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# Bite force measurement in children with primary dentition

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**Objectives.** To determine the magnitude of the biting forces in young children aged 3–6 years in the primary dentition and analyse the potential effects of caries and malocclusion on maximum bite force.

**Methods.** Children aged 3–6 years of age attending primary schools within a major city in the UK were recruited to participate in this study. The magnitude of the bite force in Newtons (N) was measured bilaterally corresponding with the 1st and 2nd primary molars and central incisors using a new specifically designed single tooth bite force gauge.

**Results.** Two-hundred and five children were included in the study. The prevalence of dental caries and malocclusion was found to be 30.4% and 17.1% respectively. The levels of bite force recorded showed comparatively wide intra- and inter-individual variation with the maximum of the three bite force measurements ranging from 12.61 (N) to 353.64 (N) (M = 196.60, SD = 69.77).

**Conclusion.** Bite forces of young children show comparatively wide intra- and inter-individual variation with some similarities with those found in the limited number of previous primary dentition studies undertaken elsewhere. The results will serve to provide key reference values for use both in paediatric dental clinical practice and wider research community.

## Introduction

Determination of individual bite force levels has been widely used in dentistry in order to understand muscle activity and mandibular movements during mastication[1] and masticatory performance[2], to study the influence of physiological factors on changes in occlusal forces[3,4], and for investigations on the biomechanics of prosthetic devices. Very few contemporary studies appear to have been undertaken that focus on young children with primary dentitions and those available tend to focus on small sample groups and include a significant number of participants who have either temporomandibular disorders or malocclusion[5,6]. The results and conclusions reached in these studies cannot therefore be deemed comparative, certainly to children with predominantly primary healthy dentitions. Similarly, whereas much effort has been made to analyse interdependencies between bite force and a number of diverse variables such as craniofacial dimensions and head posture[7], chewing performance[8], clenching strength[9], and masticatory muscle thickness and occlusal contacts[10] there still remains a need to more fully understand bite forces in very young children with healthy primary dentitions and appreciate the dynamic interplay of a range of influencing variables. The purpose of this study therefore was to determine the magnitude of the biting forces in very young children aged 3–6 years in the primary dentition and analyse the potential effects of caries and malocclusion on maximum bite force.

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### *Factors influencing bite force measurements*

Measurements of bite force are prone to variations in experimental methods, including instrumentation design, the attitude and

approach taken by the researcher, the degree of cooperation of the child participant[11], the position within the dental arch the bite force measurements are taken, head position[12] and the extent of the vertical separation of the teeth and jaws when accommodating the measurement device[13]. A systematic and extensive search of the evidence based literature reveals numerous attempts to relate occlusal forces to many other independent variables. Age, gender, the size, thickness and activity of the masticatory muscles, dental occlusion, the number of teeth in occlusal contact, the number of teeth present, stages of dental eruption, condition of dentition, facial morphology, temporomandibular joint and arch form and pain are just some of the individual variations that have been found to influence the magnitude of the bite force[14,15]; however, not all of these factors are independent; for example, as individuals increase in age, they increase in body size with concomitant increase in muscle mass and strength[16] along with changes in dentition, increased occlusal contacts and near occlusal contacts and hence their ability to apply larger bite forces. This study reports the result of the primary phase of a research study which set out to establish and systematically analyse bite force values in healthy children within a closely controlled age range with primary dentitions.

## Materials and methods

### *Subjects*

The study comprised a stratified random sample of 205 children (from 3.25 to 6.33 years of age; 58.5% male and 41.5% female) who were attending primary schools within a major city in the UK during the period of investigation. The study was designed and conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki (version, 2008 http://www.wma.net/). This study was approved by the local research ethics committee and University ethics committee. Written parental consent was sought after having received full information about the present study. Additionally, in order to empower the children as research participants and conduct truly child-centred research with children as active partners rather than subjects of research[17,18] the verbal assent of all child participants was secured using a specifically designed storybook combined with a dedicated story time session as part of the child's school day. A child's dissent superseded the parental consent.

### *Methods*

The magnitude of the bite force in Newtons (N) was measured bilaterally corresponding with the 1st and 2nd primary molars and central incisors by asking participants to bite on a new specifically designed single tooth bite force gauge at the maximum comfortable voluntary bite force (MCVBF) without clenching. The bite force measurement gauge incorporated a number of critical concept design factors to ensure its safe and effective function and ability to operate in all segments of the child's mouth yet small enough to be unobtrusive. The main body of the bite force measurement instrument accommodated single use parallel bite sensor prongs. It permitted natural occlusion and required minimal jaw opening when measurements were being recorded. *In vitro* calibration of the bite force sensor was undertaken at room temperature against a Lloyd LR10K universal testing machine immediately prior to and following each data collection period. The child was asked to perform a maximum voluntary comfortable bite force (MVCBF) for 2–3 s with a 5 s interval between each recording. The influences of a number of predictor variables including weight, height, gender, age, ethnicity and dental status on maximum bite force were subsequently analysed.

Each child was seated in a chair with their head and body in a natural upright position with their head fixed keeping the Frankfort plane approximately parallel to the floor. Prior to the bite force measurements being taken a standard clinical dental examination was carried out under natural illumination by one registered dentist using the standard dental charting technique verifying the number

of teeth present, the stage of dentition: primary and noting any alterations/anomalies of form, structure or number. Caries experiences were assessed both at the tooth and surface levels using a dental mirror and dental probe and in accord with WHO criteria[19]. Tooth surface loss was not graded. A morphological examination of the occlusion in accord with criteria stipulated by such as Keski-Nisula *et al.* and Saadia[20,21], was completed and the presence and nature of any malocclusion noted. Children were excluded from the study at this juncture if they were found to have missing teeth in the regions to be used for recording the bite force measurements, if they were likely to experience pain or discomfort related to primary teeth about to exfoliate or their dental health was deemed to be of such a poor condition that it would compromise measurement or the procedure would cause unnecessary discomfort. None of the children in the study presented with signs or symptoms of temporomandibular joint dysfunction although a small number of children presented with malocclusion. These children were still included in the study for possible comparative analysis.

### *Anthropometric assessments*

Given what is known in respect of the influence of various body variables, the body weight and height of each child was obtained for later correlation with bite force recordings. Standing height was measured to the nearest 1.00 mm using a portable Leicester Height Meter which does not require re-calibration each time it is moved and is recommended by the Child Growth Foundation as standard and reliable growth equipment (Harlow Healthcare, Tyne and Wear, UK). Each child stood without shoes and with her/his back straight against the measuring rod with the feet closely aligned with the foot positioner and the child's head in a straight line. The calliper gauge was then pushed on the head so that the measuring tongue rested without sagging. Body weight was measured using a Seca 835 calibrated electronic scale (Seca, Birmingham, UK) capable of measuring up to a maximum weight of 50 kg (to the nearest 0.1 kg), resting on a solid base and remaining in the same position throughout the series of measurements taken. Body Mass index was subsequently computed from the height and weight measurements [weight (kg)/height$^2$ (cm)].

Base-line data was also collected concerning the children's gender, age, socio-demographic details and ethnicity (whilst maintaining confidentiality and anonymity) for later comparative analysis.

### *Statistical analyses*

SPSS (version 13) for Windows (SPSS Inc. Chicago, IL, USA 2004) computer software was used for data analysis. Normality of the distributions was assessed by the parameters of skewness and kurtosis and by the Kolmogorov–Smirnov (K–S) and Shapiro–Wilk (S–W) ('goodness of fit') tests. All data were analysed by conventional statistical methods, i.e., mean, median and standard deviation (SD).

### *Repeatability and reproducibility*

Repeatability and reproducibility on the repeated measurements of the bite force measurements were assessed using Bland Altman's plots[22] and Dahlberg's formula[23].

## Results

The reliability of the bite force sensor to record reproducible force levels between the three loading positions was found to be equal to 99.5%. The errors for the bite force anterior, bite force right posterior and bite force left posterior were 4.2 N, 3.0 N and 4.0 N respectively. When the overall maximum bite force results were subject to Dahlberg's formula then the error was exceedingly small at 2.1 N.

### *Caries status and prevalence of malocclusion*

The prevalence of dental caries and malocclusion in the 205 children examined was found to be 30.4% ($n = 61$) and 17.1% ($n = 34$) respectively. When differences in the type

and severity of malocclusion among the participants in the present study were subdivided, the most frequent observed type was anterior open bite followed by crossbites. Overjet was the least observed category. Decayed, missing and filled surfaces (dmfs) and decayed, missing and filled teeth (dmft) scores ranged from 0 to 49 and 0 to 13 respectively. The total mean dmfs for the 205 children examined was 2.92 (SD = 7.32) and the mean dmft was 1.30 (SD = 2.75). Girls were found to have slightly higher dmfs and dmft scores than the boys. There was no statistical difference however found in the mean dmfs scores and gender and/or the mean dmft scores and gender.

### *Bite force magnitude and comparisons*

The levels of bite force recorded showed comparatively wide intra- and inter-individual variation with the maximum of the three bite force measurements ranging from 12.61 (N) to 353.64 (N) (M = 196.60, SD = 69.77) (Table 1). When the mean values of the maximum bite forces for boys were compared with those obtained from girls there was a slightly increased bite force in males (M = 203.90, CI = 192.04–215.80) than in girls (M = 186.19, CI = 169.60–202). This difference was, however not statistically significant $t$ (199) = 1.77, $P = 0.078$, $r = 0.13$. The maximum, minimum and mean bite forces for each of the three loading positions, along with their respective standard deviations and standard error of means for the total sample are given in Table 2. The variations in bite force measurements (N) for each of the three loading positions according to gender are illustrated in Table 3.

The mean bite force level recorded in the front anterior region was found to be lower

**Table 1. Maximum, minimum, mean, and SD for the maximum bite force recordings (N), age (years), weight (kg) and height (cm) for the total sample.**

| All participants | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Maximum bite force from the three readings obtained (N)** | **Age (years)** | **Weight (kg)** | **Height (cm)** | **BMI** | **dmfs** | **dmft** |
| Participants (*n*) | 199 | 205 | 205 | 205 | 205 | 205 | 205 |
| Maximum | 353.64 | 6.33 | 28.7 | 123.30 | 22.10 | 49 | 13 |
| Minimum | 12.61 | 3.25 | 13.0 | 95.30 | 12.2 | 0 | 0 |
| Mean | 196.60 | 4.77 | 19.07 | 108.70 | 16.18 | 2.92 | 1.30 |
| SD | 69.77 | 0.60 | 2.98 | 6.09 | 1.64 | 7.32 | 2.75 |

**Table 2. The maximum, minimum and mean bite forces (Newtons) for each of the three loading positions [including their respective standard deviations (SD) for the total sample (*n* = 199)].**

| **Loading position** | **Maximum (Newtons)** | **Minimum (Newtons)** | **Mean** | **SD** |
|---|---|---|---|---|
| Bite force anterior (N = 194) | 140.09 | 6.87 | 49.58 | 29.50 |
| Bite force right posterior (N = 199) | 353.64 | 8.05 | 179.74 | 72.15 |
| Bite force left posterior (N = 198) | 337.11 | 12.61 | 175.07 | 66.90 |

**Table 3. The variations in bite force measurements (N) for each of the three loading positions according to gender.**

| | **Maximum** | | **Minimum** | | **Mean** | | **SD** | |
|---|---|---|---|---|---|---|---|---|
| **Loading position** | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** | **Male** | **Female** |
| Bite force anterior (N = 194) | 120.20 | 140.09 | 8.05 | 6.87 | 53.42 | 44.11 | 30.34 | 27.51 |
| Bite force right posterior (N = 199) | 319.87 | 353.64 | 41.50 | 8.05 | 188.78 | 166.83 | 66.73 | 77.87 |
| Bite force left posterior (N = 198) | 337.11 | 329.01 | 26.21 | 12.61 | 178.65 | 169.91 | 66.85 | 69.85 |

than all other regions with a slightly higher mean maximum bite force found on the right side (M = 179.9 N) compared to that on the left (M = 175.1 N). Paired *t* test results revealed no statistical significance [$t$ (197) = 1.24, $P > 0.05$] between the bite forces recorded on the right *versus* the left side of the dental arch.

Results from Spearman's rank correlation coefficient showed that there was a significant negative correlation between the child's caries experience and her/his maximum bite force, (dmfs $r_s = -0.16$, $r_s^2 = 0.31$, $P < 0.05$; dmft $r_s = -0.15$, $r_s^2 = 0.30$, $P < 0.05$).

Comparison of means for the maximum bite force measurements obtained from participants with normal occlusion *versus* those with malocclusion showed that the maximum bite force for those with malocclusion was slightly lower (M = 194.2) than those without (M = 197.10). This difference was not, however statistically significant $t$ (197) = 0.224, $P > 0.05$).

## Discussion

The magnitude of the child's bite force in this study showed substantial intra and inter individual variability with the maximum comfortable voluntary bite force ranging from 12.61 to 353.64 Newtons. The mean maximum bite force levels obtained in this study both for the whole sample (M = 196.60) and in the different sex groups corresponded closely with former and more recently published values of children within similar age ranges[24–26]. Some of the variations in bite force noted here may have been due to factors such as the degree of cooperation of the child participant as well as other independent variables such as age, gender, physiological development, dental occlusion, the number of teeth in occlusal contact, the number of teeth present as well as the condition of the child's dentition. No statistical differences were observed in maximum bite force in the children with or without primary occlusion, leading one to conclude that the bite force in this age group and associated phase of dentition may depend on alternative more complex factors such as prevalence of caries and the compensatory effects noted with malocclusion in the primary dentition phase[27]. The overall dental caries experience of this study sample showed some improvement on the national picture of 40%[28] and below the overall British means experience of 3.8 and SiC Index of 3.2 as reported by Pitts *et al.*[29]. It is not unexpected to note that occlusal force distribution in this study sample was greater on the posterior primary teeth (primary first and second molar region). Whether the bite force magnitude would remain or decline as the bite point moves even more posteriorly and the nature of any masticatory muscle activity in children merits further exploration.

Paired *t*-test results revealed no statistical significance [$t$ (197) = 1.24, $P > 0.05$] between the bite forces recorded on the right *versus* the left side of the dental arch. This is surprising given what is purported in respect of even young children displaying a preferred chewing side[30] and what is known about the differences in jaw movements and capabilities of the masseter muscle on the preferred chewing side compared to those on the non-preferred chewing side (albeit in adults)[31,32].

Whereas bipoint serial correlation coefficients in this present study confirm earlier findings that generally males exert slightly higher bite force values (M = 203.90) than their female counterparts (M = 186.19)[33] this was shown not to be statistically significant at the 0.05 level indicating this difference is not influential during growth and development in young children.

Whilst no attempt was made to quantify variation in bite force along all points of the tooth row, the findings nevertheless indicate that the activity of the masticatory muscles changes with bite point position during the production of maximum voluntary bite loads. A number of factors might be attributable to the observed changes in bite force magnitude, including variation in the supporting structures of the teeth along the child's tooth row, changes in the maximum voluntary activity of the masticatory muscles within different regions of the dental arch and the need to maintain joint stability during dynamic force production[34]. It can also be speculated that unlike during posterior biting, lateral deviation of the mandible

may be occurring during biting on certain objects with the incisors (brought about by the contraction of the contralateral superficial masseter and medial pterygoid muscles) with a resultant configurational change in bite force magnitude; however, many of these possible explanations merit further testing in children as opposed to adults.

The findings obtained in this study are important since they have helped determine absolute values and ranges for maximum comfortable bite forces in healthy young children (aged 3 to 6 years) with primary dentitions. This data can therefore serve to provide key reference values for use both in paediatric dental clinical practice and the wider research community.

**What this paper adds**

- A novel instrument has been developed that is capable of accurately recording reproducible force levels between the three loading positions in young children.
- The paper provides key bite force reference values for healthy young children in the primary dentition derived from a robust primary study.
- Whilst some variation in bite force was indicated between the sexes and those with and without malocclusion, these results proved statistically non-significant for this particular research group.

**Why this paper is important for paediatric dentists**

- Provides key reference values for bite force measurement in young children.
- Individual measurements can be usefully applied during extensive dental rehabilitation cases.

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