

# Masticatory dysfunction in persons with Down's syndrome.

## Part 1: aetiology and incidence

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**SUMMARY** The functional and anatomical characteristics of Down's syndrome have direct repercussions on oral health. Orofacial dysfunction is on account of poor neuromotor control, muscle weakness, dental anomalies, dysmorphology and intercurrent illness. In particular, feeding and swallowing are impaired. The aim of this first article was to summarize the orofacial difficulties encountered by persons with Down's syndrome at all stages of life and to explain their aetiology. Indicators are proposed for the identification of masticatory problems

within this population and reduced masticatory efficiency is discussed in relation to repercussions on oral and general health and on the social integration of persons with Down's syndrome. A second article will describe techniques for preventing, treating and compensating for masticatory dysfunction in this population.

**KEYWORDS:** Down's syndrome, mastication, deglutition, adults, children

Accepted for publication 9 March 2008

### Introduction

Down's syndrome is an autosomal chromosome anomaly resulting from trisomy of all or a critical part of the twenty-first chromosome. The incidence of Down's syndrome births varies between authors and countries from 0.14 to 1.66 in 1000 live births (1–7). Currently, the incidence of Down's syndrome births is decreasing slightly in countries where antenatal screening and pregnancy termination are legal, despite increased maternal age (8, 9). However, the life expectancy of persons with Down's syndrome has increased dramatically over the last century on account of appropriate health and social care (10, 11). Thus, the prevalence of persons with Down's syndrome in the population is predicted to remain static or even to increase over the next decade.

The orofacial syndrome linked to trisomy 21 has been widely documented and the direct repercussions on oral health described (12). The characteristics of Down's syndrome include dysfunction on account of

poor neuromotor control (13), dental anomalies, orofacial dysmorphology and intercurrent illness (12). Anatomically, the facial mid-third is underdeveloped but the mandible follows normal development (14). The oral and facial musculature, in particular, the tongue and lips are hypotonic (Fig. 1). The tongue gives the impression of being abnormally large on account of muscle weakness and an anterior, low position in the mouth ('relative macroglossia') (15, 16). The temporomandibular joints are reported to be lax (12, 17).

Feeding is particularly affected although only a few studies exist describing the difficulties encountered by persons with Down's syndrome at different stages throughout life. Reduced masticatory efficiency has repercussions on oral and general health and on the social integration of persons with Down's syndrome. The aim of this article was to summarize this information and to give practical indicators for the identification of masticatory problems within this population.



**Fig. 1.** This young woman shows many of the oral signs of Down's syndrome: dental agenesis, retained deciduous teeth, periodontitis with gingival inflammation, defective oral hygiene, a hypotonic tongue held low in the mouth, a hypotonic soft palate, tonsillar inflammation, an underdeveloped maxilla and an edge to edge occlusion in retruded position but mandibular protrusion to achieve a comfortable rest position.

*The incidence of feeding problems in persons with Down's syndrome from birth to adulthood*

Feeding problems in neonates with Down's syndrome have been frequently reported with 57% of 216 babies with Down's syndrome having feeding problems in one study (18) and 68% of 22 babies in another (19). Feeding problems continue to be reported by caregivers as the child with Down's syndrome grows up (19–23). The introduction of solids has been reported to be difficult in infants with Down's syndrome (19, 24, 25) and the period of transition prolonged (22). In one study of 44 Dutch infants with Down's syndrome, the first introduction of bread was at 12 months (compared to 8 months for controls) and the first 'meal' requiring mastication was introduced at 24 months (compared to 12 months for controls) (24). Vomiting and or food refusal have been reported on the introduction of solids in infants with Down's syndrome (19), and in older

children there may be reluctance to chew, more sucking of food (26) and refusal of anything but pureed or soft food (27). Thus in a group of 56 children with Down's syndrome, 80% were reported to have feeding problems (21). Problems continue into adulthood although data concerning older subjects are rare. In one study of persons with Down's syndrome between 8 and 39 years of age, 38.4% of subjects were unable to eat all types of food while 41.9% and 24.2% had difficulty eating a whole apple or chewing meat, respectively (25). It was concluded that approximately a quarter of the adult population with Down's syndrome has major functional problems (25).

*Aetiology and description of orofacial dysfunction in persons with Down's syndrome*

*Hierarchy of normal orofacial development* The aetiology of orofacial dysfunction can only be described in relation to an understanding of normal orofacial development. The development of orofacial function follows hierarchical progress. A new-born baby must first breathe then suckle. The respiratory and suckle-swallow reflexes are thus the first to present. Babies must be able to coordinate suckling and nose breathing for successful feeding. Suckling involves thrusting the tongue forward under the nipple or teat and then moving the tongue back over the surface of the palate to send the liquid bolus into the oesophagus. As the deciduous teeth erupt, both chewing and speech functions develop. Oral sensitivity decreases with the 'oral phase' of development as the baby repeatedly brings hands, toys and finger foods up to the mouth. The gag reflex recedes behind the last erupted tooth. The tongue starts to lateralize during chewing, bringing morsels of food between the teeth. On swallowing, an oral seal is essential. The teeth come together to stabilize the mandible against the maxilla and cranial base (28, 29). Both mature swallow function and mature rotary chewing depend upon this ability to stabilize the mandible (12), as peripheral sensory stimuli from the periodontal, mucosal and muscle receptors are necessary to elicit the sensory stimulation for motor control (30). The tongue then collects the bolus in the mouth before rising up to meet the palate and chasing the food backwards with a slight negative pressure change in the mouth. Tongue thrust is therefore eliminated and by the age of four the child should have developed a mature respiratory, swallowing and

feeding pattern. For facial expression and speech to develop correctly, these oromotor stages must be acquired.

*Orofacial development in persons with Down's syndrome* Orofacial dysfunction in Down's syndrome is related to poor muscle tonicity, oromotor incoordination, mouth-breathing and underdevelopment of the facial mid third (31). These factors are dependent on both genetic predisposition (32) and on interplay between muscle function and skeletal development during growth (31).

Mouth breathing is frequently encountered in this population, as the nasal airways are narrow and children with Down's syndrome are prone to upper respiratory disease on account of immune deficiency (19, 33). Adenoids and tonsils are often chronically inflamed and swollen, resulting in congestion of the upper airways (34–36). In children who mouth-breathe, the mandible is lowered, the lips are parted and the tongue assumes an anterior position over the lower teeth to allow free passage of air (26).

Oromotor function is altered on account of marked hypotonicity of the tongue and inefficient lingual lateralization. On account of the lack of tonicity, the tongue takes up a low, anterior resting position in the mouth, thus appearing abnormally large ('relative macroglossia') (15, 16). Oral exploration is poor and oral patterns are difficult to initiate, grade and sustain (37). The jaw-closing muscles are weak and oromotor coordination is poor (13, 19, 22, 38). Certain infants with Down's syndrome will tend to avoid the oral phase of development and bring objects to the mouth less often, or later than other children. This is related to poor motor development but may also be caused by and/or aggravate the persistence of an anterior gag reflex (19, 24).

In terms of skeletal development, the discrepancy between the alveolar arches may be minimal at birth but this quickly becomes marked with growth (14), in part on account of the lack of the muscular influence of the tongue in shaping the maxilla. Reduced maxillary growth means that the primary teeth may erupt into a position without a stable resting occlusion, often with the incisors in an edge to edge relationship or with a reverse overjet (Fig. 2). Swallowing is compromised if the tongue is required to form the anterior oral seal on account of an open bite or if it is used as a 'bumper' to stabilize the mandible against the upper



**Fig. 2.** An underdeveloped maxilla and an Angle Class III relationship are already identifiable for this infant with Down's syndrome.

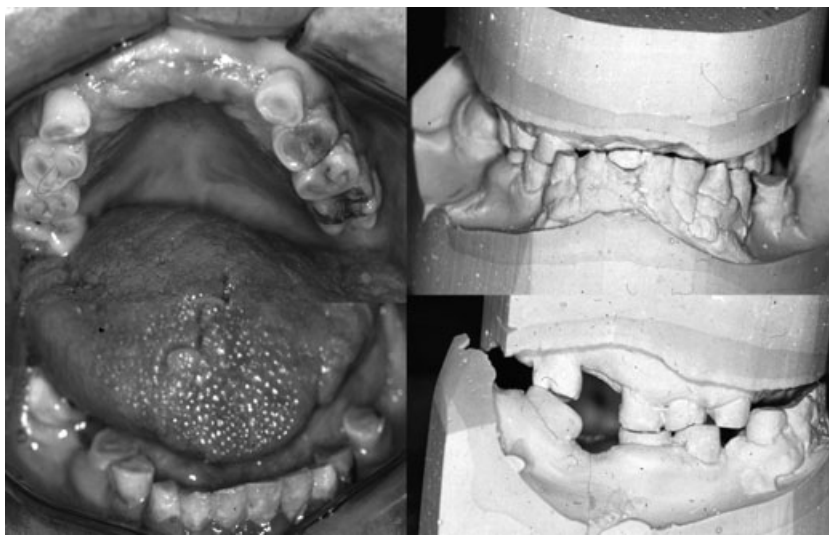
arch (39, 40) (Fig. 3). In these conditions, depression of the tongue is difficult to achieve, especially in the presence of poor intrinsic tongue tonicity. In addition, if mouth-breathing persists, disruption of the respiration-deglutition sequence leads to persistence of a primary swallow function with active displacement of the bolus by forward-backward movement of the tongue against the palate. Tongue thrusting is thus encouraged (25). The developmental consequences of this abnormal function may be a high narrow palate and an elongated tongue on account of the preferential development of longitudinal muscle fibres. In addition, the child may unconsciously try to avoid the discomfort of malocclusion by protruding the mandible, effectively trapping the maxilla behind the mandible and retarding further growth. Mandibular protrusion is facilitated in children with Down's syndrome on account of laxity of the temporomandibular joint ligaments. A clenching or grinding habit may develop as the teeth erupt in an attempt to find a position of comfort and subconsciously to eliminate occlusal interference (25). Severe tooth wear and unconscious facial movement or grimacing (orofacial dyskinesia) may result (25, 40–42) (Fig. 4).

*Feeding problems in persons with Down's syndrome* Feeding is affected by all of the above factors. At birth, suckling is affected on account of weak musculature (22) and poor oromotor coordination (19), particularly in the presence of cardiac insufficiency (18, 22, 23, 43). Oromotor problems include difficulty in suck initiation,

**Fig. 3.** The tongue may act as a 'bumper' between the arches – either covering both teeth and lower lip or just the teeth.



**Fig. 4.** Severe tooth wear on account of bruxism in an 8-year-old child with Down's syndrome.



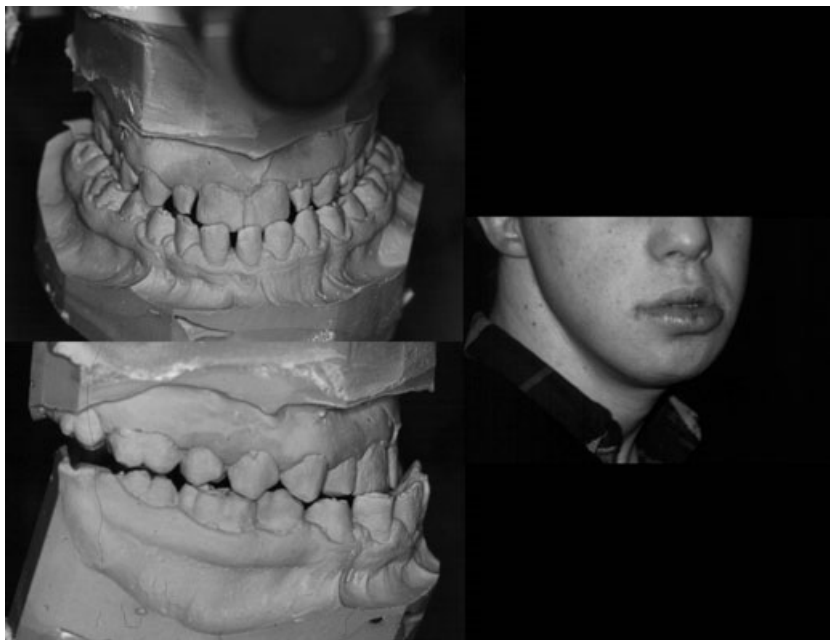
weak lip seal, decreased suction force, fatigue and poor coordination of the suckling/swallowing/breathing sequence (38).

As the child grows, mature swallowing and chewing function may be difficult to attain. Oromotor coordination may be insufficient to obtain small jaw movements or to fully control the food bolus from the lips to the pharynx (13, 19, 22, 38). Movement is arrhythmic with incoordination of the lips and mouth and excessive vertical opening (44, 45). A delay in the initiation of oral movement has been noted (19) as well as frequent pauses within the masticatory cycle. Masticatory time is increased on account of inefficiency in tongue lateralization and in collection of food into a bolus (26); (25, 46, 47). Abnormal chewing cycles may be induced by lack of an occlusal rest position and chewing efficiency negatively affected by a reduced occlusal contact area (48, 49). Video recordings of 4- to 5-year-old children with Down's syndrome eating a standardized meal showed that tongue protrusion in this population is marked (26). Food is held longer in the mouth than in control subjects, whether solid, semi-solid or puree. Food loss from the mouth, drool-

ing, food debris remaining in the mouth and potential swallowing incoordination may be problematic (37). Swallow function in children with Down's syndrome has been assessed using video fluoroscopy and silent aspiration was shown to be a problem with liquid and semi liquid food reaching the bronchi (38).

Difficulties in feeding persist into adulthood if the early acquisition of the basic functions of respiration, swallowing and mastication is impaired. Dysfunction then becomes habitual (Fig. 5). Using a simple method of evaluation involving video-recording during a standardized meal, it was shown that young adults with Down's syndrome had a significantly lower mean chewing frequency, a significantly higher number of masticatory cycles with open mouth, and refused more food types compared to controls (46, 47, 50). Chewing time was prolonged with more masticatory cycles on chewing both natural and test foods than controls (46, 47, 50). In addition, non-functional masticatory cycles and the swallowing of large, poorly chewed morsels have been noted. Such behaviour may lead to belching (corresponding to the swallowing of air), coughing (corresponding to the aspiration of food), sighing and





**Fig. 5.** A young adult with Down's syndrome showing under-developed maxilla, mandibular protrusion and the typical 'pouting' profile that results.

spillage of food during meals and in copious drinking between mouthfuls (25, 40). Long-term mandibular protrusion combined with hyperlaxity of the temporomandibular joint ligaments (17) may also result in chronic luxation of the joint in later years (40, 42).

#### *Repercussions of feeding problems*

The consequences of feeding problems are multiple and the link between certain systemic problems and masticatory inefficiency deserves to be further investigated. Digestive symptoms have been found to be related to masticatory disturbances and may reduce with oral rehabilitation (51). Gastrointestinal defects have been found to be twenty times more common in the population with Down's syndrome than in control subjects (52, 53). The problems of digestion and of intestinal and oesophageal obstruction that are encountered in this population may be in part related to the tendency to swallow morsels of food whole (40, 51, 54). Decreased masticatory capacity might also be linked to the observation that 40% of the persons with Down's syndrome over 8 years of age suffer from constipation (25). Moreover, it has been suggested that digestive malabsorption and altered metabolism in Down's syndrome may aggravate immunological deficiency and cause chronic malnutrition, increasing the risk of early ageing (55–58). Nutritional deficiency may also appear if the choice of food is reduced on account of masticatory

dysfunction. A person with Down's syndrome who has difficulty eating raw fruit or vegetables may leave themselves open to deficiencies in certain vitamins or minerals, affecting general health and immunity (20, 54, 58–60). Persons with masticatory dysfunction will tend to eat softer food types, often high in carbohydrate and cholesterol content (54). Masticatory activity also contributes to the feeling of satiety and when food is swallowed whole or is only partially chewed, the notion of satiety on eating may be reduced (54, 61). It has thus been suggested that persons with Down's syndrome and reduced chewing efficiency might require a higher number of food intakes to attain the same degree of satiation and/or pleasure from a meal, leading to a greater quantity of food ingested. In consequence, there may be a link between reduced chewing efficiency and a tendency to obesity (62, 63).

Another significant finding is that poor eating skills have been shown to be important predictors of mortality in persons with Down's syndrome. Respiratory infection is the commonest cause of death for this population and is greatly raised compared with controls (9, 64–67). A potential link with aspiration cannot be ignored (65, 68). Aspiration is usually silent but may be associated with coughing or choking. Both children and adults with Down's syndrome and a history of recurrent respiratory infection should ideally undergo a video fluoroscopic examination to assess the presence of aspiration and so that feeding guidelines can be given (69–72).

In addition, mouth-breathing and lingual hypotonicity may lead to serious obstructive sleep apnoea. The prevalence of obstructive sleep apnoea has been reported at over 50% for the population with Down's syndrome and this has repercussions for cognitive function and awareness (36, 45, 73–77).

In the dental domain, it is likely that the severe, early onset periodontitis encountered in persons with Down's syndrome may be aggravated by a lack of periodontal stimulation by masticatory action and stable tooth contacts. Although immunological defects and poor oral hygiene are the primary causal factors of periodontitis in Down's syndrome (78–80), the periodontal structures need stimulation for health to be maintained (81).

Eating problems can also cause major difficulties in social integration and represent an additional disadvantage for the patient with Down's syndrome and his/her family. A child that refuses solids cannot eat at the school canteen and cannot participate in the social activities associated with food (birthday parties, school fêtes, etc.). Adults may find themselves further stigmatized by socially unacceptable eating habits, such as

tongue protrusion (82) and eating with the mouth open and food spillage, and these problems may reduce integration and social contact. It is also of note that certain scales of cognitive disability include orofacial dyskinesia or uncontrolled facial movements, as indicators of degree of severity of disability (83). Facial movements are associated with marked malocclusion, particularly mandibular protrusion and bruxism and should not be cause for stigmatization of the person with Down's syndrome (40). Severe facial dysmorphism and tongue protrusion are also sources of aesthetic stigma and may be correlated with reduced social integration, independent of cognitive ability (40, 84).

*Indicators of orofacial dysfunction in persons with Down's syndrome*

Unfortunately feeding difficulties, although evoked, are generally underestimated by the child's caregivers (19, 25). It may be that persons with Down's syndrome do not express discomfort or difficulty in eating, in the same way that they do not always express pain sensation in a recognizable fashion (85, 86). Problems

**Table 1.** Indicators of masticatory dysfunction in persons with Down's syndrome

Parental/caregiver report	Observation while eating and drinking (e.g. a glass of water, a pot of fruit puree and a quarter raw apple may be provided in the surgery)	Clinical examination
Mouth open at rest	Placement of the tongue under the cup	Mouth open at rest
Tongue protrusion	on drinking	Mouth-breathing
Drooling	Poor lingual lateralization	Tongue protrusion
Snoring	Poor bolus lateralization	Tongue used to stabilize mandible constantly
Recurrent upper and lower respiratory tract infections	Swallowing without chewing	or on swallowing
Tooth grinding	Coughing, choking or belching	Reduced tongue sensitivity
Pouting profile	Food loss from the mouth	Reduced tongue tonicity and mobility
Uncontrolled facial movements	Drooling on drinking	Low, anterior tongue position
Slow introduction of finger foods	Chewing cycles with open mouth	Enlarged tonsils
Delayed use of feeding utensils	Tongue protrusion on swallowing and chewing	Delayed dental eruption
Refusal of solids, mixed puree-solid textures or hard foods		Tooth wear related to bruxism
Refusal to chew		Maxillary endognathism
Refusal to swallow		Reduced facial mid-third
Spitting out of food		Orofacial dyskinesia
Retention of food in the mouth		Mandibular protrusion
Slow at eating		Lack of stable occlusal rest position
Frequent coughing, choking or belching during meals		Angular cheilosis (inefficient saliva control)
Food spillage from the mouth		Food debris retained in mouth

with eating are thus easily assumed to be behavioural or just 'normal' for this population and therefore the demand for treatment is not made. Furthermore, health professionals are often untrained in the diagnosis and treatment of functional problems, and the barrier of intellectual disability may be perceived to be too great to ensure co-operation (84). This is demonstrated by the fact that children with Down's syndrome are reported to receive significantly less dental treatment than their siblings, despite having a greater normative need and consulting more regularly (87). It is extremely important for a dentist to recognize feeding problems in infants and children at an age when simple intervention is still possible. It is also important to recognize the repercussions that feeding problems may present for both children and adults. To aid both parents and professionals in the identification of oral dysfunction in persons with Down's syndrome a list of common indicators is given in Table 1. The authors believe that all persons with Down's syndrome presenting to dental services should be screened for these simple indicators of underlying functional problems, so that these may be addressed where possible.

## Conclusion

Orofacial dysfunction in Down's syndrome is related to both genetic predisposition and to the interplay between muscle function and skeletal development during growth. The recognition of functional problems is of paramount importance to avoid further medical and social disadvantage for this population. A series of indicators are given that may aid the dentist to diagnose problems as they arise. In a second article, techniques for the prevention and compensation of orofacial dysfunction will be described.

## References

- Hahn J, Shaw G. Trends in Down syndrome prevalence in California, 1983–1988. *Paediatr Perinat Epidemiol.* 1993;7:450–460.
- Stoll C, Alembik Y, Dott B, Roth MP. Study of Down syndrome in 238942 consecutive births. *Ann Genet.* 1998;41:44–51.
- Dzurova D, Pikhart H. Down syndrome, paternal age and education: comparison of California and the Czech Republic. *BMC Public Health.* 2005;5:69.
- Jou HJ, Kuo YS, Hsu JJ, Shyu MK, Hsieh TT, Hsieh FJ. The evolving national birth prevalence of Down syndrome in Taiwan. A study on the impact of second trimester maternal serum screening. *Prenat Diagn.* 2005;25:665–670.
- Canfield MA, Honein MA, Yuskiv N, Xing J, Mai CT, Collins JS *et al.* National estimates and race/ethnic-specific variation of selected birth defects in the United States, 1999–2001. *Birth Defects Res A Clin Mol Teratol.* 2006;76:747–756.
- Reimand T, Ounap K, Zordania R, Ilus T, Uibo O, Sitska M *et al.* Descriptive epidemiology of Down's syndrome in Estonia. *Paediatr Perinat Epidemiol.* 2006;20:512–519.
- Coory MD, Roselli T, Carroll HJ. Antenatal care implications of population-based trends in Down syndrome birth rates by rurality and antenatal care provider, Queensland, 1990–2004. *Med J Aust.* 2007;186:230–234.
- Huether CA. Projection of Down's syndrome births in the United States 1979–2000, and the potential effects of prenatal diagnosis. *Am J Public Health.* 1983;73:1186–1189.
- Bittles AH, Bower C, Hussain R, Glasson EJ. The four ages of Down syndrome. *Eur J Public Health.* 2006;17:221–225.
- Janicki MP, Dalton AJ, Henderson CM, Davidson PW. Mortality and morbidity among older adults with intellectual disability: health services considerations. *Disabil Rehabil.* 1999;21:284–294.
- Fryers T. Survival in Down syndrome. *J Ment Defic Res.* 1986;30:101–110.
- Hennequin M, Faulks D, Veyrune JL, Bourdiol P. Significance of oral health in persons with Down syndrome: a literature review. *Dev Med Child Neurol.* 1999;41:275–283.
- Frith U, Frith CD. Specific motor disabilities in Down syndrome. *J Child Psychol Psychiatry.* 1974;15:293–301.
- Fischer-Brandies H. Cephalometric comparison between children with and without Down's syndrome. *Eur J Orthod.* 1988;10:255–263.
- Hoyer H, Limbrock GJ. Orofacial regulation therapy in children with Down syndrome using the methods and appliances of Castillo-Morales. *J Dent Child.* 1990;57:442–444.
- Dodd B, Leahy J. Down's syndrome and tongue size. *Med J Aust.* 1984;140:748.
- Carlstedt K, Dahlhöf G, Nilsson B, Modeer T. Effect of palatal plate therapy in children with Down syndrome. A one-year study. *Acta Odontol Scand.* 1996;54:122–125.
- Spahis J, Wilson G. Down syndrome: perinatal complications and counselling experiences in 216 patients. *Am J Med Genet.* 1999;89:96–99.
- Spender Q, Stein A, Dennis J, Reilly S, Percy E, Cave D. An exploration of feeding difficulties in children with Down syndrome. *Dev Med Child Neurol.* 1996;38:681–694.
- Calvert S, Vivian V, Calvert G. Dietary adequacy, feeding practices and eating behavior of children with Down's syndrome. *J Am Diet Assoc.* 1976;69:152–156.
- Pipes P, Holm V. Feeding children with Down syndrome. *J Am Diet Assoc.* 1980;77:277–282.
- Cullen S, Cronk C, Puschel S, Schnell R, Reed R. Social development and feeding milestones of young Down syndrome children. *Am J Ment Defic.* 1981;85:410–415.
- Aumonier ME, Cunningham CC. Breast feeding in infants with Down syndrome. *Child Care Health Dev.* 1983;9:247–255.

24. Hopman E, Csizmadia C, Bastiani W, Engels Q, De Graaf E, Le Cessie S *et al.* Eating habits of young children with Down syndrome in The Netherlands: adequate nutrition intakes but delayed introduction of solid food. *J Am Diet Assoc.* 1998;98:790–794.
25. Hennequin M, Allison PJ, Veyrune JL. Prevalence of oral health problems in a group of individuals with Down syndrome in France. *Dev Med Child Neurol.* 2000a;42:691–698.
26. Gisel E, Lange L, Niman C. Tongue movements in 4- and 5-year old Down's syndrome children during eating: a comparison with normal children. *Am J Occup Ther.* 1984a;38:660–665.
27. Field D, Garland M, Williams K. Correlates of specific childhood feeding problems. *J Paediatr Child Health.* 2003;39:299–304.
28. Bakke M, Michler L, Moller E. Occlusal control of mandibular elevator muscles. *Scand J Dent Res.* 1992;100:284–291.
29. Woda A, Fontanelle A. Physiologie de l'appareil manducateur. In: Chateau M, ed. *Bases fondamentales de l'orthopédie dento-faciale.* 2nd ed. Paris, France: Cahiers de Prothèse; 1993:167–229.
30. Hirano K, Hirano S, Hayakawa I. The role of oral sensorimotor function in masticatory ability. *J Oral Rehabil.* 2004;31:199–205.
31. Shapiro BL, Gorlin RJ, Redman RS, Bruhl HH. The palate and Down syndrome. *N Engl J Med.* 1967;276:1460–1463.
32. Delabar JM, Theophile D, Rahmani Z, Chettouh Z, Blouin JL, Prieur M *et al.* Molecular mapping of twenty-four features of Down syndrome on chromosome 21. *Eur J Hum Genet.* 1993;1:114–124.
33. Cuadrado E, Barrera MJ. Immune dysfunction in Down's syndrome: primary immune deficiency or early senescence of the immune system? *Clin Immunol Immunopathol.* 1996;78:209–214.
34. Mason R, Proffitt WW. The tongue thrust controversy: background and recommendations. *J Speech Hear Disord.* 1974;39:115–132.
35. Talmant J, Rouvre M, Thibault JL, Turpin P. Contribution à l'étude des rapports de la ventilation avec la morphogénèse cranio-faciale. *Déductions thérapeutiques concernant l'ODF.* *Orthod Fr.* 1982;53:7–181.
36. Kavanagh KT, Kahane JC, Kordan B. Risks and benefits of adenotonsillectomy for children with Down syndrome. *Am J Ment Defic.* 1986;91:22–29.
37. Palmer JB, Rudin NJ, Lara G, Crompton AW. Coordination of mastication and swallowing. *Dysphagia.* 1992;7:187–200.
38. Frazier J, Friedman B. Swallow function in children with Down syndrome: a retrospective study. *Dev Med Child Neurol.* 1996;38:695–703.
39. Gisel E, Lange L, Niman C. Chewing cycles in 4- and 5-year old Down's syndrome children: a comparison of eating efficacy with normals. *Am J Occup Ther.* 1984b;38:666–670.
40. Faulks D, Veyrune JL, Hennequin M. Consequences of oral rehabilitation on dyskinesia in adults with Down's syndrome. A clinical report. *J Oral Rehabil.* 2002;29:209–218.
41. Bell EJ, Kaidonis J, Townsend GC. Tooth wear in children with Down syndrome. *Aust Dent J.* 2002;47:30–35.
42. Mazille MN, Veyrune JL, Hennequin M. Compenser les grandes dysmorphies: le concept de la stabilisation de la mandibule. *Real Clin.* 2005;16:63–74.
43. Lewis E, Kritzing A. Parental experiences of feeding problems in their infants with Down syndrome. *Downs Syndr Res Pract.* 2004;9:45–52.
44. Limbrock GJ, Hoyer H, Scheying H. Drooling, chewing and swallowing dysfunctions in children with cerebral palsy: treatment according to Castillo-Morales. *J Dent Child.* 1990; 57:445–451.
45. Light J. Sensory/motor therapy for the treatment of oral dyskinesia. A new approach to the treatment of oromofunctional disorders with the use of tactile cueing handheld exercisers. *Int J Orofacial Myology.* 1995;21:23–28.
46. Allison PJ, Peyron MA, Faye M, Hennequin M. Video evaluation for mastication validation in persons with Down syndrome. *Dysphagia.* 2004;19:95–99.
47. Hennequin M, Allison PJ, Veyrune JL, Faye M, Peyron MA. Clinical evaluation of mastication: validation of video versus electromyography. *Clin Nutr.* 2005a;24:314–320.
48. Luke DA, Lucas PW. Chewing efficiency in relation to occlusal and other variations in the natural human dentition. *Br Dent J.* 1985;159:401–403.
49. English JD, Buschang PH, Throckmorton GS. Does malocclusion affect masticatory performance? *Angle Orthod.* 2002;72: 21–27.
50. Hennequin M, Allison P, Faulks D, Orliaguet T, Feine J. Chewing indicators between adults with Down syndrome and controls. *J Dent Res.* 2005b;84:1057–1061.
51. Mercier P, Poitras P. Gastrointestinal symptoms and masticatory dysfunction. *J Gastroenterol Hepatol.* 1992;7:61–65.
52. Torfs C, Christianson R. Anomalies in Down syndrome individuals in a large population-based registry. *Am J Med Genet.* 1998;77:431–438.
53. Wallace RA. Clinical audit of gastrointestinal conditions occurring among adults with Down syndrome. *J Intellect Dev Disabil.* 2007;32:45–50.
54. N'Gom PI, Woda A. Influence of impaired mastication on nutrition. *J Prosthet Dent.* 2002;87:667–673.
55. Abalan F, Jouan A, Weerts MT, Solles C, Brus J, Sauneron MF. A study of digestive absorption in four cases of Down's syndrome. Down's syndrome, malnutrition, malabsorption and Alzheimer's disease. *Med Hypotheses.* 1990;31:35–38.
56. Bhaskaram P. Immunobiology of mild micronutrient deficiencies. *Br J Nutr.* 2001;85:S75–S80.
57. Gonzalez-Gross M, Marcos A, Pietrzik K. Nutrition and cognitive impairment in the elderly. *Br J Nutr.* 2001;86:313–321.
58. Thiel RJ, Fowkes SW. Down syndrome and epilepsy: a nutritional connection? *Med Hypotheses.* 2004;62:35–44.
59. Unonu J, Johnson A. Feeding patterns, food energy, nutrient intakes, and anthropometric measurements of selected black preschool children with Down syndrome. *J Am Diet Assoc.* 1992;92:856–858.
60. Erickson KL, Medina EA, Hubbard NE. Micronutrients and innate immunity. *J Infect Dis.* 2000;182(suppl):S5–S10.



61. Wagner M, Hewitt MI. Oral satiety in the obese and non-obese. *J Am Diet Assoc.* 1975;67:344–346.
62. Murakami K, Sasaki S, Takahashi Y, Uenishi K, Yamasaki M, Hayabuchi H *et al.* Hardness (difficulty of chewing) of the habitual diet in relation to body mass index and waist circumference in free-living Japanese women aged 18–22 years. *Am J Clin Nutr.* 2007;86:206–213.
63. Veyrune JL, Chaussain-Miller C, Czernichow S, Ciangura C, Nicolas E, Hennequin M. Impact of morbid obesity on chewing ability. *Obes Surg.* 2008; (Epub ahead of print).
64. Chaney RH, Eyman RK, Miller CR. The relationship of congenital heart disease and respiratory infection mortality in patients with Down syndrome. *J Ment Defic Res.* 1985;29:23–27.
65. Eyman RK, Call TL, White JF. Life expectancy of persons with Down syndrome. *Am J Ment Retard.* 1991;6:603–612.
66. Chaney RH, Eyman RK. Patterns in mortality over 60 years among persons with mental retardation in a residential facility. *Ment Retard.* 2000;38:289–293.
67. Day SM, Strauss DJ, Shavelle RM, Reynolds RJ. Mortality and causes of death in persons with Down syndrome in California. *Dev Med Child Neurol.* 2005;47:171–176.
68. Reddihough DS, Baikié G, Walstab JE. Cerebral palsy in Victoria, Australia: mortality and causes of death. *J Paediatr Child Health.* 2001;37:183–186.
69. Griggs CA, Jones PM, Lee RE. Videofluoroscopic investigation of feeding disorders of children with multiple handicap. *Dev Med Child Neurol.* 1989;31:303–308.
70. Fung CW, Khong PL, To R, Goh W, Wong V. Videofluoroscopic study of swallowing in children with neurodevelopmental disorders. *Pediatr Int.* 2004;46:26–30.
71. DeMatteo C, Matovich D, Hjartarson A. Comparison of clinical and videofluoroscopic evaluation of children with feeding and swallowing difficulties. *Dev Med Child Neurol.* 2005;47:149–157.
72. Rogers B, Arvedson J. Assessment of infant oral sensorimotor and swallowing function. *Ment Retard Dev Disabil Res Rev.* 2005;11:74–82.
73. Hultcrantz E, Svanholm H. Down syndrome and sleep apnea – a therapeutic challenge. *Int J Pediatr Otorhinolaryngol.* 1991;21:263–268.
74. Marcus CL, Keens TG, Bautista DB, von Pechmann WS, Ward SL. Obstructive sleep apnoea in children with Down syndrome. *Pediatrics* 1991;88:132–139.
75. Venail F, Gardiner Q, Mondain M. ENT and speech disorders in children with Down's syndrome: an overview of pathophysiology, clinical features, treatments, and current management. *Clin Pediatr.* 2004;43:783–791.
76. Shott SR, Amin R, Chini B, Heubi C, Hotze S, Akers R. Obstructive sleep apnoea. Should all children with Down syndrome be tested? *Arch Otolaryngol Head Neck Surg.* 2006;132:432–436.
77. Ng DK, Hui HN, Chan CH, Kwok KL, Chow PY, Cheung JM *et al.* Obstructive sleep apnoea in children with Down syndrome. *Singapore Med J.* 2006;47:774–779.
78. Shaw L, Saxby MS. Periodontal destruction in Down's syndrome and in juvenile periodontitis. How close a similarity? *J Periodontol.* 1986;57:709–715.
79. Agholme MB, Dahllof G, Modeer T. Changes of periodontal status in patients with Down syndrome during a 7-year period. *Eur J Oral Sci.* 1999;107:82–88.
80. Morgan J. Why is periodontal disease more prevalent and more severe in people with Down syndrome? *Spec Care Dentist.* 2007;27:196–201.
81. Planas P. Rehabilitation neuro-occlusale: RNO. *Orthod Fr.* 1971;42:333–347.
82. Purdy AH, Deitz JC, Harris SR. Efficacy of two treatment approaches to reduce tongue protrusion of children with Down syndrome. *Dev Med Child Neurol.* 1987;29:469–476.
83. Dinan TG, Golden T. Orofacial dyskinesia in Down's syndrome. *Br J Psychiatry.* 1990;157:131–132.
84. Allison PJ, Faulks D, Hennequin M. Dentist-related barriers to treatment in a group of individuals with Down syndrome. *J Disabil Oral Health.* 2001;2:18–26.
85. Hennequin M, Morin C, Feine JS. Pain expression and stimulus localisation in individuals with Down's syndrome. *Lancet.* 2000b;2:1882–1887.
86. Hennequin M, Faulks D, Allison PJ. Parents' ability to perceive pain experienced by their child with Down syndrome. *J Orofacial Pain.* 2003;17:347–353.
87. Allison PJ, Hennequin M, Faulks D. Dental care access among individuals with Down syndrome in France. *Spec Care Dentist.* 2000;20:28–34.

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