Masticatory evaluation of anterior open bite malocclusion using the colorimetric capsule method

Eduardo Carpinski Corrêa, DDS, MS ■ Fernando Akio Maeda, DDS, MS, PhD
Andre Luís Ribeiro de Miranda, DDS, MS, PhD ■ Paulo Eduardo Guedes Carvalho, DDS, MS, PhD
Lucas Hian da Silva, DDS, MS, PhD ■ Fernando César Torres, DDS, MS, PhD

This pediatric study aimed to assess the masticatory function of patients with anterior open bite through a method that utilizes colorimetric capsules. The sample consisted of 106 patients aged 7-11 years, of whom 51 presented with anterior open bite (experimental group) and 55 presented with normal overbite (control group). The colorimetric capsules used in this evaluation contained basic fuchsin granules, which were used to produce a solution after they were ground during chewing. Each patient was asked to chew 1 capsule for 20 seconds. The absorbance of the obtained solutions was analyzed with a spectrophotometer. Greater masticatory efficiency is directly related to the greater light absorbance of a solution, since light absorbance increases with solution concentration. A nonparametric Wilcoxon test indicated that the solutions obtained from the control group presented significantly greater light absorbance than did those from the experimental group ($P < 0.05$). Therefore, children with an anterior open bite exhibited less masticatory efficiency than those with a normal overbite.

Received: March 20, 2017
Revised: June 27, 2017
Accepted: July 26, 2017

Key words: anterior open bite, colorimetric capsules, malocclusion, masticatory function, spectrophotometry

GENERAL DENTISTRY SELF-INSTRUCTION CE CREDIT
Exercise No. 431, p. 60
Subject code: Occlusion (180)

An anterior open bite is defined as a negative overbite between the incisal edges of the maxillary and mandibular anterior teeth when the posterior teeth are in occlusion.[1,2] This malocclusion affects about 17% of the population aged 6-17 years, and its treatment is a challenge because the resulting correction is prone to relapse.[3,4] This dental condition has a multifactorial etiology and causes unfavorable changes in esthetics and speech.[5]

It has been reported that patients with a dolichofacial pattern and open bite have poor masticatory function, as their high mandibular angle is associated with weaker musculature.[6-9] Individuals with an open bite tend to have a greater rotation of the mandible downward and backward combined with greater vertical growth of the posterior dentoalveolar bone and tissue.[10,11] These changes reduce the cross-sectional area of the masticatory muscles, which leads to a decrease in maximum bite force.[12,13]

Mastication consists of degrading food mechanically until it is transformed into smaller particles that can be swallowed and more easily digested.[14] Masticatory efficiency can be evaluated by different methods. Among the most commonly used methods is electromyography, which monitors electrical muscle activity by means of sensors.[15] Another method of evaluation is fractional sieving, which assesses the size of particles after individuals grind test food for a determined number of masticatory cycles. Although hardened jelly cubes and condensation silicone tablets may be used, it is possible to use natural food such as bread, almonds, carrots, or peanuts. Nevertheless, such tests have provided diverse results due to the lack of uniformity in the quality and quantity of the food, which also may be partially dissolved by saliva or swallowed.[16]

Because of such difficulties, a method of using colorimetric capsules was developed with the aim to provide a test material with more stable physical properties.[16] The main advantage of the capsules is that the material is completely recovered after mastication without the risk of being swallowed or dissolved by saliva.[17] The colorimetric method involves measuring the concentration of pigment released during chewing. To improve this method, standardized synthetic capsules containing basic fuchsin granules (ME-mastig, JP Indústria Farmacêutica) were developed.[16] The content of the capsule, after being ground during mastication, is transformed into a solution. The concentration of the solution is then measured by spectrophotometric analysis; the greater the solution concentration, the greater the light absorbance, thus indicating greater masticatory efficiency.

Anterior open bite is a prevalent problem, often associated with a dolichofacial pattern, weaker masticatory muscles, and a decrease in maximum bite force.[3,6-9] The present study aimed

Fig 1. Colorimetric capsules used for the evaluation of masticatory efficiency.

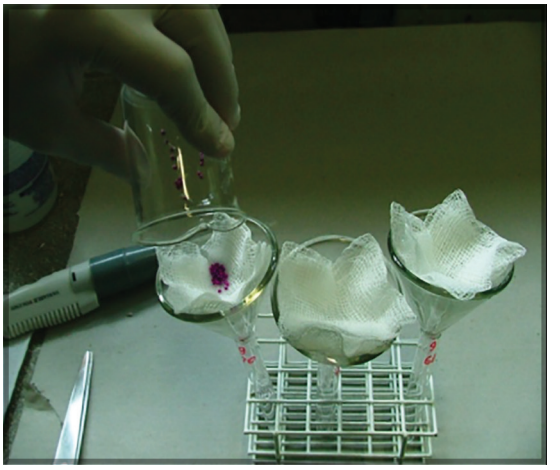


Fig 2. Filtration of the capsule content after mastication.

to assess the masticatory efficiency in children with an anterior open bite by using colorimetric capsules and comparing the results to a control group with normal overbite.

Materials and methods

Students of 2 public elementary schools in São Bernardo do Campo and Camanducaia, Brazil, formed the initial sample of this study (N = 412). The research ethics committee of the Methodist University of São Paulo approved this study (protocol No. 360474-10).

A total of 106 children, 7-11 years old, passed the inclusion criteria. In this sample, 51 presented with an anterior open bite (experimental group) and 55 with a normal overbite (control group). The inclusion criteria were a Class I molar relationship, no occlusal caries, no anterior or posterior crossbite, no previous orthodontic treatment, no dental agenesis or early loss of primary teeth, and no history of parafunctional sucking habits as well as the absence of any kind of lesion or pain in the teeth, soft tissues, or temporomandibular joint that could interfere in masticatory function. Children with an anterior open bite of at least 1 mm (overbite less than 1 mm) were selected for the experimental group, and those with a normal overbite (overbite from 1 to 3 mm) were selected for the control group.

The children were comfortably seated at their desks at their own schools while a single orthodontist performed an intraoral examination using a wooden tongue depressor under good illumination. A millimeter ruler was positioned parallel to the mandibular incisors in order to measure the overbite.

The masticatory efficiency was measured using ME-mastig colorimetric capsules. The elliptical capsules were made with a polyvinyl chloride external layer (0.2 mm thick). The capsules were 20 mm long × 9 mm wide × 5 mm thick (Fig 1). The capsules contain approximately 250 mg of fuchsin granules agglutinated by lactose, microcrystalline cellulose, starch, sucrose, hydrogenated oil, basic fuchsin, and water. Each fuchsin granule was coated with Eudragit E100 acrylic polymer (Evonik) and standardized to 1 mm in diameter.

One student at a time was asked to masticate 1 capsule for 20 seconds, timed by the examiner. The mastication was freely and habitually performed with no chewing-side preference. Subsequently, the capsules were recovered and stored in plastic containers, which were labeled with the child's identification number and corresponding group for analysis of the content.

The capsules were stored an average of 1 week before analysis. As the capsules were not ruptured by the teeth during the test, the storage time made no difference in the outcome. At the time of analysis, the content of each capsule was dissolved in 5 mL of water and stirred for 30 seconds. The resulting solution was filtered to separate the grains that had not been ground (Fig 2). The extracted solution was analyzed in a spectrophotometer (Beckman DU-640 UV-Visible, Beckman Coulter) to measure its light absorbance at a visible wavelength of 546 nm. The masticatory efficiency was assumed to be directly proportional and related to the light absorbance of the solution, since light absorbance would increase with the solution concentration.

The Shapiro-Wilk normality test was applied to evaluate the distribution of data. A nonparametric Wilcoxon test was used to compare the experimental group with the control group ($\alpha = 0.05$).

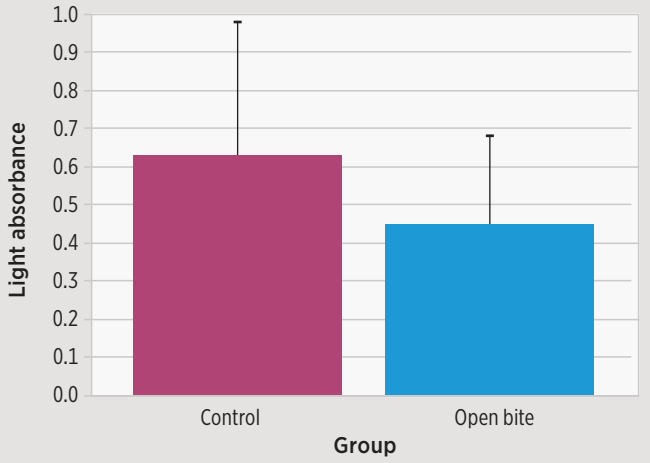
Results

The data did not present a normal distribution ($P = 0.001$). Therefore, the hypothesis of normality was rejected. The children with an anterior open bite showed statistically lower values of absorbance ($P < 0.05$) than did children in the control group (Chart). The mean (SD) measured absorbance values were 0.448 (0.241) and 0.628 (0.362) for the experimental and control groups, respectively.

Discussion

The specimens obtained from children in the anterior open bite group showed lower values of fuchsin concentration than did those from the control group. This finding indicates that children with an anterior open bite exhibit less masticatory efficiency than children with normal occlusion. The reduced masticatory efficiency found among the experimental group in this study can be attributed to the fact that less masseter and anterior temporal muscle activity occurs in individuals with

Chart. Mean absorbance of colorimetric solutions.[a]



[a]Open bite group, n = 51; control (normal overbite) group, n = 55. Error bars represent the standard deviation.

open bite, as has been demonstrated in children of a similar age to those in the present study.[7] Furthermore, it has been found that anterior open bite patients have a significantly shorter closing cycle during chewing than individuals with normal occlusion, which also directly influences masticatory efficiency.[7] Although some studies report that higher maximum bite force increases masticatory efficiency, it has been shown that masticatory efficiency is more dependent on the amount and duration of the closing cycles during chewing.[18-20] However, there is some disagreement in the literature, as it has also been reported that individuals with an anterior open bite and those with normal occlusion have similar maximum bite forces.[21,22]

The mixed dentition phase is an ideal time for clinicians to treat open bite with specific appliances designed to allow development of the anterior dentoalveolar process, eliminate sucking habits, and avoid tongue interpositioning.[21] The finding of reduced masticatory efficiency for children with anterior open bite can influence the options for orthodontic and orthopedic treatment. From a clinical point of view, individuals with poor masticatory efficiency and an anterior open bite cannot undergo orthopedic treatments using functional appliances, since these appliances depend on masticatory muscles to achieve good results. In other words, the use of a posterior bite block to control vertical development of the posterior region of the dentoalveolar process in patients with anterior open bite is directly influenced by masticatory muscle force.

Poor masticatory efficiency can generate problems other than those related to orthodontic treatment choices. Patients with an anterior open bite should also be warned about the possible systemic problems caused by inadequate mastication, since poorly ground food can lead to digestive disorders and choking.[23]

The use of colorimetric capsules in the present study was effective for evaluating masticatory efficiency in a simple manner and without the bias of natural media (eg, gum, raisins, and peanuts), which includes the risk that the natural medium will be swallowed or dissolved by saliva. In addition, filtering and obtaining the solution from the ground fuchsin grains present within the capsules does not depend on a complex apparatus; if the fuchsin grains have not been ground, they remain within the cellulose coating and will not become solutes. Moreover, the behavior of the colorimetric capsules has been shown to be similar to that of aforementioned natural foods, correctly promoting the activation of the masticatory muscles.[24]

Only children with an anterior open bite were selected for the experimental group in this study, since it is a common malocclusion that causes esthetic and functional problems.[23] Reduced muscle efficiency has been associated with an anterior open bite because, in general, patients with open bite have a more vertical facial growth pattern that presents weaker masticatory muscles.[8] Consequently, this study focused on select children with a more vertical pattern of facial growth, while a history of a parafunctional sucking habit was an exclusion criterion; children whose parents or caregivers reported thumbsucking or pacifier sucking after 3 years of age were excluded from the study. Therefore, the experimental group was formed from a skeletal open bite sample selected without the need for lateral radiographs, which would have been ethically questionable.

The children who participated in the present study were 7-11 years old. This age group was chosen not only because an anterior open bite is more common in this phase of life (approximately 17%) but also because it is a preferable time for treatment of this anomaly.[3] Treatment may involve interruption of lingual interpositioning or possible sucking habits by means of appliances, such as a fixed or removable palatal plate.[25] The absence of caries, early loss of teeth, and/or dental agenesis were among the inclusion criteria used in the study, since these factors might affect the grinding of foods (ie, masticatory efficiency). However, a greater contact surface between opposing teeth results in better biting and food grinding. In fact, the occlusal contact surface area and bite force could explain 60%-72% of variations in masticatory efficiency.[26]

Although only children were included in the present study, the observed differences in masticatory efficiency would probably be the same for adults. It has been reported that individuals with an anterior open bite have poor muscle efficiency, independent of their age; this property directly reflects on masticatory efficiency.[21] In other words, individuals with anterior open bite use more motor units of the masseter and temporal muscles on both sides of the mouth to generate the necessary force for mastication than do individuals with a normal overbite.

Another issue that may be obvious, but is related to the poor masticatory efficiency in patients with an anterior open bite, is that their anterior teeth do not act during mastication. Although the posterior teeth of these individuals are in contact with the opposing dentition, allowing food to be ground, the anterior teeth are not. As a result, these patients lose sensitivity during chewing because (1) they cannot establish a physiologic pattern, and (2) periodontal mechanoreceptors are more specialized in the region of anterior teeth, as proven by electromyography.[27,28]

Conclusion

Knowledge of a patient's masticatory force and efficiency may be decisive for defining a proper orthodontic and orthopedic treatment regimen. In this study, chewing of colorimetric capsules,

followed by analysis of light absorbance, proved to be an easy-to-use method for evaluating masticatory efficiency in children. Based on the results presented in this study, it can be concluded that children with an anterior open bite exhibit less masticatory efficiency than patients with normal occlusion.

Author information

Dr Corrêa is in private practice in Camanducaia, Brazil. Drs Maeda, Carvalho, Silva, and Torres are associate professors, Master's Program in Odontology, School of Dentistry, City University of São Paulo, Brazil. Dr Miranda is a professor, Department of Orthodontics, School of Dentistry, Methodist University of São Paulo, Brazil.

Disclaimer

The authors report no conflicts of interest pertaining to any of the products or companies discussed in this article.

References

1. Burford D, Noar JH. The causes, diagnosis and treatment of anterior open bite. *Dent Update.* 2003;30(5):235-241.
2. Galletto L, Urbaniak J, Subtelny JD. Adult anterior open bite. *Am J Orthod Dentofacial Orthop.* 1990;97(6):522-526.
3. Tausche E, Luck O, Harzer W. Prevalence of malocclusions in the early mixed dentition and orthodontic treatment need. *Eur J Orthod.* 2004;26(3):237-244.
4. Greenlee GM, Huang GJ, Chen SS, Chen J, Koepsell T, Hujoel P. Stability of treatment for anterior open-bite malocclusion: a meta-analysis. *Am J Orthod Dentofacial Orthop.* 2011;139 (2):154-169.
5. Lin LH, Huang GW, Chen CS. Etiology and treatment modalities of anterior open bite malocclusion. *J Experiment Clin Med.* 2013;5(1):1-4.
6. Tanaka E, Iwabe T, Watanabe M, Kato M, Tanne K. An adolescent case of anterior open bite with masticatory muscle dysfunction. *Angle Orthod.* 2003;73(5):608-613.
7. Piancino MG, Isola G, Merlo A, Dalessandri D, Debernardi C, Bracco P. Chewing pattern and muscular activation in open bite patients. *J Electromyograph Kinesiol.* 2012;22(2):273-279.
8. Cha BK, Kim CH, Baek SH. Skeletal sagittal and vertical facial types and electromyographic activity of the masticatory muscle. *Angle Orthod.* 2007;77(3):463-470.
9. Ingervall B, Thilander B. Relation between facial morphology and activity of the masticatory muscles. *J Oral Rehabil.* 1974;1(2):131-147.
10. Arvystas MG. Treatment of anterior skeletal open-bite deformity. *Am J Orthod.* 1977; 72(2):147-164.
11. Sassouni V, Nanda S. Analysis of dentofacial vertical proportions. *Am J Orthod.* 1964; 50(11):801-823.
12. Moller E. The chewing apparatus. An electromyographic study of the action of the muscles of mastication and its correlation to facial morphology. *Acta Physiol Scand Suppl.* 1966;280:1-229.
13. Sassouni V. A classification of skeletal facial types. *Am J Orthod.* 1969;55(2):109-123.
14. Fontijn-Tekamp FA, Slagter AP, Van Der Bilt A, et al. Biting and chewing in overdentures, full dentures, and natural dentitions. *J Dent Res.* 2000;79(7):1519-1524.
15. Ueda HM, Ishizuka Y, Miyamoto K, Morimoto N, Tanne K. Relationship between masticatory muscle activity and vertical craniofacial morphology. *Angle Orthod.* 1998;68(3):233-238.
16. Escudeiro Santos C, de Freitas O, Spadaro AC, Mestriner-Junior W. Development of a colorimetric system for evaluation of the masticatory efficiency. *Braz Dent J.* 2006;17(2):95-99.
17. Ribeiro JA, de Resende CM, Lopes AL, et al. Evaluation of complete denture quality and masticatory efficiency in denture wearers. *Int J Prosthodont.* 2012;25(6):625-630.
18. Iwase M, Ohashi M, Tachibana H, Toyoshima T, Nagumo M. Bite force, occlusal contact area and masticatory efficiency before and after orthognathic surgical correction of mandibular prognathism. *Int J Oral Maxillofac Surg.* 2006;35(12):1102-1107.
19. Julien KC, Buschang PH, Throckmorton GS, Dechow PC. Normal masticatory performance in young adults and children. *Arch Oral Biol.* 1996;41(1):69-75.
20. Rowlerson A, Raoul G, Daniel Y, et al. Fiber-type differences in masseter muscle associated with different facial morphologies. *Am J Orthod Dentofacial Orthop.* 2005;127(1):37-46.
21. Yousefzadeh F, Shcherbatyy V, King GJ, Huang GJ, Liu ZJ. Cephalometric and electromyographic study of patients of East African ethnicity with and without anterior open bite. *Am J Orthod Dentofacial Orthop.* 2010;137(2):236-246.
22. Proffit WR, Fields HW. Occlusal forces in normal- and long-face children. *J Dent Res.* 1983;62(5):571-574.
23. de Almeida MR, de Almeida RR, Conti AC, et al. Long-term stability of an anterior open-bite malocclusion treated in the mixed dentition: a case report. *J Appl Oral Sci.* 2006;14(6):470-475.
24. Cazal MS, da Silva AM, Galo R, Junior WM, da Silva MA. Comparison of dynamic electromyographic analysis of masticatory capsules with materials of different textures. *Cranio.* 2015:1-7.
25. Farsi NM, Salama FS. Sucking habits in Saudi children: prevalence, contributing factors and effects on the primary dentition. *Pediatr Dent.* 1997;19(1):28-33.
26. Lucas PW, Luke DA. Optimum mouthful for food comminution in human mastication. *Arch Oral Biol.* 1984;29(3):205-210.
27. Johnsen SE, Trulsson M. Receptive field properties of human periodontal afferents responding to loading of premolar and molar teeth. *J Neurophysiol.* 2003;89(3):1478-1487.
28. Trulsson M, Johansson RS. Encoding of tooth loads by human periodontal afferents and their role in jaw motor control. *Prog Neurobiol.* 1996;49(3):267-284.