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Masticatory parameters of children with and without clinically diagnosed caries in permanent dentition

ABSTRACT

Aim Mastication turns food into a bolus and prepares it for chemical digestion. Any condition affecting tooth structure and position may have an impact on mastication. The aim of this study is to compare masticatory performance (MP) and maximum bite force (MBF) between children with and without clinically visible caries in permanent first molars.

Materials and methods The study was conducted with 50 children in good general condition aged 12-14 years (25 girls, 25 boys) with no orthodontic/skeletal anomalies and no missing teeth due to dental trauma or extraction. Maximum bite force was measured bilaterally using strain gauge sensors. Masticatory performance was evaluated by silicone tablet comminution test.

Results Masticatory performance was superior in caries-free children when compared to children with caries. Maximum bite force values in children with and without caries were not statistically different.

Conclusions Caries reduces masticatory performance. Therefore, treatment is crucial for masticatory efficiency.

Keywords Dental caries, Masticatory performance, Bite force

Introduction

Mastication is the act of cutting or grinding food between teeth which turns it into a bolus to be swallowed and prepares it for chemical digestion [Woda et al., 2011]. Feedback for neuromotor control of mastication is provided by inter-arch contact in the occlusal area and receptors in the temporomandibular joint, dental pulp, periodontium [Lemos et al., 2006; van der Bilt et al., 2008]. Therefore, any condition affecting tooth structure and position may have an impact on mastication [Decerle et al., 2013].

Masticatory capacity is usually assessed according to masticatory performance (MP) and maximum bite force (MBF) [Lemos et al., 2006; Oueis, 2009; Hatch et al., 2001; Ohira et al., 2012]. High MBF levels and small median particle sizes (MPS) in MP tests are considered indicators of an efficient masticatory system [Su et al., 2009; Julien et al., 1996; Kampe et al., 1987]. Factors including age, sex, occlusion, number of teeth present, dentition stage, facial morphology and temporomandibular joint disorders have been reported to influence MBF and MP [Barrera et al., 2011; van der Bilt, 2011; Owais et al., 2013; Castelo et al., 2010; Duarte Gaviao et al., 2006].

Dental caries is the most frequent disease for which parents seek dental treatment for their children [Selwitz et al., 2007; Agostini et al., 2001]. However, treatment is usually sought only after the onset of pain and discomfort. Patients with missing teeth or those requiring prosthodontic treatment have been shown to have low MP and MBF [Selwitz et al., 2007; Ayhan et al., 1996; Hatch et al., 2001; Fontijn-Tekamp et al., 2000]. Reduced masticatory capacity may also predispose patients to softer food preferences, which are typically low in fiber and protein, high in carbohydrate content, and thus may lead to nutritional deficiencies and gastrointestinal problems [Hatch et al., 2001; Fontijn-Tekamp et al., 2000; de Moraes Tureli et al., 2010; N'Gom P and Woda, 2002].

While the negative effect of caries on mastication has been reported in individuals with severely compromised dentition, few studies have examined its effect on MP and MBF [Decerle et al., 2013]. To investigate this further, our study aimed to compare MP and MBF between children with and without clinically diagnosed caries in early permanent dentition.

Materials and methods

Participants

This cross-sectional study was conducted at the Paediatric Dentistry Clinic of Marmara University, in full accordance with the ethical principles of the Helsinki Declaration (version 2008) and with the approval of the Yeditepe University Medical School Ethical Committee (Protocol Number: 208). Parents of 12-14 year-olds who attended the Pediatric Dentistry Clinic of Marmara University and had panoramic radiograph obtained within the last 6

months, were contacted from randomised patient records. The purpose of the study was explained to the parents and those willing to participate in the study were scheduled for an examination. One researcher (M.S.K.) performed the clinical examination to check the children's eligibility according to inclusion criteria. Caries was checked on dry surfaces. Localised enamel breakdown in opaque or discoloured enamel and/or grayish discolouration from the underlying dentin, cavitation in opaque or discoloured enamel with exposed dentin beneath were considered as caries (Ekstrand Classification 3-4) [Ekstrand et al., 1998]. Intact enamel without any change in translucency after air drying was recorded as without caries. Following the clinical oral examination, panoramic radiographs of the children were also studied to exclude proximal or other caries that might have been missed during the clinical assessment.

Inclusion criteria

Parents of the children who fulfilled the following inclusion criteria gave written informed consents. Additionally, in order to ensure full cooperation of the children, no child was included without his/her verbal consent. Inclusion criteria were as follows.

1. Angle Class I molar relationship with no anterior or posterior cross-bite or open-bite.
2. No local dental pain.
3. No extracted teeth.
4. No gingival inflammation, periodontal disease, or tooth mobility.
5. No reported systemic disease.
6. No parafunctional habits, no pathological facet-wearing and no soft-tissue abnormalities.
7. No restored teeth.
8. No symptoms of temporomandibular joint dysfunction (such as restricted mandibular opening, muscular pain, pain in the jaws, headache, ear ache, pain/difficulty when opening the mouth).
9. In the carious group, at least one carious first permanent molar (FPM) on the right and/or left side of the dental arch without proximal involvement.
10. No proximal caries detected on the radiograph.

Sample size and anthropometric data

A previous study measuring bite force in children was used as a basis for power analysis conducted to estimate the number of participants required in this study [Owais et al., 2013]. This was determined to be a minimum of 15 subjects per group ($\alpha = 0.05$, $\beta = 0.20$). Accordingly, the study was conducted with 50 children (25 girls, 25 boys) aged 12-14 years who met the inclusion criteria, with 25 children in the caries group and 25 children in the caries-free group. In order to minimise the effects of age and body size on MBF and MP, the ages, heights and weights of children were compared between the groups. Height was measured with a portable stadiometer (model 213, Seca, Germany). Each child stood with his/her back

straight against the rod without shoes and with the Frankfort horizontal plane positioned parallel to the floor. Body weight was measured using a calibrated electronic scale (model 813, Seca, Germany) without shoes and heavy clothing.

Bite force measurement

The bite force was measured using a portable device consisting of three cylindrical strain gauges similar to the Istanbul Bite Force Recorder designed by Diracoglu et al. [2008, 2011]. Previous studies have shown this device to provide reliable force measurements in vitro and in vivo [Diraçoğlu et al., 2008; Diraço lu et al., 2011]. Each strain gauge (Model 13; Honeywell Sensotec, Columbus, OH), with dimensions of 9.7 mm diameter x 3.3 mm height, was placed between 0.85-mm thick stainless steel (type 316L) panels which were hinged together with stainless steel wire (0.254 mm diameter). The panels were in the form of two dental arches with dimensions based on a dental casting obtained from one child in the caries-free group. The outer surfaces of the panels were covered with a thin layer of disposable bandage tape to buffer the surface during biting and the entire mouth piece was covered with a sterile latex glove which was changed after each use. The mouth piece was approximately 6 mm in thickness before use (incl. the covering) and was found to comfortably fit each child tested.

Force calibration was performed by placing the strain-gauge sensors at the mid-incisor and in the left and right FPM regions (Fig. 1). Each sensor (with its associated electronic circuit) was calibrated by a small hand press between 0-588 Newton in 98-Newton steps. Calibration slopes were 113,266 and 247 Newton/Volt, respectively for the mid-incisor, right-molar and left-molar sensors. The zero-error of each sensor channel was corrected in

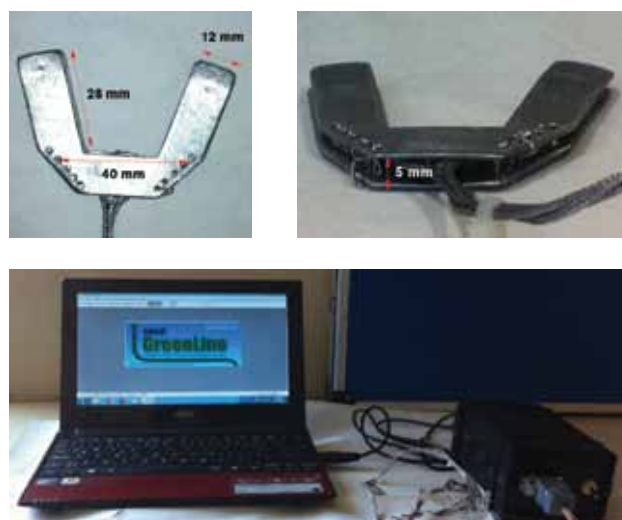


FIG. 1 The portable bite force recorder used in the study. On top the mouthpiece; below the mouthpiece, processor/recorder unit, and a personal computer.



FIG. 2 Silicone tablets for the masticatory performance test.

the device. Each calibration point was an average of four repetitive measurements. The relative error of the entire recording device was less than 2%. A linear calibration fit was almost perfect for each sensor ($R^2 \geq 0.998$).

Each child was asked to perform bilateral clenching three times while seated and facing forward in a natural position. There were 30 seconds of rest between measurements to avoid poor performance due to fatigue. Output from each sensor was recorded by a data logger (HOBO U12; Onset Computer, Bourne, MA). After each session, the data were transferred to a PC via USB cable, and saved as a separate computer file for analysis using the software program Onset Greenline. The maximum voltage value (Volts) of the three tests was converted to a force value (Newtons) using the calibration slopes given above. The sum of the right (RBF) and the left (LBF) sides was recorded as the MBF value [Koc et al., 2011; van der Bilt et al., 2008; van Kampen et al., 2002]. The sum was considered to approximate the total force exerted due to the masticatory muscles.

Masticatory performance

Masticatory performance was determined by silicone tablet comminution as reported in the literature [Albert et al., 2003]. Silicone tablets (Optosil Comfort Putty, Heraeus Kulzer GmbH, Germany) were prepared and stored in plastic bags for up to seven days before use. Tablets were of a standardised size (20 mm diameter x 5 mm height) and hardness (62-65 Shore), as measured by a Type A Shore durometer (Kori Seiki MFG Co. LTD Japan). Tablets were cut into quarters to ease chewing and weighed before use (Fig. 2), with approximately 11 g given to each participant. Participants were asked to bilaterally chew 3 silicone quarter-tablets 20 times in a single chewing cycle, and to repeat the procedure for a total of 6 cycles. There was a resting period for 30 seconds between cycles to avoid fatigue. At the end of the test, the participants spit into a plastic cup and were allowed to swish until no fragment was left behind. Fragmented particles were dried at room temperature for 24 hours and weighed to check for material loss. In cases of mass loss greater than 6%, the test was either repeated, or the sample was excluded from the study. Fragmented particles were separated by sieving them through a stack of 6 sieves with progressively smaller aperture sizes (5.4, 4, 2, 1, 0.5, and 0.25 mm) placed on a laboratory vibrator for two minutes. Fragments separated according to particle size were weighed by using an electronic scale accurate

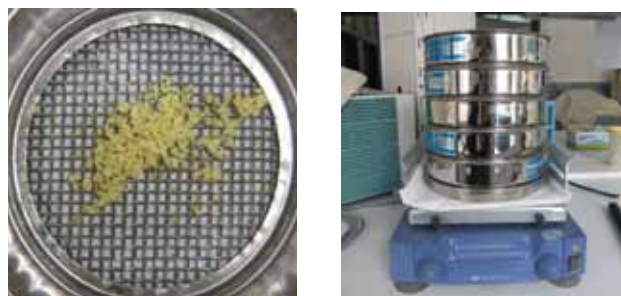


FIG. 3 Sieves and the fragmented particles used in the masticatory performance test.

to 0.0001 g (Fig. 3). Cumulative percentages (defined as the mass percentage of sample able to pass through each successive sieve) were plotted as a function of the aperture size, and a curve was interpolated through the data points by Excel software program (Microsoft Office 2007). MPS was defined as the theoretical sieve aperture size through which 50% mass of the chewed particles could pass. This median size was found on the interpolated curve for each participant [Aras et al., 2009].

Statistical analyses

Statistical analyses were performed by using SPSS 20.0 for Windows (IBM Corporation, Chicago, IL, USA). Normality of the distributions was confirmed by skewness, kurtosis and the Kolmogorov-Smirnov test. Paired-sample t-test was used to evaluate differences between LBF and RBF in each group. Independent-sample t-test was used to compare MP and BF between groups and to compare boys and girls within the same group. All results were considered significant at $p < 0.05$.

Results

The study sample consisted of 50 children who fulfilled the inclusion criteria. The sample was homogeneous in terms of the measured anthropometric data except for the presence of caries in the carious group. Specifically, there was no statistical difference between the control and the carious groups in terms of age ($p = 0.427$), weight ($p = 0.506$) and height ($p = 0.202$) (Table 1). The mean number of decayed teeth in the carious group was 3.08 ± 0.88 . Furthermore, no significant differences were found between the anthropometric data of boys and girls within each group.

Maximum bite force

There was no significant difference between right and left segmental bite forces (RBF, LBF) in either study group. Additionally, for both RBF and LBF, no group differences were found (Table 2). Maximum bite force levels in children with and without clinically diagnosed caries were similar. The mean MBF in the carious group was approximately

316 N compared to 356 N in the control group, but this difference was not statistically significant ($p = 0.286$) (Table 2).

Masticatory performance

Median particle size of children with caries (4.40 ± 0.62 mm) was significantly larger than caries-free (3.82 ± 0.75 mm) children, which showed lower MP in children with caries ($p = 0.006$) (Fig. 4).

Discussion

Dental caries, which is the most common oral health problem in the world [Balakrishnan et al., 2000], is a progressive disease. It begins with enamel demineralisation and continues to enamel cavitation. If left untreated, dental caries can cause pulpal and periapical infection and tooth loss [Selwitz et al., 2007]. However, asymptomatic caries in children are rarely treated in a timely manner; dental treatment is usually delayed until the onset of complaints. To our knowledge, none of the previous studies on this topic reported the effects of caries on MBF and MP with well-defined caries level/severity criteria.

The carious process has a detrimental effect on the structural integrity of the tooth, and hence on the primary masticatory function. Chewing capacity, in turn, has an effect on food choices, making dental health crucial in terms of nutrition [Barbosa et al., 2013], which is closely related to children's physical development [Ayhan et al., 1996; Heinrich-Weltzien et al., 2013; van Gemert-Schriks

et al., 2011]. However, despite the commonality of dental caries, the effect of the disease on the masticatory function of children has seldom been studied [Su et al., 2009; Shiau and Wang, 1993]. Thus, we specifically studied the effect of the carious process on food comminution and MBF. For the study groups, we selected children with similar ages, heights, body weights and maxillomandibular skeletal relations. Our results revealed impaired comminution in the carious group.

Changes in mastication patterns and loss of antagonistic contacts due to caries have been reported as the cause of this impaired comminution [Decerle et al., 2013]. According to Decerle et al. [2013], untreated caries reduces occlusal interarch contacts in adults, resulting in a decrease in MP. For 11-12 year-old children, Barbosa et al. [2013] reported a positive correlation between number of decayed teeth and MPS. De MoraisTureli et al. [2010] also found higher MPS with higher dmft/DMFT scores in normal and underweight 8-12 year-old children. Similarly, we observed that children with clinically visible carious FPMs had lower MP. Although the participants of our study had fewer carious teeth than those in Decerle et al. [2013], a significantly lower MP was still found in participants with caries when compared to controls. First permanent molars exert the greatest bite force in the dental arch [Mansour and Reynik, 1975; Tortopidis et al., 1998]. In our study, the loss of interarch contacts in cavitated FPMs resulted in poorer masticatory performance, but we could not verify a significant change in the maximum bite force.

Advanced caries can cause pain in response to mechanical stimuli. In order to eliminate any pain-related negative effect on MP and MBF, our study included only children without spontaneous pain and pain upon percussion. Shiau and Wang [1993] observed lower MBF values in children with decayed and missing teeth during the stages of mixed and permanent dentition. Similarly, Su et al. [2009] and Mountain et al. [2011] reported lower MBF in children with carious primary teeth. Some researchers [Shiau and Wang, 1993] have attributed the negative effect of caries on MBF to pain or fear of pain from periodontal mechanoreceptors and a damaged occlusal table. Although the carious group in our study had lower MBF compared to controls, this was

	Control Mean± SD	Caries Mean± SD
Age (Year)	12.30± 0.55	12.20± 0.51
Sex	15 Girls	14 Girls
	10 Boys	11 Boys
D	0	3.08±0.88
Weight (kg)	44.4± 12.24	42.14± 10.66
Height (m)	1.49± 0.09	1.45± 0.10
SD: Standard deviation, D: Number of decayed permanent teeth		

TABLE 1 Anthropometric data of the study sample.

	LBF (N) Mean± SD	RBF (N) Mean± SD	MBF Sum (LBF+RBF) (N) Mean± SD
Control Group	158.52±71.87	197.28±92.14	355.80±131.00
Caries Group	149.11±92.72	166.40±74.81	315.51±130.53
p	0.692	0.205	0.286

TABLE 2 Bite force values in the carious and the control group.

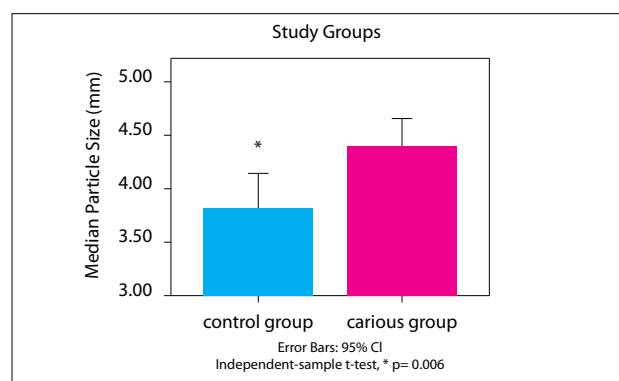


FIG. 4 Masticatory performance in the study groups.

not statistically significant. The high variance of bite force levels in our participants may be due to the age group selected and, in particular, the variability in pubertal timing.

Caries diagnosis in our study was assessed by clinical examination and panoramic radiographs. Children in our study had already been examined with panoramic x-ray by their primary examiner during their initial oral examination for various reasons (e.g. eruption sequence, etc.) before their assignment to attending physician for treatment. Our aim was to compare BF and MP in cavitated and non-cavitated FPMs but also panoramic radiographs were used to further exclude hidden major proximal caries. Lack of bitewing radiography for proximal caries examination is a shortcoming of our study, however BF and MP in intact occlusal surfaces vs cavitated could be assessed.

In summary, the results of our study suggest that caries may reduce MP in children. Future studies may focus on the ability of restorative treatment to re-establish the masticatory capacity.

Acknowledgement

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Key messages

- Masticatory performance is hindered by caries even in asymptomatic stages.
- Maximum bite force does not differ in asymptomatic caries.

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