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ORIGINAL PAPER

# Association Between Feeding Problems and Oral Health Status in Children with Autism Spectrum Disorder

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## Abstract

A number of studies have been made of mealtime behavioral problems and food selectivity in patients with autism spectrum disorder (ASD), though not from a multidisciplinary perspective where diet and dental care are investigated in children with ASD. In the present study, the parents of 55 children with ASD and 91 children with typical development (TD) between 6 and 18 years of age completed the Brief Assessment of Mealtime Behavior in Children (BAMBIC) and a food consumption frequency questionnaire. A pediatric dentist performed an oral exploration of the participants according to the criteria of the World Health Organization (WHO). Food rejection and limited food variety were associated to an increased prevalence of malocclusion and altered Community Periodontal Index scores in children with ASD.

**Keywords** Autism spectrum disorder · Mealtime behavior · Pediatric dentistry · Food selectivity

## Introduction

Autism spectrum disorder (ASD) is a chronic neurodevelopmental disorder characterized by impairments in social interaction and communication and restricted, repetitive patterns of behavior, interests or activities (American Psychiatric Association 2013). The prevalence of ASD has increased in recent decades, particularly since the late 1990s. This increase is probably a consequence of the changes in diagnostic criteria of the disorder. The prevalence has continued to increase especially among people without intellectual impairments, despite consistent application of the diagnostic and statistical manual of mental disorders-Fifth Edition (DSM-V) (Baxter et al. 2015; Fombonne 2018; Williams et al. 2006). Such individuals may be at an increased risk of suffering oral health problems because of their special circumstances and certain limitations referred to oral hygiene (Murshid 2014; Sarnat et al. 2015). Likewise, children with ASD usually present eating habits characterized by rejection and/or preferences for certain foods (Chistol et al. 2018; Gray and Chiang 2017)—a situation that may lead to malnutrition and oral disorders (da Silva et al. 2017; Kotha et al. 2018; Murshid 2014), thereby complicating their nutritional status (Liu et al. 2016; Malhi et al. 2017; Mari-Bauset et al. 2015).

Certain restricted, repetitive patterns of behaviors and interests of individuals with ASD may be related to sensory characteristics, as well as to sensory processing and integration difficulties (Boudjarane et al. 2017; Castro et al. 2016; Curtin et al. 2015). In this regard, different authors (Bandini et al. 2017; Castro et al. 2016; Curtin et al. 2015; Johnson et al. 2014; Lockner et al. 2008) have suggested that certain sensory features may contribute to mealtime behavioral problems in children with ASD. As an example, food hyperselectivity is characterized by a narrow range of foods chosen by the child,

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where restricted and repetitive patterns of behavior could result in preferences for foods based on their shape, color or appearance (Bandini et al. 2017, 2019; Castro et al. 2016; Chistol et al. 2018). Although the findings of these studies are consistent, and a high incidence of food behavioral problems has been observed in children with ASD, their impact in relation to oral health has not been addressed to date.

Children with ASD constitute a very heterogeneous population group with common behavioral characteristics that may interfere with the care of oral health (Du et al. 2018; El Khatib et al. 2014; Nelson et al. 2015). Previous studies (Al-Maweri and Zimmer 2015; Al-Nowaiser et al. 2017; Al-Sehaibany 2017) have reported that poor oral health has a negative impact upon food digestion, chewing capacity, speech and occlusion, resulting in negative effects in terms of quality of life among disabled children. On the other hand, the treatment and maintenance of oral health in these children represent a challenge for dental professionals, due to the complications sometimes found in managing their sensory difficulties and limited patient cooperation in the dental office (Blomqvist et al. 2014; Cermak et al. 2015; Delli et al. 2013; Du et al. 2018; El Khatib et al. 2014; Loo et al. 2009).

Although there are no buccodental disorders specific of children with ASD, such patients may exhibit deficient dental care and oral hygiene, resulting in caries and/or periodontal disease (Kotha et al. 2018; Luppanapornlarp et al. 2010; Marshall et al. 2010; Qiao et al. 2018). In some cases these children exhibit oral habits such as oral breathing, daytime and nighttime bruxism, or atypical swallowing patterns, etc., which may give rise to facial and buccodental alterations as well as malocclusions (Al-Sehaibany 2017; da Silva et al. 2017; Fontaine-Sylvestre et al. 2017; Sarnat et al. 2015). Such habits could contribute to significant dental problems such as soft tissue damage, dental loss and wear, anterior open bite and posterior crossbite (Du et al. 2018; Fontaine-Sylvestre et al. 2017; Luppanapornlarp et al. 2010; Orellana et al. 2012).

In general, the findings of previous investigations referred to oral health in pediatric populations with ASD are contradictory and inconclusive, and studies on the association between mealtime behavioral disorders and oral health in children with ASD are lacking. The aim of the present study was therefore to evaluate buccodental health in children with ASD and correlate the findings to their eating habits. Our working hypothesis was that children with ASD have greater oral disorders than children with typical development (TD), due to the possible association of poor eating behavior.

## Methods

### Study Subjects

A cross-sectional, case–control observational study was carried out in Madrid Complutense University and the University of Granada (Spain) between January 2016 and December 2017. This was a multidisciplinary study involving specialists in dentistry, nutrition and medical physiology. Initially, a total of 200 children agreed to participate in the study: 82 in the experimental group (children with ASD) and 118 controls (children with typical development, TD). The children with ASD were recruited from different ASD special education centers and centers with inclusion classes for children with this disorder. All the children in the experimental group were between 6 and 18 years of age and were diagnosed with ASD based on the DSM-V criteria. Subjects receiving special diets (e.g., casein and gluten free), those with food allergies or medications capable of modifying dietary intake and which could alter oral health were excluded from the study. In the case of the control group, schools in the same area and children of similar socioeconomic status as the special schools attended by the ASD group were selected. Before starting the study, the parents or legal representatives of the children received an explanation of the study and the tests to be carried out, and were informed of data compilation and the maintenance of data confidentiality according to Spanish legislation. Informed consent was obtained in all cases. The study was approved by the Ethics Committee of San Carlos University Clinic Hospital (Madrid, Spain). Finally, 32 and 25 children were excluded in the experimental and control group, respectively, due to non-collaboration in the oral examination, failure to report for the oral examination, or failure to receive or complete the questionnaires. The final sample thus consisted of 144 children selected from different education centers: 51 with ASD (experimental group) and 93 with TD (control group).

### Food Frequency Questionnaire (FFQ)

The Food Frequency Questionnaire (FFQ) was used by the parents to report the frequency of intake of different food groups (per day, week, month or year), based on a list of 200 foods, with the purpose of evaluating the eating habits of the study population. We determined percentage adequacy of the frequency of intake of the different food groups in each child participating in the study, based on the recommendations of the Spanish Society of Community Nutrition (Sociedad Española de Nutrición

Comunitaria, SENC) (Grupo Colaborativo de la Sociedad Española de Nutrición Comunitaria et al. 2016). In relation to each food group, the children were classified as follows: frequency of intake less than that recommended; frequency of intake within the recommended range; or frequency of intake in excess of that recommended, based on the food pyramid proposed by the SENC (Grupo Colaborativo de la Sociedad Española de Nutrición Comunitaria et al. 2016). In those cases where the SENC failed to specify a frequency of intake for a given food because it is consumed only occasionally or in small portions, we reported the results as the number of portions consumed in 1 week. Lastly, food hyperselectivity was defined when at least 33% of the different foods recorded showed a frequency of intake less than that recommended by the SENC (Bandini et al. 2017).

### Brief Assessment of Mealtime Behavior in Children (BAMBIC)

Food selectivity and mealtime behavior was evaluated using the Brief Assessment of Mealtime Behavior in Children (BAMBIC) (Hendy et al. 2013), a summarized version of the original 18-item BAMBI questionnaire. The parents used the BAMBIC to assess three frequent feeding problems: (i) limited food variety; (ii) food rejection; and (iii) disruptive behavior during meals.

The BAMBIC consists of 10 items, and the scores corresponding to each subscale of the instrument were established by the mean score of 5 points assigned to the elements within each of the three feeding problem categories defined above. In order to measure the feeding disorders in the children, the parents assigned scores of 5 points according to the frequency of each possible situation during the last 6 months: 1 = never; 2 = rarely; 3 = occasionally; 4 = often; 5 = almost all meals). The parents were also questioned about the preferences of their children regarding soft foods.

### Oral Exploration

The participants in the study were examined in school, sitting in a chair under natural light and using a sterile exploration kit comprising an oral probe and mirror, and cotton tips. One same pediatric dentist performed the intraoral exploration while another team member recorded the findings. Intra-operator reliability was previously evaluated in a pilot study involving 17 subjects, performing each exploration twice, and obtaining a kappa index of 0.8. The intraoral examination was carried out according to the criteria of the (World Health Organization 1987), which defines a healthy tooth as showing no current caries or treated carious lesions. Temporary material fillings were regarded as dental caries. Oral hygiene in turn was scored using the (Silness and Loe 1964), while periodontal health was visually scored with the Community Periodontal Index. The presence of anteroposterior, vertical and transverse malocclusions was recorded (Angle 1899).

### Statistical Analysis

The differences in characteristics between the children with ASD and the children with TD were analyzed using the Student *t* test for quantitative variables and the Chi squared test for qualitative variables. The Chi squared test with Bonferroni correction was used to analyze the proportions of children with ASD and TD showing food selectivity based on the food frequency of consumption data. The cut-off point for food hyperselectivity was defined as the rejection of 33% or more of the offered foods (Curtin et al. 2015). Mealtime behavioral problems were determined using the Student t-test to establish differences in the mean scores obtained by children with ASD versus children with TD. The model was corrected for the factor age. All the data were reported as the mean and standard deviation. The BAMBIC data were classified into three categories: food rejection, limited variety and disruptive behavior (Hendy et al. 2013). Analysis of covariance (ANCOVA) was used to evaluate the association between mealtime behavioral problems according to the questionnaire and food hyperselectivity in children with ADS versus children with TD. The model was corrected for the factor age. The Chi squared test with Bonferroni correction was used to analyze oral health in the two groups in the case of categorical variables, while the Student t-test was used in the case of numerical variables. The effect of food hyperselectivity upon oral health in children with ASD and children with TD was explored by ANCOVA. The model was corrected for the factor age. Statistical significance was considered for $p < 0.05$. The SPSS version 25.0 statistical package (SPSS Inc., Chicago, IL, USA) was used throughout.

## Results

Table 1 summarizes the characteristics of the children (age, weight, height, body mass index [BMI], gender and place of residence) referred to both the total sample and the two study groups (children with ASD and children with TD). The results showed statistically significant differences in age between the children with ASD and the children with TD ($p < 0.05$). The age-adjusted comparative analysis of body weight, height and BMI showed no statistically significant differences between the two groups.

The Chi squared test with Bonferroni correction showed significant differences in the distribution of BMI between the groups ($\chi^2 = 13.754$ ($n = 144$); $p = 0.003$), with a

**Table 1** Main characteristics of the children with typical development (TD) and the children with autism spectrum disorder (ASD)

| | Total (n = 144) Mean (SE); % (number of subjects) | TD children (n = 93) Mean (SE); % (number of subjects) | ASD children (n = 51) Mean (SE); % (number of subjects) |
|---|---|---|---|
| Age (years) | 10.7 (2.98) | 9.56 (1.67) | 12.84 (3.67)[a] |
| Weight (kg) | 42.0 (1.47) | 40.5 (1.44) | 44.4 (2.10) |
| Height (cm) | 145.4 (1.30) | 145.9 (1.04) | 144.2 (1.49) |
| BMI (kg/m²) | 19.2 (0.37) | 18.7 (0.43) | 19.9 (0.62) |
| BMI z-score | 0.00 (0.94) | – 0.06 (0.75) | 0.11 (1.23) |
| Normal weight (5–85 pth) | 61.3 (87) | 69.9 (65) | 44.9 (22)[b] |
| Underweight (≤ 5 pth) | 8.5 (12) | 3.20 (3) | 18.4 (9)[b] |
| Overweight (≥ 85– < 95 pth) | 19.0 (27) | 18.3 (17) | 20.4 (10) |
| Obesity (≥ 95 pth) | 11.3 (16) | 8.6 (8) | 16.3 (8) |
| Sex | | | |
| Male | 60.8 (87) | 53.8 (50) | 74.0 (37)[b] |
| Female | 39.2 (56) | 46.2 (43) | 26.0 (13)[b] |
| Population | | | |
| Madrid | 45.5 (65) | 49.5 (46) | 38.0 (19) |
| Granada | 54.5 (78) | 50.5 (47) | 62.0 (31) |

Age is expressed as the mean and standard deviation

All anthropometrical variables were corrected for age factor and expressed as the mean and standard error (SE)

BMI categories, sex and population variables are expressed as the percentage and number of subjects

The standardized z-scores of the BMI was calculated adjusted by age

BMI status was categorized, using National Health and Nutrition Examination Survey (NHANES) criteria, into the following four categories: underweight (≤ 5th percentile); healthy (> 5th to < 85th percentiles); overweight (≥ 85th to < 95th percentiles); and obese (≥ 95th percentile)

*ASD* Autism spectrum disorder, *TD* typical development, *BMI* body mass index

[a]The t-Student test was used to compare the values of children with TD and with ASD ($p < 0.05$)

[b]The p-value was obtained by the Chi squared test ($p < 0.05$)

comparatively greater presence of low-weight children in the ASD group (18.4% vs. 3.20% in the control group). On the other hand, a lesser percentage of children with ASD were within the normal BMI range (44.9% vs. 69.9% in the control group). No statistically significant differences were observed in the different age intervals. In relation to gender, statistically significant differences ($p = 0.027$) were observed for both the children with ASD and the controls. Bonferroni correction identified a greater presence of males in both study groups. There were no significant differences between the groups in terms of place of residence ($p = 0.189$).

Table 2 analyzes the sample distribution according to the food hyperselectivity, based on the frequency of food consumption and compares the mealtime behavioral disorders according to the Brief Assessment of Mealtime Behavior in Children (BAMBIC) in children with TD versus those with ASD. The Chi squared test identified significant differences in food hyperselectivity between the groups ($\chi^2 = 4.351$ ($n = 91$); $p = 0.049$). Application of the Bonferroni correction revealed a greater presence of children with food hyperselectivity in the ASD group (60.6% vs. 37.9% in the control group). In relation to mealtime behavior, statistically significant differences ($p < 0.05$) were observed for all three dimensions studied, i.e., food rejection, disruptive behavior and limited variety, with higher scores in the ASD group than among the controls.

Table 3 in turn shows the comparative analysis of the scores obtained on evaluating the eating problems (BAMBIC) and their association to food selectivity (assessed by means of the FFQ) in the children with ASD versus those with TD. Those children with ASD that showed food hyperselectivity (defined as rejection of 33% or more of the offered foods according to the FFQ) also exhibited significantly more food rejection than the TD group ($p = 0.025$). Similarly, those children with ASD that showed food hyperselectivity also yielded higher scores referred to disruptive behavior compared with the children with TD ($p = 0.004$), as well as higher scores referred to limited food variety ($p = 0.003$).

Table 4 shows the comparative analysis and distribution of the participants according to oral health in the ASD and TD groups. There were no significant differences in the DMFT (decayed, missing and filled teeth) and Dmft (decayed, filled and missing) caries indices between the

**Table 2** Analysis of sample distribution according to the food hyperselectivity, based on the frequency of food consumption and comparative analysis of mealtime behavioral disorders according to the Brief Assessment of Mealtime Behavior in Children (BAMBIC) in children with TD versus those with ASD

| | Total (n = 91) % (number of subjects); Mean (SE) | TD children (n = 58) % (number of subjects); Mean (SE) | ASD children (n = 33) % (number of subjects); Mean (SE) | P value |
|---|---|---|---|---|
| Food frequency | | | | |
| < 33% of FFQ | 53.8 (49) | 62.1 (36) | 39.4 (13) | 0.049 |
| > 33% of FFQ | 46.2 (42) | 37.9 (22)[a] | 60.6 (20)[a] | |
| BAMBIC | | | | |
| Food rejection | 2.60 (0.08) | 2.31 (0.1) | 3.17 (0.15) | 0.001 |
| Limited variety | – 2.43 (0.24) | – 3.05 (0.29) | – 1.16 (0.43) | 0.001 |
| Disruptive behaviour | 2.64 (0.06) | 2.48 (0.07) | 2.96 (0.11) | 0.001 |

Food frequency is expressed as the percentage of subjects

Brief Assessment of Mealtime Behavior in Children is expressed as the mean and standard error

The cut-off point for food hyperselectivity was defined as the rejection of 33% or more of the offered foods

The Student t-test was used to compare the values of the children with ASD versus those with TD ($p < 0.05$)

The BAMBIC classified the scores into three categories: food rejection, limited food variety and disruptive behavior

The model has been corrected for age factor

[a]The p-value for qualitative variables was obtained by the Chi squared test with Bonferroni correction ($p < 0.05$)

**Table 3** Comparative analysis of behavioral disorders according to the Brief Assessment of Mealtime Behavior in Children (BAMBIC) and food hyperselectivity in children with TD versus those with ASD

| | Total (n = 91) | | TD children (n = 58) | | ASD children (n = 33) | | p group | p all |
|---|---|---|---|---|---|---|---|---|
| | Mean | (SE) | Mean | (SE) | Mean | (SE) | | |
| Food rejection | | | | | | | | |
| < 33% FFQ | 1.10 | (0.25) | 1.06 | (0.16) | 1.22 | (0.41) | 0.004 | 0.297 |
| > 33% FFQ | 1.28 | (0.48) | 1.12 | (0.36) | 1.45 | (0.54) | | |
| Disruptive behaviour | | | | | | | | |
| < 33% FFQ | 2.31 | (0.60) | 2.25 | (0.52) | 2.48 | (0.82) | 0.001 | 0.150 |
| > 33% FFQ | 2.90 | (0.92) | 2.39 | (0.63) | 3.16[a] | (0.92) | | |
| Limited variety | | | | | | | | |
| < 33% FFQ | 1.17 | (0.31) | 1.06 | (0.15) | 1.17 | (0.30) | 0.002 | 0.011 |
| > 33% FFQ | 1.13 | (0.26) | 1.05 | (0.12) | 1.32[a] | (0.40) | | |

All data are expressed as the mean and standard error

Analysis of covariance (ANCOVA) was used to compare the values of the children with ASD versus those with TD ($p < 0.05$)

Food hyperselectivity was defined as the rejection of 33% or more of the offered foods based on the Food Frequency Questionnaire (FFQ)

The model has been corrected for age factor

two groups. The Chi squared test was used to qualitatively assess the prevalence of caries according to the presence or absence of carious lesions—no statistically significant differences being observed between the two groups. With regard to dentition eruptive stage, a greater presence of temporary teeth and first phase mixed dentition was noted in the ASD group compared with the TD group, while a larger number of children with TD had permanent teeth.

On the other hand, bruxism was found to be more prevalent in the ASD group than among the controls (58% vs. 20.4%, respectively). The periodontal findings based on the Community Periodontal Index revealed a greater percentage of children with healthy periodontal conditions in the TD group versus the ASD group (43% vs. 24%, respectively). Dental calculus was also more prevalent in the ASD group (24% vs. 9.7%, respectively). The assessment of oral hygiene based on the Silness and Löe index showed the relationship between these variables to be significant ($p = 0.014$). Dental plaque was seen to be more prevalent in the ASD group than among the controls (50.5%

**Table 4** Analysis of sample distribution according to the oral health parameters in children with ASD and children with TD

| | Total (n = 144) Mean (SE); % (number of subjects) | TD children (n = 93) Mean (SE); % (number of subjects) | ASD children (n = 51) Mean (SE); % (number of subjects) | p value |
|---|---|---|---|---|
| DMFT | 0.64 (0.15) | 0.60 (0.19) | 0.70 (0.28) | 0.750 |
| Dmft | 0.83 (0.16) | 0.83 (0.18) | 0.85 (0.46) | 0.959 |
| Prevalence caries | | | | |
| Caries | 29.2 (56) | 7.60 (35) | 42.0 (21) | 0.641 |
| Eruptive stage | | | | |
| Decidious dentition | 2.80 (4) | 4.30 (4) | 0 (0) | 0.000 |
| Mixed dentition phase 1 | 41.3 (59) | 52.7 (49) | 20.0 (10)[a] | |
| Mixed dentition phase 2 | 16.8 (24) | 22.6 (21) | 6.00 (3)[a] | |
| Permanent dentition | 39.2 (56) | 20.4 (19) | 74.0 (37)[a] | |
| Prevalence bruxism | | | | |
| Bruxism | 33.6 (48) | 20.4 (19) | 58.0 (29)[a] | 0.000 |
| Community periodontal index | | | | |
| Healthy | 36.4 (52) | 43.0 (40) | 24.0 (12)[a] | 0.011 |
| Inflammation without bleeding | 23.8 (34) | 26.9 (25) | 18.0 (9) | |
| Inflammation with bleeding | 25.2 (36) | 20.4 (19) | 34.0 (17) | |
| Dental calculus | 14.7 (21) | 9.70 (9) | 24.0 (12)[a] | |
| Silness-loe index hygiene | | | | |
| No plaque | 41.3 (59) | 50.5 (47) | 24.0 (12)[a] | 0.014 |
| Plaque presence only detected with probe | 11.2 (16) | 8.60 (8) | 16.0 (8) | |
| Moderate plaque and visible | 28.7 (41) | 22.6 (21) | 40.0 (20)[a] | |
| Abundance plaque (> 1/3) | 18.9 (27) | 18.3 (17) | 20.0 (10) | |
| Malocclusion | | | | |
| No malocclusion | 40.6 (58) | 49.5 (46) | 24.0 (12)[a] | 0.000 |
| Class I crowding | 19.6 (28) | 8.60 (8) | 40.0 (20)[a] | |
| Class II | 11.9 (17) | 12.9 (12) | 10.0 (5) | |
| Class III | 7.70 (11) | 8.60 (8) | 6.00 (3) | |
| Openbite | 9.10 (13) | 4.30 (4) | 18.0 (9)[a] | |
| Crossbite | 6.30 (9) | 8.60 (8) | 2.00 (1) | |
| Non-valuable patient with orthodontics | 4.90 (7) | 7.50 (7) | 0 (0) | |

DMFT and Dmft data are expressed as the mean and standard error (SE)

The prevalence of caries, the eruptive stage, the presence of bruxism, the Community Periodontal Index, the Silness and Löe hygiene index and the malocclusion are expressed as percentage of subjects

The Student t-test was used to compare DMFT and Dmft scores between the ASD and TD groups ($p < 0.05$)

The model has been corrected for age factor

*DMFT* decayed, missing, filled teeth

*Dmft* decayed, missing, filled index

[a]The p-value was obtained by the Chi squared test with Bonferroni correction ($p < 0.05$) for the prevalence of caries, the eruptive stage, the presence of bruxism, the Community Periodontal Index, the Silness and Löe hygiene index and the malocclusion

vs. 24%, respectively). Moderate and visible plaque was more frequent in the ASD group than in the TD group (40% vs. 22.6%, respectively). Lastly, malocclusion was more prevalent in the ASD group than in the TD group (49.5% vs. 24%, respectively). Open bite was found to be more common in the children with ASD (18% vs. 4.3%, respectively), in the same way as crowding (40% vs. 8.6%, respectively).

Table 5 shows the comparative analysis of the association between oral health problems and mealtime behavior. Those children with ASD that showed increased food rejection had a higher prevalence of both malocclusion and altered Community Periodontal Index scores, as well as a greater presence of bruxism ($p < 0.05$). On the other hand, with regard to mealtime disruptive behavior, the scores were found to be higher in those children with ASD that presented

**Table 5** Comparative analysis of oral health in accordance to mealtime behavioral problems based on the Brief Assessment of Mealtime Behavior in Children (BAMBIC) in children with TD versus those with ASD

| | Total (n = 144) | | TD children (n = 93) | | ASD children (n = 51) | | p group | p all |
|---|---|---|---|---|---|---|---|---|
| | Mean | (SE) | Mean | (SE) | Mean | (SE) | | |
| *Food refusal* | | | | | | | | |
| Prevalence of caries | | | | | | | | |
| Caries | 1.21 | 0.45 | 1.12 | 0.36 | 1.36 | 0.56 | 0.000 | 0.498 |
| Occlusion | | | | | | | | |
| No malocclusion | 1.05 | 0.14 | 1.05 | 0.15 | 1.05 | 0.13 | 0.001 | 0.273 |
| Class I crowding | 1.31 | 0.44 | 1.00 | 0.29 | 1.39 | 0.46 | | |
| Class II | 1.03 | 0.11 | 1.04 | 0.11 | 1.02 | 0.35 | | |
| Class III | 1.23 | 0.31 | 1.01 | 0.21 | 1.55 | 0.19 | | |
| Openbite | 1.33 | 0.71 | 1.05 | 0.56 | 1.53 | 0.86 | | |
| Crossbite | 1.41 | 0.61 | 1.33 | 0.60 | 2.00 | 0.35 | | |
| Periodontal index | | | | | | | | |
| Healthy | 1.12 | 0.35 | 1.04 | 0.11 | 1.40 | 0.66 | 0.003 | 0.496 |
| Inflammation without bleeding | 1.00 | 0.36 | 1.00 | 0.25 | 1.00 | 0.21 | | |
| Inflammation with bleeding | 1.34 | 0.48 | 1.25 | 0.47 | 1.45 | 0.50 | | |
| Dental calculus | 1.30 | 0.38 | 1.13 | 0.29 | 1.40 | 0.40 | | |
| Prevalence of bruxism | | | | | | | | |
| Bruxism | 1.15 | 0.27 | 1.04 | 0.12 | 1.57 | 0.33 | 0.000 | 0.050 |
| *Disruptive behaviour* | | | | | | | | |
| Prevalence of caries | | | | | | | | |
| Caries | 1.19 | 0.31 | 1.11 | 0.19 | 1.33 | 0.42 | 0.000 | 0.443 |
| Occlusion | | | | | | | | |
| Normal occlusion | 1.08 | 0.17 | 1.05 | 0.15 | 1.22 | 0.27 | 0.000 | 0.042 |
| Class I crowding | 1.14 | 0.29 | 1.00 | 0.11 | 1.17 | 0.31 | | |
| Class II | 1.14 | 0.33 | 1.04 | 0.11 | 2.00 | 0.13 | | |
| Class III | 1.09 | 0.16 | 1.08 | 0.16 | 1.11 | 0.19 | | |
| Openbite | 1.29 | 0.48 | 1.02 | 0.19 | 1.46 | 0.57 | | |
| Crossbite | 1.12 | 0.17 | 1.09 | 0.13 | 1.33 | 0.21 | | |
| Periodontal index | | | | | | | | |
| Healthy | 1.07 | 0.23 | 1.04 | 0.11 | 1.18 | 0.44 | 0.009 | 0.942 |
| Inflammation without bleeding | 1.09 | 0.18 | 1.05 | 0.13 | 1.25 | 0.31 | | |
| Inflammation with bleeding | 1.18 | 0.28 | 1.08 | 0.15 | 1.30 | 0.34 | | |
| Dental calculus | 1.21 | 0.33 | 1.13 | 0.29 | 1.25 | 0.36 | | |
| Prevalence of bruxism | | | | | | | | |
| Bruxism | 1.15 | 0.30 | 1.02 | 0.09 | 1.25 | 0.37 | 0.000 | 0.747 |
| *Limited variety* | | | | | | | | |
| Prevalence of caries | | | | | | | | |
| Caries | 2.64 | 0.74 | 2.44 | 0.67 | 2.98 | 0.75 | 0.001 | 0.842 |
| Occlusion | | | | | | | | |
| Normal occlusion | 2.37 | 0.62 | 2.27 | 0.59 | 2.91 | 0.51 | 0.104 | 0.353 |
| Class I crowding | 2.80 | 1.03 | 2.31 | 0.51 | 2.92 | 1.10 | | |
| Class II | 2.19 | 0.74 | 2.06 | 0.67 | 3.25 | 0.78 | | |
| Class III | 2.42 | 0.53 | 2.18 | 0.12 | 2.75 | 0.75 | | |
| Openbite | 2.81 | 0.66 | 2.50 | 0.98 | 3.00 | 0.81 | | |
| Crossbite | 2.28 | 0.74 | 2.42 | 0.67 | 1.25 | 0.93 | | |
| Periodontal index | | | | | | | | |
| Healthy | 2.38 | 0.65 | 2.40 | 0.45 | 3.00 | 0.88 | 0.000 | 0.025 |
| Inflammation without bleeding | 2.44 | 0.61 | 2.35 | 0.55 | 2.81 | 0.65 | | |
| Inflammation with bleeding | 2.41 | 0.70 | 2.43 | 0.73 | 2.38 | 0.71 | | |
| Dental calculus | 2.94 | 1.12 | 2.15 | 0.80 | 3.38 | 1.06 | | |
| Prevalence of bruxism | | | | | | | | |
| Bruxism | 2.73 | 0.65 | 2.45 | 0.36 | 2.95 | 0.74 | 0.004 | 0.878 |

All data are expressed as the mean and standard error

Analysis of covariance (ANCOVA) was used to compare the values of the children with ASD versus those with TD ($p < 0.05$)

The BAMBIC classified the scores into three categories: food rejection, limited food variety and disruptive behavior

The model has been corrected for age factor malocclusion ($p = 0.046$), an altered Community Periodontal Index score ($p = 0.011$) and bruxism ($p = 0.018$). Lastly, in relation to oral health, the children with ASD showed higher limited food variety scores regardless of their oral health conditions ($p < 0.05$), while in relation to oral habits, higher limited food variety scores were only significantly related to bruxism ($p = 0.016$).

## Discussion

The present study found children with autism spectrum disorder (ASD) to yield higher scores referred to mealtime behavioral problems and greater food selectivity than children with typical development (TD). Likewise, oral disease was more prevalent in the ASD group, despite the fact that the caries index was low in both groups. The analysis of the relationship between food selectivity and oral disease revealed an association between food rejection and limited food variety and an increased prevalence of malocclusions, altered Community Periodontal Index scores and bruxism in the children with ASD versus the controls. Few studies to date have examined the association between diet and oral health in children with ASD (Klein and Nowak 1999; Kotha et al. 2018; Murshid 2014; Sarnat et al. 2016). Although a number of authors have described eating selectivity in children with ASD (Bandini et al. 2017; Barnhill et al. 2016; Castro et al. 2016), to the best of our knowledge this is the first study to explore the association between oral health and mealtime behavior (including eating selectivity) in children with ASD.

With regard to the study sample characteristics, we found a higher prevalence of altered body mass index (BMI) in the ASD group than in the TD group (55.1% vs. 30.1%, respectively). Recent publications have reported mean BMI values in children with ASD similar to those recorded in our study (Malhi et al. 2017; Neumeyer et al. 2018). Specifically, in our series the prevalence of both low weight and obesity was seen to be higher among the children with ASD. This is consistent with the findings of the study by (Marí-Bauset et al. 2015), likewise conducted in Spain, and which reported a risk of low BMI values in children with ASD (Marí-Bauset et al. 2015). On the other hand, Hyman et al. (2012) have suggested that children with ASD between 5 and 11 years of age have a higher incidence of low body weight.

Food hyperselectivity has been described as one of the characteristics of children with ASD. On defining food hyperselectivity as the rejection of 33% or more of the offered foods as assessed by the Food Frequency Questionnaire (FFQ), we found hyperselectivity to be more common in the ASD group than among the controls (60.6% vs. 37.9%, respectively). Curtin et al. (2015) evaluated 53 children with ASD and 58 with TD between 3 and 11 years of age using the same method as in our series and recorded an even higher prevalence of food hyperselectivity in the ASD group (66% vs. 24% in the children with TD). Additionally, our comparative analysis of the scores obtained on evaluating the eating problems in the children with ASD versus those with TD based on the Brief Assessment of Mealtime Behavior in Children (BAMBIC) revealed significantly higher scores in the ASD group for all three dimensions studied (food rejection, disruptive behavior and limited variety). This suggests that mealtime behavior is more altered in children with ASD than in children with TD. This is consistent with the findings of Castro et al. (2016), who evaluated mealtime behavior based on the Behavioral Pediatric Feeding Assessment Scale (BPFA), and found children with ASD to have greater problems at mealtimes than the controls. These authors also reported a limited range of foods in the children with ASD. Malhi et al. (2017) obtained similar results on comparing a group of children with ASD versus a group of children with TD, based on the Children's Eating Behavior Inventory (CEBI). They found the children with ASD to have significantly higher CEBI scores and more feeding problems than the children with TD. In contrast, other authors (Liu et al. 2016) have reported no marked differences in mealtime behavioral problems (oral sensitivity, mild eating problems, or mild resistance to the introduction of new foods) between children with or without ASD—this suggesting general mealtime behavior to be similar between the two groups of children.

In line with the abovementioned results, our study demonstrates the relationship between mealtime behavioral problems and food hyperselectivity (defined as the rejection of 33% or more of the offered foods as assessed by the FFQ), with the observation of statistically significant differences between the two study groups (Table 3). Specifically, children with ASD and food hyperselectivity showed higher food rejection scores than the children with TD ($p = 0.025$), as well as greater disruptive behavior ($p = 0.004$). Likewise, the children with ASD and food hyperselectivity showed more limited food variety than the controls. In relation to severe food selectivity, other authors (Sharp et al. 2018) investigating food intake, nutritional adequacy and growth in children with ASD have found 78% of the children to reject one or more food groups. Furthermore, these children exhibited a broad range of mealtime behavioral disorders, with food rejection in 77.1% of the cases and disruptive behavior in 70% (Sharp et al. 2018). As a limitation, hyperselectivity evaluating 33% of the food consumed implied limitations for interpretation of the results, because the diet was not comprehensively evaluated for quantitative macro- and micronutrient intake, and the volume of food consumed was not assessed. Future research therefore should address the quantitative and qualitative determination of food intake and the quality of the diet as two complementary tools for determining the relationship with behavioral problems during meals.

In the oral exploration of our sample of children, the caries indices were found to be low in both groups, though the prevalence of caries reached 42% in the children with ASD. Du et al. (2018) recently reported similar findings in a series of children with ASD, where 37.0% had dental caries and 35.4% presented evidence of untreated carious lesions. A recent meta-analysis (da Silva et al. 2017) underscored that the prevalence of dental caries and periodontal disease may be regarded as high in children and young adults with ASD—thus pointing to the need for adequate oral health policies targeted to these individuals. Specifically, the prevalence of caries in the permanent and temporary dentition of children with ASD was found to be about 60%, though with important variability among studies (21–91.4%). With regard to oral hygiene, dental plaque was seen to be less prevalent among the controls than in the children with ASD (24% vs. 50.5%, respectively), and the latter moreover had a higher prevalence of moderate and visible plaque compared with the controls (40% vs. 22.6%, respectively). This is consistent with the findings of other studies in which abundant dental plaque was seen to be frequent in patients with ASD (DeMattei et al. 2007; Du et al. 2015). This greater presence of dental plaque is attributable to oral hypersensitivity and the manual dexterity problems characterizing children with special needs (Stein et al. 2013).

Compared with the controls, the children with ASD included in our study showed a greater prevalence of bruxism (58% vs. 20.4%, respectively), periodontal disease and malocclusion (49.5% vs. 24%, respectively). Different studies (Schreck and Mulick 2000) have reported bruxism to be a common habit in children with ASD. This is consistent with the observations of Al-Sehaibany (2017), who found bruxism to be the most common oral parafunctional habit in children with ASD, with a prevalence of 54.7%, though this study was based on the administration of a questionnaire among the parents of preschool children. On the other hand, correct periodontal health was seen to be more prevalent in the TD group than among the children with ASD. Likewise, dental calculus was more prevalent in the ASD group than among the controls (24% vs. 9.7%, respectively). Over 50% of the autistic patients analyzed by different authors (Klein and Nowak 1999; Shapira et al. 1989) presented gingivitis to one degree or other. On the other hand, with regard to the presence of malocclusions in our series, both open bite (18% vs. 4.3%, respectively) and crowding were more common in the ASD group than in the controls (40% vs. 8.6%, respectively). Other authors (Du et al. 2015) have documented a greater prevalence of overbite, overjet and anterior crossbite in children with ASD versus the controls, though statistical significance was not reached.

The study of the association between oral health and food selectivity showed the prevalence of malocclusion, altered Community Periodontal Index scores and bruxism to be greater among the children with ASD, who moreover yielded higher scores referred to food rejection and disruptive behavior versus the children with TD. The children with ASD that yielded higher food rejection scores also had more bruxism that the controls. On the other hand, occlusion problems were seen to be directly associated to food rejection ($p = 0.042$), with higher crossbite and open bite scores in the ASD group. Additionally, in our study we found altered BMI to be associated to both oral health problems and food hyperselectivity (data not shown), considering that altered BMI could be of multifactorial origin. In line with the sensory processing difficulties, these patients may exhibit hyposensitivity, with diminished muscle tone, chewing problems and atypical chewing patterns that may explain the observed association between mealtime behavioral disorders and malocclusion (Ben-Sasson et al. 2008; Dunn et al. 2008; Nadon et al. 2011). The children with ASD that exhibited greater disruptive behavior during meals had a greater prevalence of malocclusion problems—specifically class II malocclusion and open bite—than the children with TD. Likewise, an altered Community Periodontal Index score was associated to greater food variety limitations. The children with ASD who moreover presented dental calculus yielded higher food selectivity scores. A relatively recent study (Sarnat et al. 2016) has found children with ASD to suffer greater eating problems and poorer oral habits than the controls, though no association to buccodental health could be established. These results were obtained from a parent survey, with no oral explorations or specific exploratory tools such as the FFQ or questionnaires assessing mealtime behavior among the children. An association therefore possibly could have been identified if such tools had been used. Another study (Klein and Nowak 1999) on the eating and nutritional habits and oral health in a series of 43 children with ASD examined food preferences and feeding patterns, and found 53% of the participants to be reluctant to try new foods. However, the associations were not analyzed, and the study moreover lacked a control group. On the other hand, we cannot confirm that feeding problems are the cause of the pathological findings in the oral cavity, though an association between such variables was recorded. Our study therefore reveals the existence of correlations between oral health (or more specifically buccodental disease) and food selectivity. We suspect that the observed associations could have been even more manifest if our sample size had been larger. Future studies in this field are therefore needed to clarify the oral health issues characterizing children with ASD.

## Conclusion

Children with ASD show greater mealtime behavioral disorders and food selectivity than children with TD. A higher prevalence of buccodental disease was observed in the ASD group, though the caries indexes were low in both groups. An association was observed between food rejection and limited food variety, and an increased prevalence of malocclusions, altered Community Periodontal Index scores and bruxism was recorded among children with ASD versus children with TD of the same age. These findings may contribute to the development of preventive protocols for improving patient oral health in the clinical setting.

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**Author Contributions** Leiva-García and Molina-López carried out the collection, analysis and interpretation of data and drafted the manuscript. Leiva-García, Molina-López, Planells E. and Planells del Pozo P. recruited the patients and collected oral health and nutritional data. Planells E. and Planells del Pozo P. carried out in study design. Leiva-García, Molina-López and Planells E. helped in the analysis and interpretation the data. Leiva-García and Molina-López helped to draft the manuscript. All authors read and approved the final manuscript.

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### Compliance with Ethical Standards

**Conflicts of interest** The authors declare that they have no conflicts of interest.

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