MASTICATORY FUNCTION AFTER COMPREHENSIVE DENTAL TREATMENT IN CHILDREN WITH SEVERE EARLY CHILDHOOD CARIES

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Abstract

Background: *Parents are frequently concerned that their child's mastication may be compromised after comprehensive dental treatment.*

Aim: *To evaluate changes in masticatory function and food preferences after dental treatment in children with early childhood caries.*

Design: *This prospective study assessed masticatory function by the (1) mixing ability test using duo-coloured chewing gum and (2) the number of chews/g and time taken to eat 6 foods before and 3 months after dental treatment. A dental examination and a food preference questionnaire were also completed.*

Results: *Twenty-five children (age: 4.9±0.5 years, baseline dmft/child: 11.4±4.9) completed the study. The mean number of restorations/child, total extractions/child and posterior extractions/child were 5.1±2.9, 6.4±5.2 and 3.6±2.3 respectively. The number of chews/g of cereal* *(p=0.014) and popcorn (p=0.003) significantly increased after dental treatment. The number of chews/g and/or duration taken for cereal (chews/g: r=0.795, p=0.000, duration: r=0.794, p=0.000) and peanuts (chews/g: r=0.459, p=0.032) were significantly associated with more extractions. There was no change in mastication function for the other foods, mixing ability score and child's food preferences after dental treatment.*

Conclusions: *An increased number of chews/g is needed for certain hard foods after dental treatment; which was associated with an increased number of total and posterior extractions.*

INTRODUCTION

Early Childhood Caries (ECC) has been reported to reduce a child's quality of life [1-6]. Several questionnaire-based studies have found that more parents of children with ECC report that their child had dental pain and a decreased ability to chew compared to parents of children without ECC [1,5]. To reduce oral pain and improve masticatory function, it is ideal to treat and restore salvageable carious teeth as well as to extract non-restorable and/or abscessed primary teeth. However, parents are frequently concerned that their child's ability to chew may be compromised after comprehensive dental treatment; especially when the treatment involves multiple extractions [7].

Current studies reporting the improvements in the oral symptoms and masticatory function in children after dental treatment are largely based on parental reports [1-3]. White *et al.* found that 69% of parents reported that their child had improved masticatory efficiency after dental treatment [8]. This finding was supported by Cantekin *et al.* who reported a reduction in chewing difficulties from 71% to 8% after dental treatment based on a parental questionnaire (Early Childhood Oral Health Impact Scale) [9]. However, Versloot and colleagues observed that masticatory problems persisted after dental treatment [10]. Notably, these studies elicited masticatory function using questionnaires and thus measured perceived rather than objective masticatory performance [8-10]. As such, these findings are confounded by social desirability and recall biases inherent in questionnaire-based studies [1-3]. To date, only two studies have objectively measured changes in masticatory function before and after dental treatment [11,12]. However, these studies used bite force to measure masticatory function, which does not mirror the dynamic nature of mastication. Instead, it is more indicative of masticatory muscle thickness, which is frequently of a substantially greater magnitude than that required for mastication [13-16]. A more ecologically valid, appropriate and reproducible approach would be to measure masticatory function by using a duo-coloured chewing gum. Quantifying the degree of mixing of duo-coloured chewing gum can indicate the level of masticatory function. This method also provides a more accurate index of the natural mixing that occurs during the mastication of food boluses [13,15]. Another useful indicator of masticatory function is the quantification of the oral processing behaviours when consuming foods of different textures. Behavioural coding video analysis offers an accurate, reproducible and non-invasive study of oral processing behaviours and micro-structural eating patterns during food consumption [17].

The goal of this study was to evaluate and quantify the objective changes in masticatory function of preschool children suffering from ECC before and after dental treatment using the mixing ability test and by assessing their oral processing behaviours with video analysis. As masticatory function is affected by the number of occlusal contacts, information on the type of dental treatment rendered, particularly extractions which are likely to result in a decrease number of occlusal contacts and masticatory performance, will be elicited [18,19]. Questionnaire-based studies have found that children with compromised dentitions favoured soft and smooth food [20,21]. However, there are no studies evaluating the changes in the child's food preferences following dental treatment. Thus, the secondary aim of this study was to assess whether dental treatment changed the child's food preferences.

METHODS

This prospective cohort study involved children aged 4- to 6-year old, recruited from the graduate clinic at the Faculty of Dentistry, National University of Singapore (NUS) between January to December 2017. Children were recruited at the consultation visit if they met the following inclusion criteria: (1) healthy children (American Society of Anesthesiologists physical status I or II); (2) able to communicate in English; (3) deciduous dentition or early mixed dentition with permanent first molars not in occlusion; (4) had ECC requiring dental treatment under general anaesthesia (GA). The rationale for selecting these children was because they were the most likely to experience a drastic change in their masticatory function. This is attributed to their need for extensive treatment and the delivery of the dental treatment in a single visit; (5) compliant with masticatory tests and (6) with no previous history of dental treatment under GA. Children with peanut allergy were excluded. The study required the child to undergo a dental examination prior to the treatment visit under GA and to complete two masticatory function tests: (1) the mixing ability test and (2) oral processing behavioural assessment with video analysis. The masticatory function tests were conducted before dental treatment (baseline) and repeated 3 months after dental treatment. Dental pain was measured using the Wong-Baker FACES pain rating scale at three time points; (1) before dental treatment (baseline), (2) 2 weeks after dental treatment and (3) 3 months after dental treatment. The study (reference number 2016/00544) was approved by the Ethics Committee of NUS. Informed consent was taken from the parent after the purpose and procedures of the study were explained to both parent and child.

There are no studies that specifically compared masticatory function before and after dental treatment using the objectives measures of masticatory function, thus extrapolation from quality of life studies on parental reports of improved masticatory function after dental treatment were used to calculate sample size. In studies by Cantekin *et al.* and White *et al.*, 60%-70% of the parents of children who underwent dental treatment reported an improvement in their child's masticatory efficacy [8,9]. The sample size for this study was calculated based on an expected change of 30% in the child's mixing ability (as measured by the mixing ability test score) after dental treatment. A minimum of 24 subjects were required at 5% significance level and 80% statistical power.

Dental examination

Dental examination using a dental mirror and an explorer was carried out on a reclined dental chair by a single examiner. Dental caries was quantified using the decayed, missing, filled teeth (dmft) index based on clinical and radiographic findings. The presence of abscesses, sinus tracts or ulcers was also recorded. The number of anterior and posterior occlusal contacts was evaluated with a shimstock and the number of occlusal contacts were recorded.

Masticatory tests

Mixing ability test

Wrigley's Boomer® red-coloured and blue-coloured chewing gum was used for the mixing ability test. The red- and blue-coloured gums were manually stuck together in the dimensions of 21mm in length, 11mm in width and 11mm in depth. Presently, studies evaluating mixing ability test in children with primary dentition have used between 20 to 60 chewing strokes to determine the mixing ability scores [22,23]. Due to the wide range of the number of chewing strokes reported to discriminate masticatory performance in preschool children in deciduous dentition, a pilot study on five 4- to 6-year old children with healthy dentitions to determine the optimal number of chewing strokes to achieve an acceptable level of mixing was conducted. In addition, a scale to assess the level of mixing was developed specifically for this study. The children chewed on a piece of duo-coloured chewing gum in 5 calibration trials for 15, 20, 25, 30 and 35 chewing strokes each time. Gum chewed for 15, 20 and 25 chewing strokes were not mixed sufficiently, while gum chewed for 35 chewing strokes resulted in a uniform colour for all 5 children. Thus, 30 chewing strokes was determined to be the optimal number of chewing strokes.

For the study, all children received verbal instructions and chewed on a trial chewing gum identical to the experimental chewing gum prior to the mixing ability test. The side of chewing was not restricted. For the mixing ability test, the children were given the experimental piece of the duo-coloured gum to chew while being observed by the examiner. The child chewed for 30 chewing strokes (counted by examiner using a tally counter) and on completion, expectorated the chewed gum into a transparent plastic bag. The chewed gum was flattened between two plastic sheets to a 2mm thin wafer. Both sides of the chewed gum wafer were photographed under white light (600nm wavelength). Images (3264 × 2448 pixels) were saved in JPEG format. Two research team members independently graded both sides of the chewed gum wafer (from 0-6) against a pre-defined mixing ability test scoring chart to quantify the degree of mixing (Figure 1). For each chewed gum wafer, the score from each side of the chewed gum wafer given by each grader was summated and averaged to obtain a mean mixing ability score. A calibration session was performed prior to commencement of the study to ensure good inter-rater agreement. Inter-rater intra-class correlation was 0.95 (95% CI: 0.86, 0.98).

Assessment of Oral Processing Behaviour via Behavioural Coding Video Analysis

Six food items of different textures ranging from hard (Froot Loops® cereal, peanuts, popcorn), moderately hard (apple slice), chewy (Fruit-plus® chewy sweet) and soft (pandan flavored chiffon cake) were used to assess the child's oral processing behaviour. These six food items (Froot Loops® cereal, peanuts, popcorn, apple, chewy sweet and pandan flavoured chiffon cake) were chosen for the assessment of oral processing behavior because they were found to be common foods consumed by children in the local population based on the local National Nutrition Survey. The food items were well-accepted by 5 children during the pilot testing and no change in the choices of the food items were needed [24]. The weight and quantity of each food item was standardized. Utilizing a pre-generated computer randomized list, the six food items were placed in separate clear containers and arranged in the order of consumption based on the randomization. The child was instructed to consume each item in their normal way and in the order presented, moving on to the next food item only when the previous one was swallowed. The child was video-recorded while consuming the 6 food items and the videos underwent behavioural coding analysis post-hoc to derive a series of objective oral processing measures. The behavioural coding procedure was adapted from Forde *et al.* and Fogel *et al.* [25,26]. The outcomes measured included (1) number of chews needed per gram (chews/g) of each food item and (2) time (in seconds) taken from the moment the food item was placed in the mouth till the food was swallowed. These measurements were derived by analyzing video recordings using the behavioural annotation software (ELAN 4.9.1; Max Planck Institute for Psycholinguistics, The Language Archive) [27]. The coding was completed by one trained member of the study team and subsequently blind-validated by a second trained video-coder. Inter-rater reliability was assessed using a two-way mixed, consistency, single measures ICC to assess the consistency between the coder [28,29]. A high level of agreement was found for the number of chews/g [ICC = 0.921 (95% CI: 0.432, 0.991)] and the time taken for each food item [ICC = 0.993 (95% CI: 0.932, 0.999)].

Food preferences

The children's food preferences were elicited before dental treatment (baseline), 2 weeks and 3 months after dental treatment, through an interviewer-administered Food Preference Questionnaire (FPQ). The choice of food items used in the FPQ were adapted from the Singapore National Nutrition Survey and a Malaysian study that was representative of children's diet in this region [24,30]. The questionnaire elicited responses for 30 items consisting mainly of different types of food. Of the 30 items, 2 were non-food objects (toilet paper and a toy car), which served as control items. The remaining 28 were food items of 6 different textures (hard/crunchy, moderately hard, moderate, chewy, soft and very soft) and comprised of individual food items (e.g. oranges, beef steak) as well as mixed food items (e.g. fried rice, porridge). The pictures of the 30 items were shown to the child on an iPad® and he/she was asked to choose from 5 different faces, ranging from a smiley face to a frowning face, representing "I like this a lot", "I like it", "It's okay", "I don't like it" and "I hate it". If the response to the item was "I don't like it" or "I hate it", the child was queried as to the reason for disliking the item. The interviewer recorded whether the disliked item was due to taste, difficulty or pain when chewing or biting the item.

Statistical analysis

Descriptive statistics were derived from the data collected. To determine the effect of dental treatment on outcome measures (i.e. change in mixing ability test score, change in number of chews/g, time taken to eat each of the 6 test food items and changes in food preferences), paired sample t-test was carried out. If the normality assumption was violated as tested using Q-Q plot, Wilcoxon signed rank test was performed. Correlation coefficients were computed to evaluate the relationship between the extent of dental treatment and the outcome variables at baseline and 3-months after dental treatment. Differences in outcome variables were calculated by deducting the value of the outcome variable before dental treatment from the value of outcome variable after dental treatment. Parametric approach (Pearson's correlation coefficient) was utilized for data that was normally distributed while non-parametric approach (Spearman's correlation coefficient) was utilized for data that was not normally distributed. Pain score at baseline and after dental treatment (2 weeks and 3 months) was compared using Friedman test. Significance level was set at p-value <0.05. All statistical analysis was carried out using SPSS (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY:IBM Corp.).

RESULTS

Thirty-five children were recruited but only data from 25 children (71.4%) were analyzed as 10 did not complete the study. Six children dropped out because they did not proceed with dental treatment and 4 were lost to follow up after dental treatment. The mean age at recruitment was 4.9 ± 0.5 years old (range: 4.0 to 5.7 years old). The dental status at baseline and at 3-months after dental treatment is detailed in Table 1. The total number of extractions (6.4±5.2) was significantly correlated (r=0.858, p-value<0.001) with the number of posterior extractions (3.6±2.3).

Mixing Ability Test

The mean mixing ability test scores at baseline and 3-months after dental treatment were 3.5±1.3 (range: 0.75 to 5.75) and 3.1±1.3 (range: 0.50 to 5.00) respectively. The change was not statistically significant (p=0.26). The mixing ability test score was not significantly associated with total number of extractions (p=0.317), posterior extractions (p=0.289), change in total number of occlusal contacts (p=0.845) and change in number of posterior occlusal contacts (p=0.852).

Figure 2 illustrates the individual changes in mixing ability test scores from baseline to 3-months after dental treatment by number of posterior contacts.

Assessment of Oral Processing Behaviour via Behavioural Coding Video Analysis (Table 2)

There was a significant increase in the number of chews/g required to eat certain food items from baseline to 3-months after dental treatment. Both popcorn ($p<0.01$) and Froot-loops® cereal ($p=0.01$) required significantly more chews/g after dental treatment compared to baseline. The median number of chews/g of popcorn increased from 58.3 (IQR=35.0, range: 33.3 to 216.7) at baseline to 86.7 (IQR=35.8, range: 45.0 to 218.3) 3-months after dental treatment. The median number of chews/g of Froot-loops® cereal increased from 72.0 (IQR=35.0, range: 44.0 to 216.0) at baseline to 94.0 (IQR=54.0, range: 52.0 to 256.0) 3-months after dental treatment. No other significant differences in chews/g were observed.

Spearman correlation coefficient showed that a child who had a greater total number of extractions and posterior extractions required more chews/g (total extractions: $r=0.795$, $p<0.001$; posterior extractions: $r=0.777$, $p<0.001$) and a longer time (total extractions: $r=0.794$, $p<0.001$; posterior extractions: ($r=0.710$, $p<0.001$) to eat Froot-loops® cereal. Masticatory function was poorer among children who had greater reductions in occlusal contacts ($r=-0.435$, $p=0.030$) after dental treatment, as indicated by the increase in the number of chews/g of Froot-loops® cereal.

For peanuts, children with greater total number of extractions and a greater decrease in posterior occlusal contacts 3-months after dental treatment also required a greater number of chews/g (total extractions: $r=0.459$, $p=0.032$; posterior extractions: $r=-0.458$, $p=0.032$).

Food preferences

Wilcoxon signed-rank tests showed no significant change in food preferences ($p>0.05$) at the child level, for each of the 28 food items in the FPQ from baseline to 3-months after dental treatment.

DISCUSSION

By evaluating masticatory function using the mixing ability test and the oral processing behaviour assessment, this study provided two objective measures of masticatory function rather than relying on parent or child self-report. The study's assumption was that masticatory function would decrease with a reduction in functional teeth and occlusal contacts. Several studies support this assumption [18,31,32]. However in this study, minimal or no change in masticatory function (as measured by the mixing ability test) after dental treatment (including treatment with significant extractions) were observed. A qualitative review of the mixing ability test scores at the individual level (Figure 2) expectedly found that children who had all their posterior teeth removed (i.e. 8 teeth) consistently had decreased scores. This is attributed to a complete loss of posterior occlusal contacts and thus loss of area available for shearing food during chewing. Though, interesting patterns were noted with regard to the magnitude of the change in mixing ability in certain individuals. Subject #23 who had full mouth extractions demonstrated only a relatively small decrease of -1.5 (range: -3.75 to 2.5) in the mixing ability test score after dental treatment, while subjects #2, #3, #4 and #15 who had fewer posterior extractions (subject #2: 3 extractions; subject #3: 3 extractions; subject #4: 4 extractions and subject #15: 4 extractions) demonstrated much larger decreases in mixing ability test scores (subject #2: -2; subject #3: -2; subject #4: -2.75; subject #15: -3.25). It may be that subjects #2, #3, #4 and #15 lost posterior teeth in their preferred chewing side resulting in the decrease in mixing ability test scores. Another interesting observation was that 5 subjects (subject #6: 4 extractions, subject #7: 1 extraction, subject #16: 7 extractions, subject #18: 6 extractions and subject #35: 2 extractions) showed an improvement in mixing ability test scores despite a decrease in the number of posterior contacts. For subject #16 and #35, a reduction in pain and fewer extractions are possible explanations for their increase in mixing ability scores. However, we postulated that another likely reason for this observation is their ability to adapt to their new dentition and oral processing behaviour. The children likely used their tongue to compress the soft and pliable chewing gum against the palate prior to comminution and swallowing omitting the use of teeth [33].

As the use of chewing gum to measure a child's masticatory function is not completely reflective of the complexity of a child's food environment, this study employed an alternative assessment of masticatory function using a representative range of different food textures that children commonly encountered in their daily diet. This study found that two of the harder foods (Froot-loops® cereal and popcorn) required significantly more chews/g after dental treatment. Though chews/g was not statistically different for peanuts after dental treatment, the increase in the number of chews/g of peanuts was associated with a decrease in the posterior occlusal contacts and an increase in the total number of extractions which provided evidence of a similar association as observed in Froot-loops® cereal and popcorn. Overall, the study's null hypothesis that would be no change in the masticatory function after comprehensive dental treatment is rejected as there were observed difficulties in eating certain hard and small foods (i.e. Fruit Loops® and peanuts) in this study. These difficulties corresponded with increased total number of extractions and posterior extractions (and corresponding decrease in posterior occlusal contacts). It was unfortunately difficult to compare masticatory function at a group level, due to the wide diversity of residual functions and adaptive changes following differing extent of dental treatment in the sample. Future trials could study a larger homogenous group of patients longitudinally to establish the impact of dental treatment involving multiple extractions on masticatory function compared aged match controls with healthy dentition.

With regard to food preferences, no significant changes were demonstrated following dental treatment suggesting that children's food preferences were unaffected by the state of their dentition. This agreed with the study by Ernest, who concluded that an individual's preference for a food is unrelated to the perceived ease of chewing the food [34] but more likely to be related to the innate preferences for sweetness and genetic differences in taste sensitivity [35-37]. A child's food preferences may also be influenced by several environmental factors, including familiarity with certain foods, maternal food preferences and the association of certain foods in different social contexts [35,37-39]. It is possible that the food items in the study's FPQ did not reflect the full complexity of the child's wider diet or were different from their normal diet. To better understand the impact of dental treatment on food preferences, future studies may seek to specifically identify food items that children actively avoided prior to treatment and to evaluate their intake of these food items after dental treatment.

This study did not utilize a commercially manufactured dual colored chewing gum for assessing masticatory function, which may have limited the ability to compare this study's results to other published studies. In addition, it would have been ideal to perform the mixing ability test twice for internal validity but this was not done due to the young age of child and compliance with repeating the test. However, the scale developed for grading mixing ability score had good inter-rater intra-class correlation (0.95), which provided validity to the observed results within the context of the study. This study assumed that the child would adapt their chewing to achieve the most optimal mastication function and thus did not restrict or record the preferred chewing side. This may have confounded the results if the child continued to chew on their preferred side even after multiple extractions on that side. In addition, recording this parameter may have provided further insight as to the inverse relationship in masticatory function and number of extractions in some children.

CONCLUSION

- There were no changes in the child's mastication function with regard to chewing soft and moderately hard foods after dental treatment.
- There was an increased number of chews/g needed for certain hard foods after dental treatment; which was associated with an increased number of total and posterior extractions and a corresponding decrease in posterior occlusal contacts.

Why this paper is important to paediatric dentists:

- Provides insight to the changes in a child's masticatory function and food preferences following multiple extractions, which is frequent in extensive dental treatment.
- Aids paediatric dentists in addressing the frequent parental concern about the changes in their child's masticatory function and eating habits after dental treatment.

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Table 1. Dental Status at Baseline and 3-months after Dental Treatment

	Baseline	3-months after dental treatment	P Value
DENTAL STATUS			
dmft (SD)	11.1 (4.9)	11.5 (4.2)	0.249
• **dt**	11.0 (4.8)	0.5 (0.9)	<0.01*
• **mt**	0.0 (0.0)	6.4 (5.2)	<0.01*
• **ft**	0.2 (0.5)	5.1 (2.9)	<0.01*
Mean (SD) number of extractions/ child	-	6.4 (5.2)	-
Mean (SD) number of posterior teeth extractions/ child	-	3.6 (2.3)	-
Mean (SD) number of all occlusal contacts/ child	6.2 (3.5)	4.9 (3.3)	0.057
Mean (SD) number of posterior occlusal contacts/ child	3.2 (1.6)	2.1 (1.4)	0.001*
MASTICATORY TEST			
Mixing Ability Test (SD)	3.5 (1.3)	3.1 (1.3)	0.258

*Statistically significant change

Table 2. Assessment of Oral Processing Behaviour via Behavioural Coding Video Analysis at Baseline and 3-months after Dental Treatment

	Median number of chews/g (baseline)	Median number of chews/g (3-months)	P Value	Median time taken/g (baseline)	Median time taken/g (3-months)	P Value
Popcorn 2 pieces; 0.3g ± 0.05g each	58.3 (IQR=35.0)	86.7 (IQR=35.8)	<0.01*	46.7 (IQR=27.5)	61.7 (IQR=36.7)	0.13
Cereal 2 pieces; 0.25g ± 0.05g each	72.0 (IQR=35.0)	94.0 (IQR=54.0)	0.01*	68.0 (IQR=46.0)	58.0 (IQR=50.0)	0.59
Apple 1 slice; 10g ± 0.5g	14.3 (IQR= 9.6)	14.8 (IQR=19.0)	0.09	11.2 (IQR=11.1)	13.3 (IQR=15.0)	0.26
Chiffon cake 4g ± 0.5g	9.5 (IQR=6.0)	8.0 (IQR=4.7)	0.09	8.8 (IQR=7.3)	6.0 (IQR=4.0)	0.12
Chewy sweet 1 piece (commercially standardized)	151.0 (IQR=51.0)	129.0 (IQR=101.0)	0.59	144.0 (IQR=51.0)	124.0 (IQR=112.0)	0.12
Peanuts 2 pieces; 0.55g ± 0.05g each	59.1 (IQR=57.3)	74.5 (IQR=113.4)	0.09	44.5 (IQR=62.7)	47.3 (IQR=64.5)	0.76

*Statistically significant change