Measurement of the Maximum Occlusal Bite Force and its Relation to the Caries Spectrum of First Permanent Molars in Early Permanent Dentition

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Objective: *To determine the maximum occlusal bite force (MOBF) of the complete spectrum of dental caries in first permanent molars (FPMs) in children aged 7-9 years.* ***Study design:*** *A cross-sectional study was conducted on 123 children. The evaluation of the caries spectrum of FPMs was carried out using the Caries Assessment Spectrum and Treatment index (CAST). The MOBF was measured in the FPM region using the portable occlusal force gauze. Independent sample t-test and one-way analysis of variance test were performed to compare MOBF with CAST scores of FPMs. Based on the CAST scores, FPMs were categorized into three groups, group 1: healthy (score 0, 1, 2), group 2: premorbid (score 3), group 3: morbid (score 4, 5).* ***Results:*** *A significantly lower MOBF was observed (167.56 N ± 49.77) in the morbid stage (group 3) than in the premorbid stage (group 2: 291.57 N ± 56.64), and healthy (group 1; 320.93 N ± 54.23). Intergroup comparison also revealed that FPMs in the healthy stage was associated with a higher bite force compared to those in the premorbid and morbid stages ($p<0.001$).* ***Conclusions:*** *The mean MOBF decreased with the progression of the caries spectrum of FPMs in early permanent dentition.*

Keywords: *Bite force, Caries spectrum; CAST index, Dental caries; Occlusal force gauze*

INTRODUCTION

Assessment of the maximum occlusal bite force (MOBF) is a quantitative measurement to evaluate masticatory efficiency.[1] The MOBF depends on age, gender, height, weight, status of the teeth, and facial morphology.[2, 3] There are few contradictions in the literature regarding the association between these variables.[4-6] A study conducted by Varga *et al* revealed that males had a higher bite force than females, with variations in gender contributing to only 17.9% and age 7.9%, and the rest was contributed by jaw functions, masticatory forces, and body mass index (BMI).[4] Similarly, another study showed a higher correlation between muscle activity and bite force.[6] In contrast, another study revealed that there is no significant difference between bite force and gender. However, boys with permanent dentitions had a higher bite force compared with those with mixed dentitions. Furthermore, bite force positively correlated with height, weight, and age in the permanent dentition.[7]

There is still a need to understand bite force in children and recognize the dynamic interplay of a range of influencing variables.[8] However, little is known about how dental caries influences the bite force and its difference between genders. Kaya *et al* reported that caries reduces masticatory performance in early permanent dentition.[9] Untreated dental caries results in impaired masticatory performance due to decreased bite force, which may result in imbalanced nutrition intake.[10] This may prompt patients to prefer softer food, which is typically low in fibers and proteins, and high

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in carbohydrates, leading to nutritional deficiencies and gastrointestinal problems.[11]

Togoo *et al* reported the prevalence of dental caries of the first permanent molar (FPM) among Saudi Arabian children as 66.4% with a decayed, missing, and filled teeth (DMFT) of 2.74 ± 1.18.[12] Other recent studies from the Kingdom of Saudi Arabia (KSA) reported a high prevalence of caries in FPMs in early permanent dentition.[13, 14] The FPMs cannot be disregarded, as they form the key to occlusion, and losing them early due to caries can have a significant impact on the development of dental arches.[12] Su *et al* and Mountain *et al* reported lower MOBF in children with carious primary teeth.[15,16] Owing to the high prevalence of caries among Saudi Arabian children, there is a need to investigate their potential effect on MOBF.

Several indices are available for the diagnosis of dental caries based on different diagnostic thresholds. In the present study, the caries assessment spectrum and treatment (CAST) index was chosen for the assessment of the stages of progression carious lesions in FPMs involving the enamel, dentin, and pulp.[17] A report from Poland illustrated that the CAST index is presently being used in populations of diverse age clusters in different nations.[18] It is an innovative instrument that describes the complete spectrum of caries processes hierarchically in epidemiological studies. Limited information is available on the impact of dental caries of FPMs on MOBF in early permanent dentition. Therefore, the present study aimed to determine the MOBF values of caries spectrum of the FPMs in 7 to 9 years old children.

MATERIALS AND METHOD

Sample Size Determination

The sample size was estimated using G*power 3.0.1. The power (1 – β) of the study was set at 0.8, and the type I error rate (α) was set at 0.05. A previous study reported the mean and standard deviation (SD) bite force of 34.53 (18.02) kilogram (kg) and 25.23 (13.85) kg for boys and girls, respectively.[10] Using the above parameters, the sample size was estimated to be 96 (48 boys and 48 girls). After adding a 20% drop-out rate, the final adjusted sample size was 120 participants.

The present study was comprised of 60 males (mean age 8.9 ± 1.56) and 60 females (mean age 8.82 ± 1.46), who visited an outpatient pediatric dental clinic. The study was conducted from January 2018 to October 2018 in the city of Sakaka, which is the capital of Al-Jouf province, located in the northern region of KSA. Written informed consent was obtained from parents/caregivers of each child before they were enrolled. The study objectives, examination procedure, possible discomfort, and associated risks were explained before obtaining consent. This study was performed following ethical principles after the approval of the Local Committee of Bioethics, Jouf University, KSA, and all procedures were fully in accordance with the Declaration of Helsinki.

The inclusion criterion was the presence of maxillary and mandibular FPMs regardless of the type of dental occlusion. Children with endodontically treated FPMs, pain/abscess involved teeth, any pre shedding mobile tooth, systemic illness, temporomandibular disorders, open posterior crossbite, a history of previous orthodontic treatment, uncooperative or fearful/apprehensive behavior, and failure to provide valid consent were excluded from the study.

Assessment of Caries Spectrum of First Permanent Molars

The screening and clinical examination of the participants were conducted in the outpatient pediatric dental clinic on a dental chair, using artificial light, disposable mouth mirrors, cotton rolls, and WHO probes to diagnose the caries status of the FPMs. The CAST index was used to record the complete spectrum of FPMs dental caries lesions, that is, sound, fissure sealed, restorative, and caries in the enamel and dentin. The main advantage of the CAST index is its simplicity in describing the complete range of stages of progression of dental caries lesions from the absence of caries, to the prevention of caries (fissure sealants), and restoration of carious lesions involving the enamel and dentin, and subsequent progression to the pulp and peri-radicular tissues. On the other hand, the CAST index combines the International Caries Detection and Assessment System (ICDAS II) and Pulp involvement (P), Ulceration (U), Fistula (F), Abscess (A) index (PUFA) components, and the missing (M) and filled (F) components of the DMFT index.[17] The description of the CAST score and criteria is given in Fig 1. No radiographs were taken to diagnose the caries lesions. Based on the CAST scores, FPMs were categorized into three groups; [17] group 1: healthy (score 0, 1, 2), group 2: premorbid (score 3), group 3: morbid (score 4, 5).

The CAST score of each FPM was recorded as if the same FPM surface had several conditions, and a higher score for each FPM was considered for further analysis.[17] For example, if there was a restoration in one pit and an enamel lesion on another surface, the score for the enamel lesion was recorded.

Measurement of the Maximum Occlusal Bite Force

On the same dental visit by each child, after recording the CAST score for FPMs, the MOBF was measured in the region of the FPM by using the movable occlusal force gauze (GM10, Nagano Keiki, Tokyo, Japan). The bite force gauze contained a hydraulic pressure gauze and a biting element made of vinyl material encased in a plastic tube.[19] The accuracy of the occlusal force gauge was investigated by Sakaguchi *et al* and reported to be an accurate device, with an accuracy of ± 1 Newton (N) and capable of recording the measured force from 0 to 1000 N.[20] The MOBF of the participants was recorded while participants were seated on a dental chair in an upright position and the bite force device consecutively placed on the first permanent molar on the right and left sides of the dental arch. The participants were instructed to bite as hard as they could and the bite force displayed digitally on the device screen in Newton. Three consecutive measurements of MOBF were taken on each side and the average of all measurements was considered as the final MOBF value of the individual. The three measurements of MOBF on each side were taken every three minutes to avoid muscular fatigue while recording the bite force. After each recording, the bite force gauge was cleaned with 70% isopropyl alcohol, and disposable latex finger cots used to measure the bite force.

Examiners Calibration

Two investigators (RKG and MKA) carried out the dental caries examination of the FPMs and MOBF registration. Inter- and intra-rater reliability was determined by the kappa agreement. The reliability of the measurements was assessed after two weeks by reexamining 10% of participants randomly. Method errors for numerical variables were examined using the Dahlberg's formula [21] and Houston coefficients of reliability for the MOBF measurement.[22]

Statistical Analysis

Statistical analyses were performed using Statistical Package for the Social Sciences(SPSS) version 24 (IBM Corp, Armonk, NY, USA). The independent sample t-test was conducted to compare the mean MOBF between sexes. One-way analysis of variance (ANOVA) test was applied to compare the mean MOBF between CAST score groups, and post hoc analysis was carried out using the Tukeys HSD correction method.

RESULTS

The results of the kappa analysis were 0.86, 0.87, and 0.82 for both intra- and inter-examiner reliability, which indicates an almost perfect agreement in the recording of the CAST scores of the FPMs. The error measurement for numerical variables, Dahlberg error, was 6N, and Houston coefficients of reliability was 87%.

In this study, boys had a slightly higher mean MOBF than girls using the CAST score. This difference was non-significant (Table 1). The highest mean MOBF was observed in CAST score zero ('0') (363.43 N ± 35.18 for boys and 311.88 N ± 5.68 for girls). The lowest mean MOBF was observed in CAST score five ('5'), which was 294.82 N ± 34.07 and 253 N ± 55.77 for boys and girls, respectively (Table 1). The CAST scores zero ('0'), one ('1'), and two ('2') showed a similar mean MOBF. A gradual non-significant decrease in mean MOBF was reported in CAST scores three ('3'), followed by four ('4'), and five ('5') in both sexes ($p > 0.05$). The lowest mean MOBF was observed in CAST score five ('5') (Fig. 2).

Table 2 illustrates the mean MOBF compared with the CAST score groups by one-way ANOVA test. Group 1 (healthy; codes: zero ('0'), one ('1'), two ('2') FPMs showed higher mean MOBFs (320.93 ± 54.23) and the lowest MOBF was reported in group 3 (morbidity stage: code four ('4'), and five ('5') FPMs. In the CAST score groups of FPMs, the mean MOBF decreased with increasing CAST score, which was statistically significant ($p < 0.001$) (Fig.3)

Post hoc Tukey's multiple pairwise comparison showed a significant difference in the mean MOBF between group 1 and group 2 ($p = 0.021$), between group 1 and group 3 ($p < 0.001$) and between groups 2 and 3 ($p < 0.001$) (Table 3).

Table 1: Mean MOBF values of CAST scores of First Permanent Molars in relation to the gender

	Group	Mean ± SD	p value
Score 0	Male	363.43 ± 35.18	0.133
	Female	311.88 ± 55.68	
Score 1	Male	358.84 ± 67.11	0.644
	Female	310.91± 55.87	
Score 2	Male	356.43 ± 25.66	0.877
	Female	301.06 ± 37.12	
Score 3	Male	311.22 ± 57.16	0.669
	Female	297.32 ± 78.12	
Score 4	Male	317.16 ± 34.07	0.137
	Female	275.61 ± 55.77	
Score 5	Male	294.82 ± 34.07	0.137
	Female	253.27 ± 55.77	

MOBF measured in newton (N)

Table 2: Comparison of mean MOBF among CAST Score groups- One-way ANOVA

Groups	Mean ± SD	ANOVA	
		F value	p value
Group 1: Healthy (score 0, 1, 2)	320.93 ± 54.23	53.4	0.000
Group 2: Premorbid stage (score 3)	291.57 ± 56.64		
Group 3: Morbidity stage (score 4, 5)	207.03 ± 49.77		

p<0.001 is highly significant

Figure 1: Scores and description of CAST index

Score	Characteristic	Description
0	Sound tooth	No visible evidence of a distinct carious lesion is present
1	Sealed	Pits and fissures have been at least partially sealed with a sealant material
2	Restored	A cavity has been restored with an (in)direct restorative material currently without a dentine carious lesion and no fistula/abscess present
3	Enamel	Distinct visual change in enamel. A clear carious related discolouration (white or brown in colour) is visible, including localized enamel breakdown without clinical visual signs of dentine involvement
4	Dentine	Internal caries-related discolouration in dentine. The lesion appears as shadows of discoloured dentine visible through enamel which may or may not exhibit a visible localized breakdown
5	Dentine	Distinct cavitation into dentine. No (expected) pulpal involvement is present
6	Pulp	Involvement of pulp chamber. Distinct cavitation reaching the pulp chamber or only root fragments are present
7	Abscess/fistula	A pus containing swelling or a pus releasing sinus tract related to a tooth with pulpal involvement due to dental caries is present
8	Lost	The tooth has been removed because of dental caries
9	Other	Does not match with any of the other categories

Figure 2: Distribution of CAST scores of FPMs according to gender

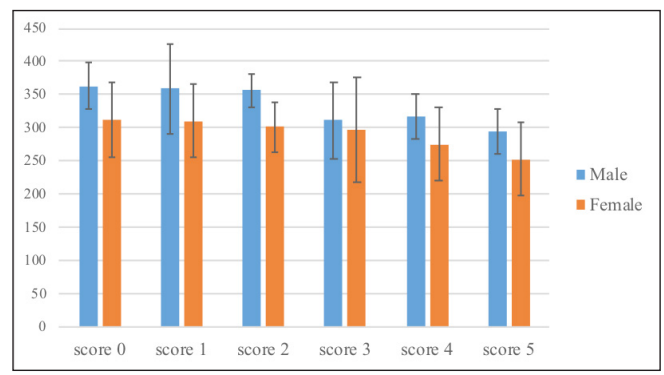
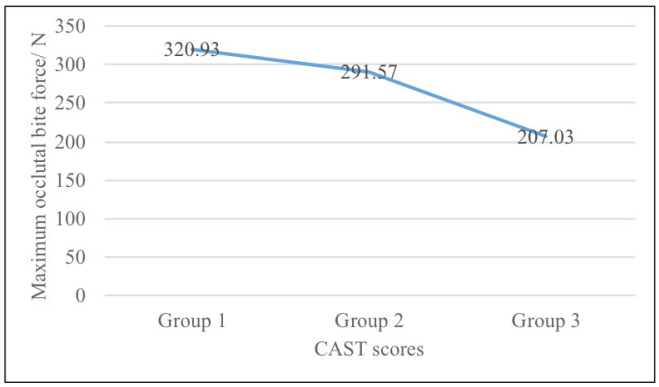


Table 3: Post hoc test – Tukeys HSD

CAST Score	Groups	Mean difference	Std. Error	Sig.	95% Confidence Interval	
					Lower bound	Upper bound
Group 1 (healthy)	Group 2	29.35*	9.88	.021	2.94	55.76
	Group 3	113.89*	13.97	.000	76.55	151.24
Group 2 (premorbid stage)	Group 1	-29.35*	9.88	.021	-55.76	-2.94
	Group 3	84.54*	13.97	.000	47.19	121.88
Group 3 (morbid stage)	Group 1	-113.89*	13.97	.000	-151.24	-76.55
	Group 2	-84.54*	13.97	.000	-121.88	-47.19

Figure 3: Mean MOBF values according to CAST score groups



DISCUSSION

The present cross-sectional study aimed to determine the MOBF with the caries spectrum of FPMs in 7-9-year-old Saudi Arabian children in the northern region of KSA. The FPM exerts the highest bite force in the dental arch.[23] It is essential to investigate the potential impact of the caries status of the FPMs on MOBF in early permanent dentition. In our study, there was no significant difference in the mean MOBF in either sex, which is in agreement with several studies.[15, 24] Few studies have reported that the mean bite force is higher in males than in females.[25, 26] This could be attributed to muscle development by androgenic hormones in males during the post-pubertal period. There was no significant difference in the mean bite force among the 4-6-year old children.[15] However, bite force increases from mixed to permanent dentition,[27] remains constant from 20 to 40 years of age and then declines.[28,29]

The mean MOBF values of 7 to 20-year-old individuals were 309.50 N ± 193.75 and 219 N ± 144.21 for men and women, respectively.[30] We reported a relatively similar MOBF with CAST scores '0', '1' and '2', these scores denoted sound or restored FPMs. According to the CAST index, sound ('0'), fissure sealed (score '1') restored teeth (score '2') were considered healthy teeth, which is in line with the epidemiological concept of the healthy,[17] whereas score '3' was considered as a reversible premorbid stage. Owais *et al* reported the mean MOBF values for the different dentition stages: 176 N in the early primary stage, 240 N in the late primary stage, 289 N in the early mixed stage, 433 N in the late mixed stage, and 527 N in the permanent dentition stage.[31] Mountain *et al* reported maximum bite force measurements ranging from 12.61 to 353.64 N in the primary dentition.[16] In our study, it was shown that the mean MOBF of FPMs decreased with an increase in the CAST score. In the present study, the mean MOBF started to decrease from CAST score '3', which is the reversible premorbid stage; it could be reversed by restoring the visible breakdown, with or without the localized enamel, to restore bite force. The presence of cavitated carious lesions involving the dentin, in CAST score '4' and '5', was predominantly associated with decreased MOBF. The occlusal bite force is seen to increase significantly following dental restoration.[32] Masticatory performance was higher in caries-free children than in children with caries.[9] However, the maximum bite force values in children with and without caries were not statistically different.[9]

In our study, the MOBF values of the CAST score groups were significantly different between the groups. The morbid stage of the FPM showed the lowest MOBF, followed by the premorbid stage and the healthy group of FPMs. The highest bite force value was observed in the healthy group of FPMs. MOBF decreases when caries progresses from cavitated enamel lesions into the dentin. The lower MOBF in the premorbidity and morbidity groups in the present study may be due to sensitivity and pain. When occlusal caries progress to advanced stages, occlusal bite forces reduces remarkably. The negative effect of caries on MOBF can also be attributed to pain or fear of pain from periodontal mechanoreceptors and a damaged occlusal table.[30]

Children with clinically visible carious FPMs had low masticatory performances.[9] Barbosa *et al* reported a positive correlation between the number of decayed teeth and masticatory performance.[33] A significant increase in the occlusal bite force following the elimination of pain, discomfort, and restoration of the occlusal surface to its normal anatomy increases the surface area for biting, leading to an increase in bite force and thus the number of occlusal contacts.[32] The masticatory performance and bite force were independent of each other, and masticatory performance was independent of muscular force and body variables.[34] Koc *et al* did not find a correlation between bite force and BMI.[26] In contrast, it has been reported that bite force decreases in obese boys but increases in obese girls, which could be due to testosterone sensitivity modulated by the fat level.[10]

Moreover, no significant mean difference was observed in maximum bite force with different kinds of occlusion in the primary dentition.[19, 35] In permanent dentition, bite force did not correlate with the Angle classification,[30, 36-38] but correlated with maxillary protrusion, anterior crossbite, crowding, and an open bite,[19] This suggests that the quality of occlusion determines the masticatory performance rather than the level of bite force. Tsai *et al* reported a negative correlation between the number of decayed teeth and the maximum bite force.[39]

The bite force apparatus used in this study has the primary advantage that it is small, portable, and easy to apply intra-orally in children. The device showed good acceptability by the children in our study. The bite force-measuring device used in this study was shown to be accurate in previous studies.[19, 31] Furthermore, it does not interfere with the tongue and is quickly disinfected by changing the disposable plastic covering. In this study, the only risk was tooth damage and this was considerably reduced by excluding patients with extensive molar restorations and developmental defects.

FPMs play a key role in the growth and development of dental arches and are the teeth most susceptible to caries. The CAST index is a potentially useful tool for planning caries control programs in both individuals and at community levels.[40] The CAST index has excellent manageability, reproducibility, validity, and reporting compared with WHO and ICDAS indexes.[41] The CAST index has been used in several studies in the literature.[18, 42, 43] A recent study showed that CAST is less tedious and utilization in research is greatly encouraged.[44] In the present study, the CAST index did not only assessed the caries spectrum but also estimated the MOBF in early permanent dentition. We did not include children with advanced caries of FPMs (severe morbid stage; CAST score '6' or '7') because these teeth had spontaneous pain, pain upon percussion and eventual loss of FPMs could negatively affect the MOBF of the individuals.

Several studies have reported the reliability of the measurement of MOBF values associated with various parameters such as; age, height, weight, BMI, craniofacial morphology, dental arch relationships, and temporomandibular disorders. In addition to these physiological factors, recording devices and techniques are essential factors in bite force measurement.[26] There is an apparent lack of clarity regarding the nature of the factors affecting bite force.[45] Further studies should be conducted to correlate the bite force values with the caries spectrum so that oral health policymakers can implement preventive and interceptive measures to restore the bite force and masticatory efficiency. The findings of the present study helped to determine the range of MOBF values with various stages of the caries spectrum of FPMs in early permanent dentition. These data can provide fundamental reference values for further research studies.

CONCLUSION

The present study revealed that mean MOBF values decreased with the progression of the caries spectrum of the FPMs. The morbid stage of the FPMs showed a lower MOBF than the premorbid stage and healthy group. Assessing MOBF with caries spectrum of FPMs would enable oral health care professionals to prevent caries lesion progression by using caries-control measures to restore masticatory efficiency and bite force in early permanent dentition.

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