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Original Article

Association between oral health status and occlusal bite force in young adults

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KEYWORDS
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Plaque weight;
Plque pH;
DMFTs

Abstract *Background/purpose:* Oral health is related to general health and a person's overall well-being. The aim of the present study was to explore the association between oral health status and bite force among young adults.
Materials and methods: Maximum bite force (MBF) was measured using Dental Prescale II in conjunction with a pressure-sensitive film and bite force analyzer in 40 young adults aged 20 to 40. Supragingival dental plaque was collected and cultured. Plaque weight, pH, and colony counts were assessed. The decayed, missing, and filled teeth index (DMFT) and body mass index (BMI) were recorded.
Results: Bite force was negatively correlated with the number of missing teeth and the sum of missing and filled teeth. When the filled-to-remaining-teeth ratio (F/R ratio) was less than 8%, the bite force was significantly higher compared to an F/R ratio of 8–25%. Additionally, the amount of total bacteria was positively correlated with total bite force, and the quantity of *Streptococcus mutans* (*S. mutans*) along with total bacteria was positively correlated with bite force in the molar region ($^{*}P < 0.05$). The molar region predominantly contributed to bite force.

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Conclusion: Elevated levels of cariogenic bacteria may increase the risk of tooth loss, subsequently leading to reduced bite force. This reduction in bite force can further impact the efficiency of chewing function and, consequently, the quality of life. An F/R ratio above 8% could be easily calculated clinically and could serve as a guide to identify patients, particularly young adults, at risk of reduced bite force.

Introduction

Oral health has multiple aspects that related to general health and are crucial to a person's overall well-being.[1] The craniofacial region enables speech, chewing, swallowing and the expression of a wide range of feelings. Daily tasks would be impacted by the oral diseases, which could reduce life expectancy. For instance, tooth decay and periodontal disease are the most common oral health issues among both young and elderly individuals.[2] Reduced nutrient consumption and pain from poor oral health would negatively impact quality of life.[3]

The oral flora, or variety of bacteria residing in the mouth and throat, is made up of about nine-hundred different species. Learning them can aid the prevention of some oral illnesses because some of them are advantageous and are thought to be necessary for preserving oral health, while others are not. For instance, *Streptococcus mutans* is detrimental to humans because it causes tooth decay. Therefore, oral microorganism distribution is a crucial aspect of oral health and an essential topic for discussion.

The coordination of the skeletal, muscular, nervous, and dental structures—all aspects of masticatory function—leads to the development of bite force. The total force of the muscle that close the jaw is known as the maximum bite force (MBF).[4,5] The size of the masticatory muscles, dental occlusion, and facial morphology are the primary determining factors in the assessment of bite force.[5,6] In the past experiences, transducers positioned or pressure-sensitive sheets could be used to monitor the maximum bite force.[7,8]

In accordance with the previous study, the bite force of females was found to be significantly greater than that of males when measured using an electronic gnathodynamometer, while no significant difference was detected between ages spanning from twenty to fifty years.[8] As the jaw closes forcefully with age and development, the bite force should remain relatively stable throughout middle age, then goes down with aging.[7] The loss of teeth and the deterioration of the dentition would cause the bite force value to greatly decrease as people aged. Bite force is primarily reduced by tooth loss in the posterior area[9] Furthermore, having trouble chewing would result from having a high DMFT score (decayed/missing/filled teeth). For instance, Tsai et al. revealed a negative relationship between maximum bite force and the number of decayed teeth.[10] According to a study by Yang et al., the number of missing teeth is negatively correlated with the maximum bite force.[11] Occlusal bite force and the larger amount of remaining teeth are strongly linked.[12] If dentures or other dental restorations were used to replace natural teeth, the bite force would be greatly reduced.[13,14] However, initial bone quality of the jaw at the implant insertion sites significantly influences the degree of improvement of a bite force.[15]

A significant portion of the literature to date has concentrated on the impact of occlusal bite force in young children and elderly.[16,17] Only a few studies have examined bite force and created databases in young individuals. The occlusal bite force between the elder and younger cohorts is still unknown. Additionally, the previous Dental Prescale and occlusal bite force device has been out of manufacturing since 2012. On top of that, a study proposed that new Dental Prescale could be used to investigate occlusal bite force and oral hypofunction.[18] Furthermore, there are studies that examine oral bacteria in both adults and children, yet very few of them focus on young individuals.[19,20]

Although substantial research has focused on oral health in various age groups, there remains a relative dearth of studies specifically addressing the oral health status of young adults and its potential long-term impacts. Our present study aimed to explore the association between oral health status and bite force among young adults, a demographic often overlooked in dental research. We determined to quantify the total and the number of *Streptococcus mutans* (*S. mutans*) in human samples and measure maximum bite force (MBF) using Dental Prescale II in order to assess oral health. The DMFT index, plaque weight and pH value were utilized to assess this population's oral health and caries experience comprehensively. This study emphasized the importance of early oral health interventions and their potential to influence long-term oral and systemic health outcomes in young adults.

Materials and methods

Sample collection

The maximum bite force and oral status and personal data were investigated in 40 young adults from age 20 to 40. The protocol was approved by Taipei Medical University Joint Institutional Review Board (Approval No. N201910042) and we followed The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The selection criteria were (1) no clinical abnormalities in the masticatory system, (2) natural dentition, with the possible exception of the third molars, healthy periodontal condition, (3) no major dental restorations (4) participants with a history of psychiatric conditions or currently taking medication were excluded. Oral health indicators such as the DMFT index and dental plaque were obtained by five trained dentists. Medical condition and history and personal data, including body mass index (BMI) were collected.

Occlusal bite force measurement

The Dental Prescale II (GC Co., Tokyo, Japan) a device constructed of two polyethylene terephthalate films and numerous microcapsules holding color-forming materials sandwiched in between them, was used to detect the occlusal bite force along with the pressure-sensitive film and bite force analyzer (GC Co.) Each participant was requested to occlude bite a film with subject's dental arch size. The subjects were asked to clench the film for 3 s. Then, scanned the film by using the bite force analysis software to determine the MBF. We used the pressure filter function of the bite force device to compute MBF in units of N.

Determination of total and Streptococcus mutans counts in human samples

Two milliliters of saliva were collected from each subject and used in 10X serial dilutions in 0.05 M phosphate buffer (pH 7.3) several times after being shaken on a mixer for 30 s. The aliquots of 50 μL of diluted saliva were plated on Mitis-salivarius-bacitracin (MSB) agar and incubated for 3 days in an anaerobic environment (37 °C, 5% CO_2, 95% N_2) for growth of Streptococcus mutans following bacterial colony counts.[21]

Supra-gingival dental plaque was collected in microtube, 1 mg dental plaque transferred, for serial dilution, to 1 mL of 0.05 M phosphate buffer and vortexed for 1 min to create a homogeneous solution. Subsequently, aliquots of the solution were cultured for 3 days in the same anaerobic environment in Brain Heart Infusion (BHI) and MSB media. On MSB or BHI agar, the colonies are counted to determine the colony-forming units (CFU). To calculate the percentage of S. mutans in plaque, the S. mutans counts on MSB agar were partitioned by the total number of bacteria counts on BHI agar.

Plaque weight and pH meter

The plaque was weighted using digital electronic microbalance (Sartorius AG, Göttingen, Germany). The pH level was examined by pH meter Thermo Scientific Orion Star™ A214 pH/ISE Benchtop Meter (Thermo Fisher Scientific Inc., Waltham, MA, USA) and pH probe Thermo Scientific Orion™ Micro pH Electrode 9863BN (Thermo Fisher Scientific Inc.)

The decayed, missing, and filled teeth (DMFT) index

DMFT index record the number of missed, filled, and decayed teeth were recorded in the mouth on dental chair of each participant.

Data analysis

A statistical analysis was carried out using SPSS software for Windows version 20.0 (SPSS Inc., Chicago, IL, USA). The independent *t*-Test, Pearson correlation analysis and one-way ANOVA was used to exam the association among different variables. Pearson correlation and the graphs were performed using GraphPad Prism software version 8.0 for Mac (GraphPad Software, San Diego, CA, USA). For all statistical tests, the significance level was set at $P < 0.05$.

Result

A total of forty Taiwanese participants aged between 20 and 40 years old recruited in present study. The average age was 23.73 years old, 21 females and 19 males with maximum bite force of 815.78 N $\pm$ 339.57, in female 829.34 N and in male 800.80 N. The plaque pH was 6.38 $\pm$ 0.58, and weight 44.63 $\pm$ 35.41 mg and DMFT was 7.78, with missing teeth 1.03, decayed teeth 3.26, and filled teeth 3.8.

The filled-to-remaining-teeth ratio (F/R ratio) was divided into three groups: group A for F/R ratios below 8%, group B for F/R ratios between 8% and 25%, and group C for F/R ratios above 25%. Moreover, the filled/decayed-to-remaining teeth ratio (FD/R ratio) was classified in three groups: group D for FD/R ratios below 15%, group E for FD/R ratios between 15% and 31%, and group F for F/R ratios above 31%; the decayed-to-remaining teeth ratio (D/R ratio) was classified in three groups: group G for D/R ratios below 4%, group H for D/R ratios between 4% and 10%, and group I for D/R ratios above 10% as shown in Table 1.

In the DMFT index, the number of missing teeth is negatively correlated with bite force with correlation coefficient $r = -0.36$, $P < 0.05$, while the number of decayed and filled teeth is not found to be correlated with bite force (Fig. 1a.). However, when the number of missing, filled, and decayed teeth were treated as three variables and randomly added up two of them, or even added up three of them, only the number of missing teeth and the number of filled teeth add up is negatively correlated with bite force, $r = -0.30$, $P < 0.05$ (Fig. 1b).

There is no correlation between the right and left sides of the mouth if we look at the mouth as separate areas for the anterior teeth region, premolar teeth region, and molar teeth region. However, the bite force from the molar region is considerably higher than that from the premolar and anterior region, $P < 0.05$ (Fig. 2).

In the F/R ratio groups, the group A (F/R <8%) had been found to have a higher bite force than group B (F/R 8–25%), $P < 0.05$ (Fig. 3).

Additionally, it was discovered that group A appeared to have a bite force from the molar region that was significantly higher than group B with $P < 0.05$, but in premolar and anterior teeth region there was no obvious differences to be found (Fig. 4). Within each group, even though the gender percentage varies (group A had 54% for males and 46% for females, group B had 23% males and 73% females, and group C had 64% males and 36% females), it didn't

Table 1 Demographic characteristics.

Characteristics	Frequency (n)	Proportion (%)
Gender		
Female	21	52.50
Male	19	47.50
Age (years old)		
20～22	14	35.00
23	13	32.50
24 or above	13	32.50
F/R ratio[a]		
Group A (<8%)	13	32.50
Group B (8–25%)	13	32.50
Group C (>25%)	14	35.00
FD/R ratio[b]		
Group D (<15%)	13	32.50
Group E (15-31%)	13	32.50
Group F (>31%)	14	35.00
D/R ratio[c]		
Group G (<4%)	14	35.00
Group H (4–10%)	13	32.50
Group I (>10%)	13	32.50

[a] F/R ratio (filled-to-remaining teeth ratio).
[b] FD/R ratio (filled and decayed teeth-to-remaining teeth ratio).
[c] D/R ratio (decayed-to-remaining teeth ratio).

appear to have an impact on bite force. Gender, age, plaque pH, BMI, weight did not demonstrate any statistically significant results among any of the categories.

In group A (F/R <8%) apart from total bacteria amount had positive correlation to the bite force, the amount of the microbes either cariogenic S. mutans, total amount, nor the ratio of S. mutans over total bacteria had been discovered correlation to bite force (r = 0.48, $P > 0.05$) however, both S. mutans (r = 0.63, $P < 0.05$) and total bacteria amount (r = 0.65, $P < 0.05$) was found positive correlated to bite force in molar region in group A (Figs. 5 and 6a-b).

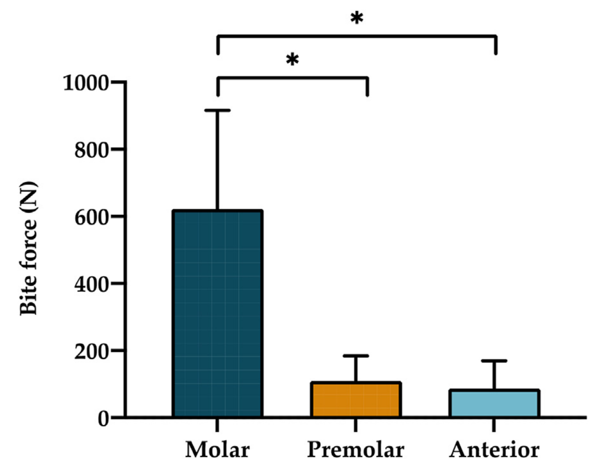

Figure 2 Bite force comparison among different dental area (molar, premolar, and anterior), $*P < 0.05$.

In FD/R grouping, bite force had no significant different among 3 groups, while bite force of molar region is significant stronger in group F (FD/R > 31 %) had significant stronger bite force than in group E (FD/R 15–31%) with $P < 0.05$ (Fig. 7).

FD/R ratio <15%, the group D, which is has significant higher S. mutans count to total bacteria ratio than group F (FD/R > 31%) $P < 0.05$ (Fig. 8a). There was no other association found within other factors among these groups. Moreover, the S. mutans count to Total bacteria ratio was significant higher in group H (D/R 4–10%) than in group G (D/R >4%) $P < 0.05$ (Fig. 8b). There was no other association found within other factors among these groups.

Discussion

This study had discovered that the bite force in young adult is not shown significant different in age and gender, the body mass index (BMI), plaque pH and weight, and the number of cultured microbes. The bite force is related to

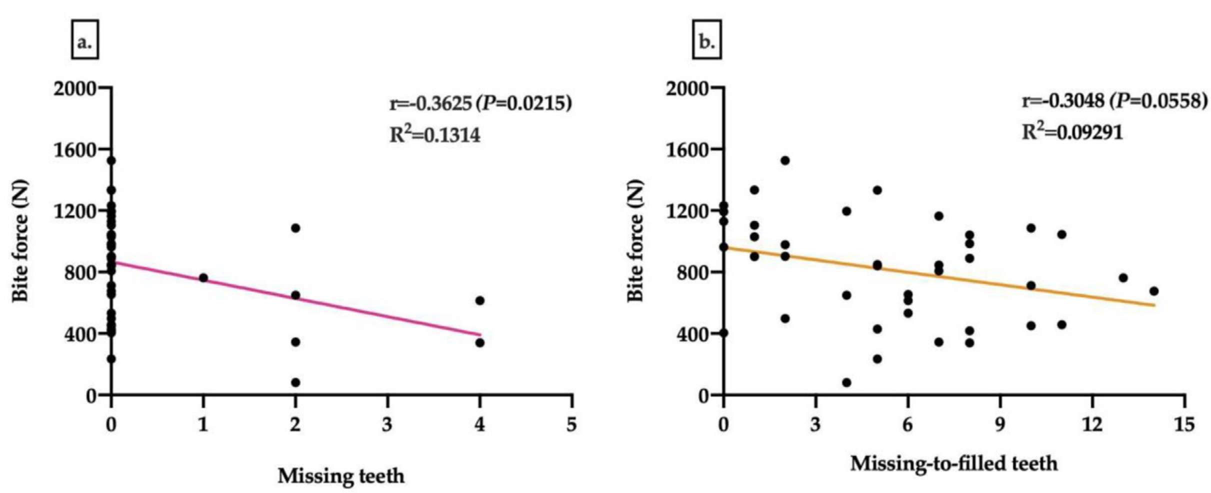

Figure 1 **(a–b). a.** Pearson correlation coefficient (r), R squared (R^2) and P-value (P) between bite force (N) and missing teeth; **b.** Correlation between bite force (N) and missing-and-filled teeth ratio.

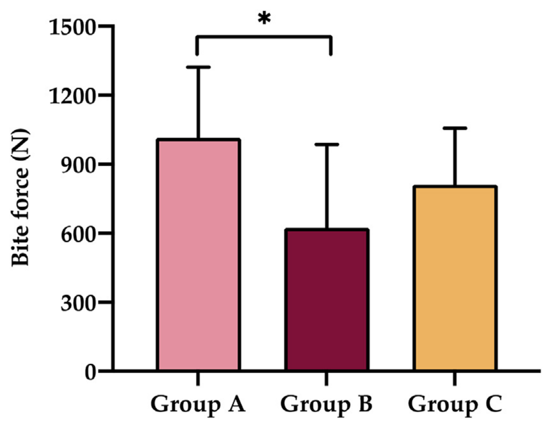

Figure 3 Bite force comparison among groups A (F/R <8%), B (F/R 8–25%), and C (F/R >25%), *$P < 0.05$.. (F/R ratio stands for filled-to-remaining teeth ratio.)

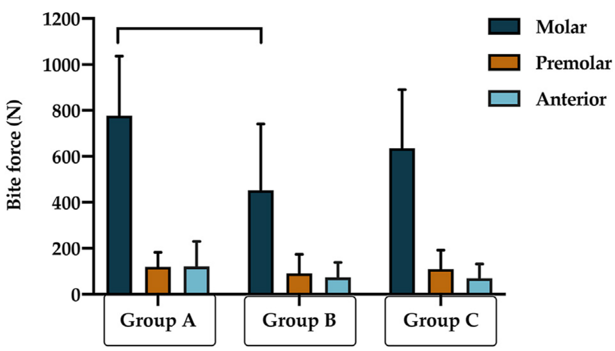

Figure 4 Comparison of the bite force in different teeth zones among groups A (F/R <8%), B (F/R 8–25%), and C (F/R >25%), *$P < 0.05$. (F/R ratio stands for filled-to-remaining teeth ratio.)

the missing number of the teeth and the sum of missing and filled teeth. When F/R ratio is less than 8% the bite force is significantly higher than 8–25%, and mostly contributed by molar region of teeth, furthermore, with the S. mutans

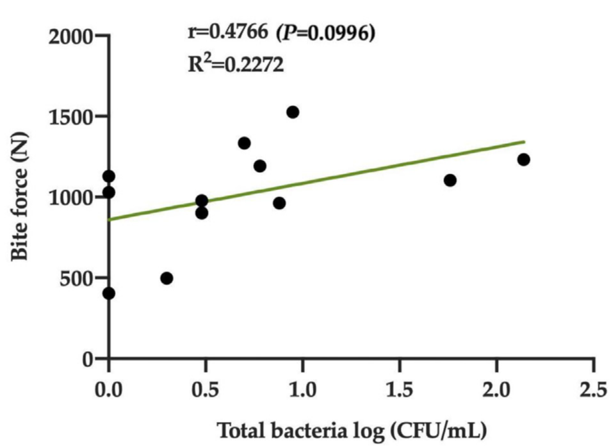

Figure 5 Pearson correlation coefficient (r), R squared (R^2) and *P*-value (*P*) between bite force (Group A, F/R <8%) and total bacteria log (CFU/mL). F/R ratio stands for filled-to-remaining teeth ratio.

count to Total bacteria ratio, when FD/R ratio less than 15% is significantly higher than FD/R over 31% and D/R 4–10% higher than D/R over 4%.

According to previous studies, in teenagers aged from 15 to 18 years old, the decayed, missing and filled teeth (DMFT) scores was around 5.2–6.1.[22] Furthermore, same to the result in the current study, the missing teeth number was related to the maximum bite force negatively.[11]

There have been studies reported that the maximal bite force is ranging from 224 N to 859 N or 258.5 ± 175.7 N.[23,24] In this current study the average bite force is about 815 N (male 800 N, female 829 N) possible explanations for this finding include the use of different devices, among the studies, with different biting elements may cause variations in the bite force measurements.

Bite force varies in areas of the oral cavity, the greatest bite force had been recorded in the first molar region.[5,25] Other study recorded that the bite force observed in anterior region is 40% of unilateral molar region, and premolar region 70 % of unilateral molar region, and if bite force was recorded bilaterally in molar region, the force would be even higher.[5,7] Same in this study, the maximum bite force is highest in the molar region significantly than in premolar and anterior teeth area.

A study had bite force from adults above 60 years of age comparing to that of young adults and found that the elders' bite force was higher although no significant level to be found, from this it was suggested that in adults with adequate dentition, age would not affect the change of bite force.[26] Additionally, the bite force stays constant from age of 20s–50s, then declines, and in the range of age 20–50 the bite force is of 400–600 N.[5,26] Stronger bite force was detected from this current study that is about 815 N (male 800 N, female 829 N) with mean age of 24 in young adult.

Studies have shown that men having a higher bite force than women.[27–29] Some suggested that the difference on bite force between men and women has been mostly due to the anatomical differences that men had greater muscular potential.[30] However, it is in contrast to study by Abu Alhaija et al., which found no significant difference in maximum bite force between men and women.[31] In this study, women had stronger bite force than man, which might have several possible reasons such as small sample size, host factor like untreated caries, fear of pain etc.

Body mass index (BMI) had no found direct effect on bite force; but according to other research, facial dimensions may influence the bite force.[28]

There was no direct relationship observed among bite force, plaque pH, and plaque weight. Bite force was found to be associated with salivary flow rates, while plaque pH and plaque weight are affected by cariogenic bacteria, and dietary factors.[32–34] Increased plaque scores have been related to higher salivary flow rates. Moreover, the pH value, buffering capacity, viscosity, and flow rate of saliva have been associated with children's caries activity.[35,36] Therefore, the plaque pH, and weight was suggested to be related to the bite force, however, the correlation of plaque pH and weight with bite force did not been found in the study.

A *Streptococcus mutans* (*S. mutans*) and a *Streptococcus sobrinus* (*S. sobrinus*) as cariogenic bacteria are associated

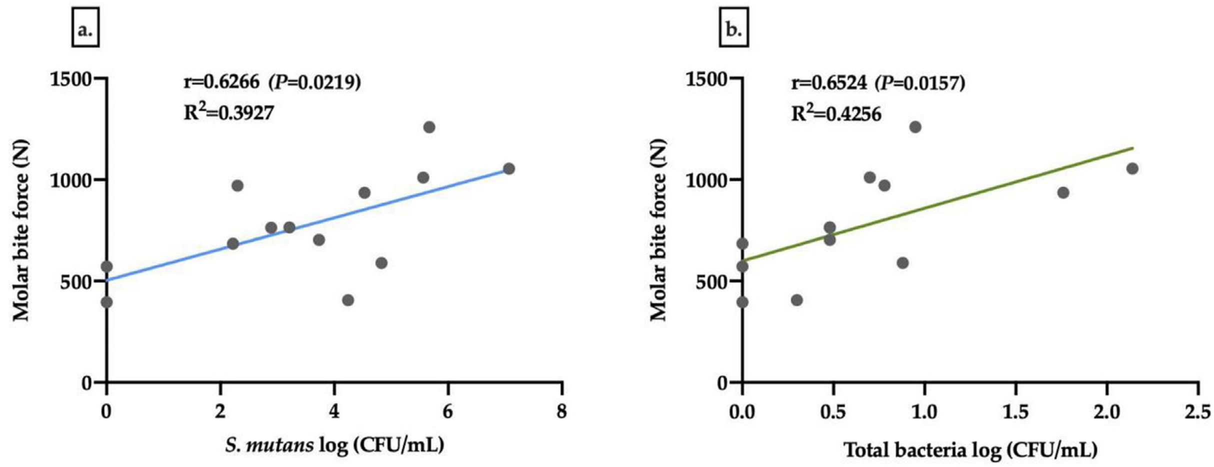

Figure 6 **a.** Pearson correlation coefficient (r), R squared (R^2) and *P*-value (*P*) between molar bite force (group A, F/R <8%) and S. mutans log (CFU/mL); **b.** Correlation between molar bite force (group A, F/R <8%) and total bacteria log (CFU/mL). F/R ratio stands for filled-to-remaining teeth ratio. (F/R ratio stands for filled-to-remaining teeth ratio).

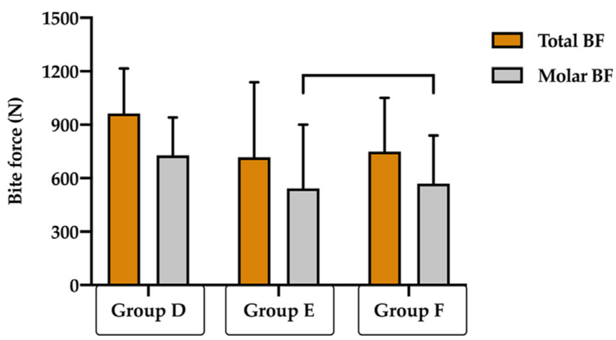

Figure 7 Bite force comparison between total bite force and molar bite force (FD/R ratio), *$P < 0.05$. (FD/R ratio stands for filled and decayed teeth-to-remaining teeth ratio).

with dental caries.[37,38] The relation of maximum bite force and the progression of caries in early permanent dentition was found in other study, moreover, the relationship between maximum bite force and oral bacteria level had been found in children after dental treatment.[39,40] In this study of young adult, the bacterial amount didn't seem to had effect on bite force.

The weight and pH value of dental plaque doesn't seem to associate with MBF and DMFT, the gender and age doesn't seem to be related to MBF either, but same to other study, less missing teeth would have stronger MBF.[7] The factors that might affect the results could be: small sample size, individual diet pattern, fear to bite due to pain or untreated dental situation, malocclusion, individual salivary flow and individual oral flora.

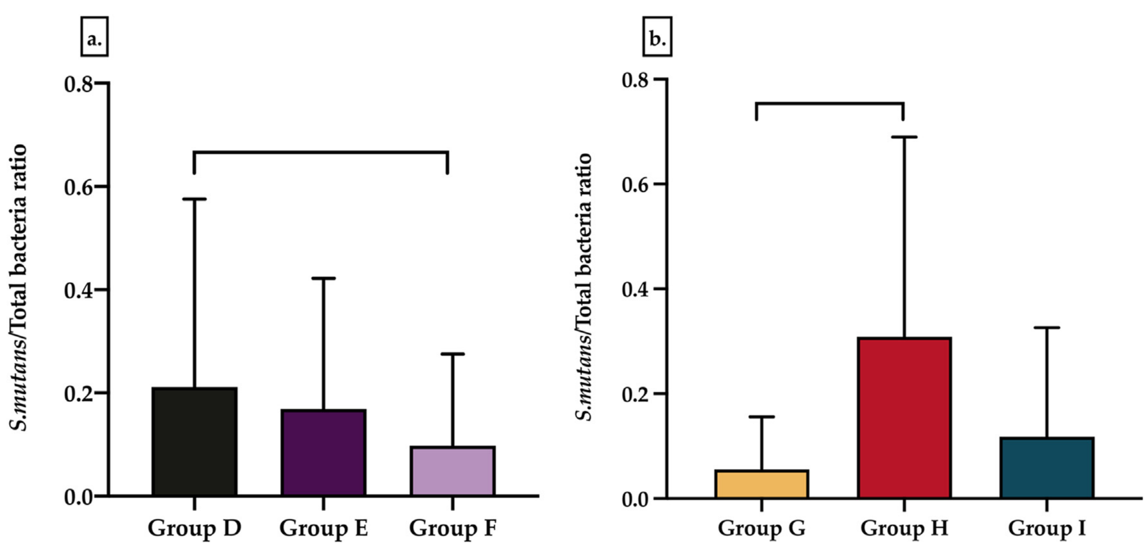

Figure 8 **(a—b). a.** Comparison between S. mutans counts-to-total bacteria ratio and groups D (FD/R<15%), E (FD/R 15—30%), and F (FD/R>31%) FD/R ratio stands for filled and decayed teeth-to-remaining teeth ratio. **b.** Comparison between S. mutans counts/total bacteria ratio and groups G (D/R<4%), H (D/R 4—10%), and I (D/R>10%); *$P < 0.05$. (FD/R ratio stands for filled and decayed teeth-to-remaining teeth ratio, D/R ratio stands for decayed teeth-to-remaining teeth ratio).

Our study revealed a significant negative correlation between maximum bite force (MBF) and either the number of missing teeth or the combined total of missing and filled teeth. When F/R ratio is less than 8% the bite force was significantly higher than F/R ratio 8–25%, the molar region was the primary contributor to bite force. In terms of oral bacterial levels, the S. mutans/Total bacteria ratio was significantly higher when the FD/R ratio was less than 15% and the D/R ratio was between 4 and 10%, compared to FD/R ratios over 31% and D/R ratios over 4%. This novel insight enhances our understanding of the interplay between oral microbial composition and dental health. Our study uniquely investigated the relationship among DMFT scores, oral microbes in ratio form, and bite force. This approach has led to the insight that the F/R ratio could be a simple yet effective clinical index for monitoring the risk of reduced bite force. Elevated levels of cariogenic bacteria may heighten the risk of tooth loss due to caries and periodontitis, both major factors leading to tooth loss in adults.[41] The inverse relationship we found between the number of missing teeth and bite force further emphasizes this risk, potentially impacting chewing efficiency and overall quality of life.

The findings from this study could serve as a valuable clinical tool to identify patients at risk of reduced bite force. An F/R ratio above 8% may be used as an indicator for preventive treatment or therapeutic plans to maintain current oral health or restore lost function. For future research, expanding the study to a broader population and incorporating additional oral health factors could refine clinical guidelines. This could enhance the timing and precision of interventions related to caries risk and bite force reduction, ultimately contributing to better oral health outcomes in an increasingly long-lived population.

Declaration of competing interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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