta Kumar, Ms. Sharon Gwinn, Dr. Sanjana Madarapu, Ms. Lorena Galvez, OHRI staff for their contributions. We also thank Dr. Domenick Zero (Emeritus professor), Dr. Anderson Hara (Director of Oral Health Research Institute), Ms. Sue Kelly, Ms. Judith Wilkinson, Ms. Kari Blackley for providing facilities and resources, management of finances, and preparation of IRB documents in supporting the conduct of the study.

Funding: This study was funded by Delta Dental foundation Inc (grant number GG-0000000807).

Conflict of Interest: The authors declare that they have no conflict of interest.

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Author contributions: The original conceptualization of the research study, along with the study design methodology was substantially contributed by the corresponding author, Grace Gomez Felix Gomez (GFG), and further refined and adapted by Thankam P. Thyvalikakath (TPT), Huiping Xu (HX), Lisa Spence (LS), Nana Gletsu-Miller (NGM). The first version of the original article was written by the corresponding author (GFG) and was critically reviewed, edited and commented on by LS, NGM, TPT, and HX. Recruitment of patients, data collection, inputs before and during the study was provided by Parul Patel (PP), Vanlianpar Bualteng (VB), Biju Cheriyan (BC). Data characteristics, data collection techniques and measurements were determined by GFG, TPT, HX, LS and NGM. Data management was completed by GFG, BC, and VB. Formal data analysis was done by HX. The figure was prepared by HX. Tables were prepared by GFG and HX. Usability analysis was done by AK, HX and GFG. Acquisition of financial support was obtained by the corresponding author GFG. All authors reviewed and approved the manuscript.

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Competing interests: The authors declare that they have no conflict of interest.

Ethics declarations

Ethics approval and consent to participate: This study received expedited approval from the Indiana University Institutional Review Board (IRB approval # 15766). The study participants provided informed consent with their signature indicating their interest in participating in the research study.

Consent for publication

Not applicable (N/A)

Table 1. Levels of malnutrition risk as defined by the three MS tools			
Risk Level	NSI	MNA-SF	MST
Range of scores	0 – 21	0 – 14	0 – 5

normal (not at risk or low risk)	0 to 2	12 to 14	0 to 1
at risk	3 to 5	8 to 11	
High nutritional risk or malnourished	≥ 6	0 to 7	≥ 2

MS – Malnutrition Screening; NSI – Nutrition Screening Initiative; MNA-SF – Mini nutrition assessment-Short form; MST – Malnutrition Screening Tool

Table 2:		
Study variables	Mean (M)	SD
Anthropometric measures		
Height (meters)	1.65	(0.09)
Weight (kgs)	85.15	(19.4)
BMI ([kgs/m ²])	31.06	(6.5)
Demographics		
Age in years	71.1	(8.8)
Sex		
Female	53	(57)
Male	40	(43)
Race		
African American/African heritage	46	(49.5)
White - White/Caucasian/European heritage/Arabic/North African heritage	46	(49.5)
Other	1	(1.1)
Denture-specific variables		
Type of denture		
Upper	43	(46.2)
Both	50	(53.8)
Years wearing current denture		
≤1 year	25	(26.9)
2-5 years	26	(28)
6-10 years	19	(20.4)
11+ years	23	(24.7)
Years of wearing dentures		
Less than ten years	46	(49.5)
10 to 20 years	29	(31.2)
More than 20 years	18	(19.4)
Age (years) at the time of receiving a denture		

<50	7	(7.5)
50-59	40	(43)
60-69	33	(35.5)
70+	13	(14)

Mean: M; Standard Deviation: SD

Table 3: Summary of frequency scores of the three malnutrition screening tools (NSI, MNA-SF, MST)		
Score	Frequency	Risk level
NSI score (Max 21 points)		
0	3	Good (n = 24)
1	14	
2	7	
3	13	Moderate nutritional risk (n = 32)
4	10	
5	9	
6	7	High nutritional risk (n = 37)
7	8	
8	4	
9	3	
10	6	
11	2	
12	5	
14	1	
16	1	
MNA-SF score (Max 14 points)		
4	1	Malnourished (n = 1)
8	5	At risk of malnutrition (n = 33)
9	4	
10	11	
11	13	
12	9	Normal nutritional status (n = 59)
13	15	
14	35	
MST score (Max 5 points)		
0	50	Not at risk (n = 67)
1	17	
2	18	At risk (n = 26)
3	5	
4	3	

NSI – Nutrition Screening Initiative; MNA-SF – Mini nutrition assessment -Short form; MST – Malnutrition Screening Tool

Table 4: Binary risk level based on three malnutrition screening (MS) tools			
NSI level	MNA-SF level	MST level	Frequency
Nutritional risk	Nutritional risk	Nutritional risk	18
Nutritional risk	Nutritional risk	Low risk	14
Nutritional risk	Low risk	Nutritional risk	4
Nutritional risk	Low risk	Low risk	33
Low risk	Nutritional risk	Low risk	2
Low risk	Low risk	Nutritional risk	4
Low risk	Low risk	Low risk	18
Total			93

Risk scores from two levels were combined as Nutritional risk or at low/not at risk levels: Nutritional risk included moderate and high nutritional risk for NSI, malnourished and at risk for malnutrition for MNA-SF and at risk for MST.

Table 5: Denture-specific variables	N	NSI score		MNA-SF score		MST score	
		Median (IQR)	P Value	Median (IQR)	P Value	Median (IQR)	P Value
Type of denture			0.960		0.890		0.75
Upper	43	5.0 (2.0 - 7.0)		13.0 (10.0 - 14.0)		0.0 (0.0 - 2.0)	
Both	50	4.0 (3.0 - 8.0)		12.5 (11.0 - 14.0)		0.0 (0.0 - 2.0)	
Years of wearing current denture			0.035*		0.024*		0.079
<=1 year	25	5.0 (3.0 - 7.0)		13.0 (12.0 - 14.0)		0.0 (0.0 - 1.0)	
2-5 years	26	6.0 (3.0 - 9.0)		12.0 (11.0 - 14.0)		0.0 (0.0 - 2.0)	
6-10 years	19	4.0 (2.0 - 8.0)		12.0 (9.0 - 14.0)		1.0 (0.0 - 2.0)	
11+ years	23	3.0 (1.0 - 5.0)		14.0 (11.0 - 14.0)		0.0 (0.0 - 2.0)	
Years of wearing dentures			0.012*		0.25		0.13
Less than ten years	46	5.0 (3.0 - 9.0)		12.0 (11.0 - 14.0)		1.0 (0.0 - 2.0)	
10 to 20 years	29	3.0 (1.0 - 7.0)		13.0 (12.0 - 14.0)		0.0 (0.0 - 1.0)	
More than 20 years	18	3.5 (1.0 - 6.0)		13.0 (10.0 - 14.0)		0.0 (0.0 - 2.0)	
Age (years) at the time of receiving a denture			0.86		0.49		0.79
<50	7	4.0 (1.0 - 6.0)		11.0 (10.0 - 14.0)		0.0 (0.0 - 2.0)	
50-59	40	5.0 (3.0 - 8.5)		13.0 (10.0 - 14.0)		0.0 (0.0 - 2.0)	
60-69	33	4.0		12.0		1.0	

		(2.0 - 8.0)		(11.0 - 14.0)		(0.0 - 2.0)	
70+	13	5.0 (3.0 - 7.0)		14.0 (12.0 - 14.0)		0.0 (0.0 - 1.0)	

* Asterisk indicates statistical significance ($p < 0.05$).

Table 6 Laboratory values for complete denture wearing study participants (FS)	Reference range	Low	Normal	High	Total N
Hemogram/Platelets/WBC Differential					
WBC, k/cumm	3.6-10.6	5	79	2	86
RBC, million/cumm	4.18-5.51 Males 3.71-5.17 Females	13	70	3	86
Hemoglobin (Hgb), g/dL	13.4-17 Males 12-15 Females	26	59	1	86
Hematocrit (Hct), %	40-54 Males 35-49 Females	21	65	0	86
MCV, fL	81-99	3	80	3	86
MCH, pg	27-34	9	77	0	86
MCHC, g/dL	32-36	2	84	0	86
RDW, %	11.5-14.5	0	68	18	86
Platelet, k/cumm	150-450	2	84	0	86
MPV, fL	7-12	0	85	1	86
Routine Chemistry test FS					
Sodium SerPI QN, mmol/L	135-145	1	84	1	86
Potassium SerPI QN, mmol/L	3.5-5.5	2	83	1	86
Chloride SerPI QN, mmol/L	98-108	1	82	3	86
Carbon Dioxide SerPI QN, mmol/L	22-29	2	67	17	86
Anion Gap, mmol/L	3-11	0	83	3	86
BUN SerPI QN, mg/dL	5-20	0	71	15	86
Creatinine SerPI QN, mg/dL	0.8-1.4 Males 0.6-1.2 Females	8	68	10	86
Calculated GFR (CKD-EPI, no race), mL/min/1.73m ²	60+	23	63	0	86
Glucose SerPI QN, mg/dL	70-99	0	57	29	86
Calcium Total SerPI QN, mg/dL	8.5-10.5	0	85	1	86
Alkaline Phos SerPI QN, Units/L	25-125	0	84	2	86
ALT SerPI QN, Units/L	7-52	0	86	0	86
AST SerPI QN, Units/L	13-39	2	84	0	86
Bilirubin Total SerPI QN, mg/dL	0-1	0	79	7	86
Protein, Total SerPI QN, g/dL	6.4-8	3	73	10	86
Albumin SerPI QN, g/dL	3.5-5	1	85	0	86
Cholesterol SerPI QN, mg/dL	0-200	0	68	18	86
Triglyceride SerPI QN, mg/dL	0-150	0	70	16	86

HDL SerPI QN, mg/dL	40+	17	69	0	86
LDL Calculated QN, mg/dL	0-100	0	57	29	86
Total Chol/HDL Ratio	0-5	0	85	1	86
Magnesium SerPI QN, mg/dL	1.6-2.9	1	85	0	86
Endo Serum/Plasma Tests					
TSH 3 rd Gen SerPI QN, mcU/mL	0.4-4.2	4	76	5	85
PTH Intact Ser QN, pg/mL	10-65	0	55	30	85
Vitamins					
Vitamin A (Retinol), mg/L	0.30-1.20	1	82	2	85
Vitamin A (Retinyl Palmitate), mg/L	0-0.10	0	84	1	85
Vitamin D Total, ng/mL	30-100	27	59	1	87
Vitamin K1 SerPI Quant, nmol/L	0.22-4.88	1	82	0	83
Vitamin B12 SerPI QN, pg/mL	200-1000	7	66	12	85
Metals					
Zinc, Serum mcg/dL	60-120	5	77	1	83

FS: Fasting specimen; cumm: Cubic millimeter; %: Percentage; g/dL: grams per deciliter; SerPI: Serum, plasma quantitative; pg: Picograms; mmol/L: millimoles per liter; mcg/dL: micrograms per deciliter; Chol: Cholesterol; PTH: Parathyroid hormone; ng/mL: nanograms per milliliter; Fl: femtoliters; k/cumm: thousands per cubic millimeter; * Asterisk indicates statistical significance.

Table 7 Spearman correlation between malnutrition screening scores and eight specific nutritional markers

Association between nutritional risk scores and laboratory values (FS)	NSI score		MNA-SF score		MST score	
	Correlation	P value	Correlation	P value	Correlation	P value
Hemoglobin (Hgb), gm/dL	-0.164	0.13	0.070	0.52	-0.178	0.1
Magnesium SerPI QN, mg/dL	-0.099	0.36	0.161	0.14	-0.115	0.29
Vitamin A (Retinol), mg/L	0.048	0.66	0.133	0.23	0.009	0.93
Vitamin A (Retinyl Palmitate), mg/L	-0.060	0.59	0.119	0.28	-0.173	0.11
Vitamin D Total, ng/mL	0.091	0.4	0.055	0.61	0.016	0.88
Vitamin K1 SerPI Quant, nmol/L	0.122	0.27	0.028	0.8	-0.231	0.035*
Vitamin B12 SerPI QN, pg/mL	0.006	0.96	0.095	0.39	0.008	0.94
Zinc, Serum mCg/dL	-0.258	0.019*	0.181	0.1	-0.320	0.003*

* Asterisk indicates statistical significance (p<0.05). FS: Fasting specimen

Table 8 Spearman correlation between malnutrition screening scores and ASA24 data

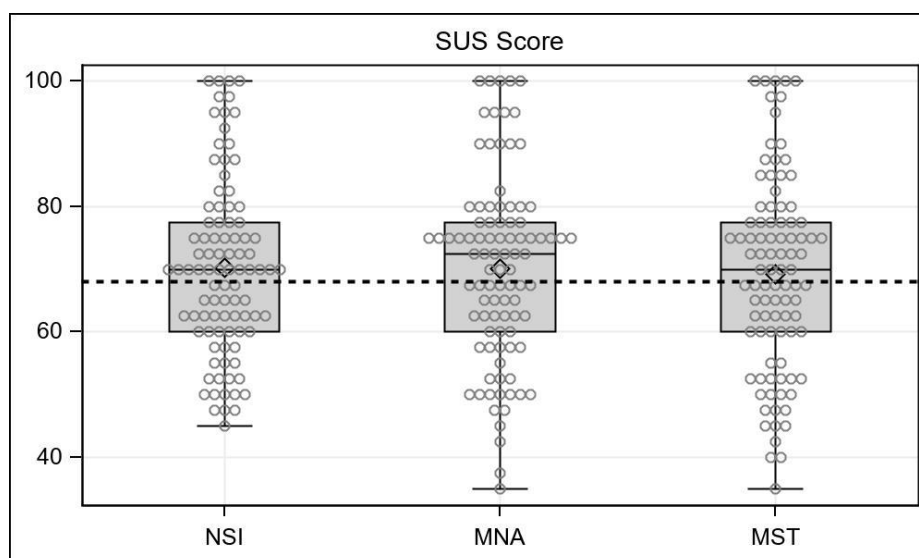
	NSI score		MNA-SF score		MST score	
	Correlation	P value	Correlation	P value	Correlation	P value
Healthy Eating Index						
Total vegetables (Max. 5)	-0.090	0.39	0.064	0.54	-0.223	0.031*
5) Greens and beans (Max. 5)	0.057	0.59	-0.085	0.42	-0.002	0.98
Total fruits (Max. 5)	0.011	0.92	0.027	0.8	0.066	0.53

Whole fruits (Max. 5)	0.029	0.78	0.024	0.82	-0.014	0.9
Whole grains (Max. 10)	-0.007	0.94	-0.021	0.84	-0.008	0.94
Total dairy (Max. 10)	0.025	0.81	0.094	0.37	-0.102	0.33
Total protein (Max. 5)	0.117	0.26	-0.134	0.2	0.012	0.91
Seafood and plant proteins (Max. 5)	0.144	0.16	-0.002	0.99	-0.025	0.82
Fatty acids (Max. 10)	0.039	0.71	-0.125	0.23	0.038	0.72
Sodium (Max. 10)	0.012	0.91	0.130	0.22	0.054	0.61
Refined grains (Max. 10)	0.074	0.48	0.067	0.52	-0.042	0.69
Saturated fats (Max. 10)	0.026	0.8	-0.080	0.45	-0.034	0.75
Added sugar (Max. 10)	0.065	0.54	-0.078	0.45	0.007	0.94
HEI total score (Max. 100)	0.112	0.29	-0.020	0.85	-0.011	0.92
Daily dietary intake						
Energy (kcal)	-0.105	0.32	0.169	0.1	-0.161	0.12
Macronutrients						
Protein (g)	-0.084	0.42	0.034	0.75	-0.161	0.12
Carbohydrate (g)	-0.094	0.37	0.173	0.098	-0.104	0.32
Fiber, total dietary (g)	-0.084	0.42	0.149	0.15	-0.163	0.12
Minerals						
Calcium (mg)	0.010	0.93	0.108	0.3	-0.094	0.37
Iron (mg)	-0.109	0.3	0.112	0.28	-0.127	0.23
Magnesium (mg)	0.027	0.8	0.111	0.29	-0.099	0.35
Phosphorus (mg)	-0.064	0.54	0.147	0.16	-0.199	0.056
Potassium (mg)	-0.078	0.46	0.210	0.044*	-0.185	0.076
Sodium (mg)	-0.132	0.21	0.062	0.55	-0.168	0.11
Zinc (mg)	-0.124	0.24	0.096	0.36	-0.139	0.18
Selenium (mcg)	-0.080	0.44	-0.045	0.67	-0.066	0.53
Copper (mg)	-0.017	0.87	0.173	0.097	-0.085	0.42
Vitamins						
Vitamin A, RAE (mcg_RAE)	0.052	0.62	0.011	0.92	-0.049	0.64
Vitamin E, alpha-tocopherol (mg)	0.015	0.88	-0.023	0.83	0.024	0.82
Vitamin D (D2 + D3) (mcg)	0.059	0.58	0.031	0.77	-0.054	0.61
Vitamin C (mg)	-0.076	0.47	0.072	0.49	-0.085	0.42
Thiamin (mg)	-0.075	0.48	0.060	0.57	-0.105	0.32
Riboflavin (mg)	-0.025	0.81	0.109	0.3	-0.080	0.45
Niacin (mg)	-0.114	0.28	-0.071	0.5	-0.050	0.64
Vitamin B-6 (mg)	-0.093	0.38	0.052	0.62	-0.128	0.22
Vitamin B-12 (mcg)	-0.009	0.94	0.040	0.7	-0.140	0.18
Choline, total (mg)	-0.034	0.75	0.063	0.55	-0.142	0.17

Vitamin K, phyloquinone (mcg)	0.037	0.72	0.070	0.5	-0.049	0.64
Folate, DFE (mcg_DFE)	-0.080	0.45	0.012	0.91	-0.055	0.6

* Asterisk indicates statistical significance (p<0.05).

Figure: 1 Boxplot of the SUS scores of the three malnutrition screening tools



NSI is nutrition screening initiative; MNA is Mini nutritional assessment short form; MST is malnutrition screening tool

Supplementary file:

Table S1

Table S1 Association between nutritional risk scores and laboratory values (FS)	NSI score		MNA-SF score		MST score	
	Correlation	P value	Correlation	P value	Correlation	P value
Hemogram/Platelets/WBC Differential						
WBC, k/cumm	-0.185	0.088	0.227 (p=0.036)*	0.036	-0.147	0.18
RBC, million/cumm	-0.112	0.3	0.018	0.87	-0.278 (p=0.01)*	0.01*
Hematocrit (Hct), %	-0.166	0.13	0.059	0.59	-0.193	0.075
MCV, fL	-0.108	0.32	0.066	0.55	0.186	0.086
MCH, pg	-0.095	0.38	0.089	0.42	0.180	0.098
MCHC, GM/dL	-0.013	0.91	0.115	0.29	0.022	0.84
RDW, %	0.178	0.1	-0.157	0.15	0.068	0.54
Platelet, k/cumm	0.030	0.78	0.126	0.25	-0.143	0.19

MPV, fL	-0.299 (p=0.005) *	0.005*	0.091	0.4	-0.139	0.2
Routine Chemistry test FS						
Sodium SerPI QN, mmol/L	-0.151	0.16	-0.118	0.28	0.021	0.85
Potassium SerPI QN, mmol/L	-0.001	0.99	0.121	0.27	-0.034	0.75
Chloride SerPI QN, mmol/L	0.024	0.82	-0.264 (p=0.014)*	0.014*	0.057	0.61
Carbon Dioxide SerPI QN, mmol/L	-0.094	0.39	0.155	0.15	0.144	0.19
Anion Gap, mmol/L	-0.064	0.56	0.006	0.96	-0.172	0.11
BUN SerPI QN, mg/dL	0.000	0.99	0.144	0.19	0.012	0.91
Creatinine SerPI QN, mg/dL	0.053	0.63	0.168	0.12	-0.046	0.67
Calculated GFR (CKD-EPI, no race), mL/min/1.73m2	0.021	0.85	-0.137	0.21	0.012	0.91
Glucose SerPI QN, mg/dL	0.034	0.75	-0.029	0.79	0.001	0.99
Calcium Total SerPI QN, mg/dL	0.008	0.94	0.020	0.85	0.096	0.38
Alkaline Phos SerPI QN, Units/L	0.052	0.63	0.064	0.56	0.018	0.87
ALT SerPI QN, Units/L	-0.324 (p=0.002) *	0.002*	0.195	0.072	-0.209	0.054
AST SerPI QN, Units/L	-0.225 (p=0.038) *	0.038*	0.075	0.49	-0.121	0.27
Bilirubin Total SerPI QN, mg/dL	-0.056	0.61	-0.036	0.74	0.044	0.69
Protein, Total SerPI QN, GM/dL	0.044	0.68	0.119	0.28	-0.126	0.25
Albumin SerPI QN, GM/dL	0.087	0.43	0.015	0.89	-0.058	0.59
Cholesterol SerPI QN, mg/dL	0.050	0.65	-0.035	0.75	0.021	0.85
Triglyceride SerPI QN, mg/dL	-0.139	0.2	0.267 (p=0.013)*	0.013*	-0.244 (p=0.024)*	0.024*
HDL SerPI QN, mg/dL	0.076	0.49	-0.129	0.24	0.138	0.2
LDL Calculated QN, mg/dL	0.047	0.67	-0.055	0.62	0.006	0.96
Total Chol/HDL Ratio	-0.072	0.51	0.099	0.37	-0.138	0.21
Endo Serum/Plasma Tests						
TSH 3 rd Gen SerPI QN, mcU/mL	-0.085	0.44	0.009	0.93	-0.121	0.27
PTH Intact Ser QN, pg/mL	0.007	0.95	-0.082	0.46	0.152	0.16

FS: Fasting specimen (specific requirement for routine chemistry labs); cumm: Cubic millimeter; %: Percentage; g/dL: grams per deciliter; SerPI: Serum, plasma quantitative; pg: Picograms; mmol/L: millimoles per liter; mcg/dL: micrograms per deciliter; Chol: Cholesterol; PTH:

Parathyroid hormone; ng/mL: nanograms per milliliter; fL: femtoliters; k/cumm: thousands per cubic millimeter; * Asterisk indicates statistical significance ($p < 0.05$).