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# REVIEW ARTICLE

# BITE FORCE, MASTICATION AND OCCLUSION IN DOWN SYNDROME: A LITERATURE REVIEW

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**ABSTRACT**

The concept of bilateral simultaneous occlusion and ideal distribution of the occlusal force are important component of the optimum occlusal condition. The Down syndrome (DS) children have many orofacial dysfunction and developmental deficiency which affect the harmony between the stomatognathic systems among these children. This paper reviews the clinical features of DS, occlusion development, mastication, bite force, factors affecting them, and methods of occlusal analysis.



## INTRODUCTION

Down syndrome (DS) is one of the most common genetic abnormalities resulting from individuals carrying an additional chromosome 21(de Moraes *et al*., 2007). Patients with DS have many clinical and oral manifestations. In DS patients, motoric growth is usually impaired which may cause speech problems and weakness of orofacial musculature (Ferrario *et al*., 2005). Due to chromosomal anomaly, the underlying pathology directly affects the oral structures and functional manifestation, which may lead to compromised swallowing, suckling, mastication, and speech (Daumer-Haas *et al*., 1994). Among the many problems associated with DS, diminished masticatory capability due to anomaly of growth patterns has substantial effect on oral and overall general health, and on the social integration of the individuals with this syndrome (Faulks *et al*., 2008). Traditionally, masticatory ability of children with DS has been evaluated using electromyography. More recently, studies have demonstrated that videos of mastication and observation of masticatory cycles could also be used to perceive mastication in these individuals.

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Digital occlusal analysis of bite is a novel concept and has become popular among prosthodontics to appraise bite pattern in individuals.More details will be given in this literature review.

### Clinical Features of Down Syndrome

DS patients have a peculiar combination of facial characteristics, irrespective of race or ethnicity.The apparent features associated with this anomaly are decreased muscle tone, a flat face, slanting eyes, asymmetrical shaped ears, and ability to extend joints beyond the usual (Aldossary, 2017). The base of the skull, the frontal bone and the paranasal sinus are substantially small, result into decreased sized sellaturcica. Vertical hypoplasia of the structures of the skull makes the cranial base flattened (Macho *et al*., 2014). Structurally, the facial mid-third is not fully developed, however, the mandible follows normal development. The oral and facial muscles, specifically the tongue and lips, are hypotonic in nature(Faulks *et al*., 2008). Due to the flattened bridge of the nose and bones of the midface, the appearance of a prognathic mandible giving rise to Class III dental and skeletal relationships(Bauer *et al*., 2012). The head is disproportionately wide because of craniofacial and oral features. Usually a small nose related to a low nasal bridge, small maxilla, ogival palate and tong with fissures and papillary hypertrophy are present (Aldossary, 2017). Among clinical signs, muscular hypotonia is predominant in patients with DS. Hypotonia or low muscle tone is distinctly evident in face expressions and oral impairment. Hypotonia in children with DS may affect motoric growth, speech impediment, and raise difficulties to move against gravitation, thus leads to inefficient motoric growth (Macho *et al*., 2014). Furthermore, this hypotonicity is associated with ligament looseness, clearly obvious all over the body. This prompts hyper-flexible of the joints(Macho *et al*., 2014). The atlanto-axial joint, responsible for stimulating communication between the first and the second vertebrae, is also unstable in about 20% of individuals. The dentist may need to be very careful while handling the neck of the individual with DS (Macho *et al*., 2014). Hypotonia can affect small and the large muscles groups of the mouth, face and throat alike. These muscles help in feeding, swallowing and speech development. Hypotonia patients such as infants and children with DS are at more prone to gastroesophageal reflux disease (GERD) and constipation. The cause of GERD is posture. Since the DS patients spend less time in the sitting position due to low muscle tone, esophageal sphincter may be reduced, thus allowing reflux(Holmes, 2014; Faulks *et al*., 2008). Another common problem associated with this population is bruxism. The problem commence at very young age, and often lasts throughout life(Macho *et al*., 2014). Chronic anxiety, not fully developed nervous system, malocclusion and TMJ dysfunction, hyper flexibility and laxity of the supporting ligaments are all associated with bruxism in DS population. Bruxism causes erosion of the pits and fissures of the occlusal surfaces, enabling self-cleaning with tongue and facilitating oral hygiene(Macho *et al*., 2014).

Macroglossia is a term used for people withunusual large tongue. DS patients have different features in skeletal and muscular systems. The skeletal system is usually characterized by absent or deficient bone growth with a smaller oral cavity. Whereas, the muscular system is characterized by extra muscles in the facial region, a large muscular tongue, and hypotonicity(López-Pérez *et al*., 2008). It is not clear whether the macroglossia in DS patients is because of the anatomically enlarged or functionally enlarged tongue as a result of an abnormal forward posture(Macho *et al*., 2014). The lack of space for the tongue is because of narrow maxilla, which may force DS patient to protrude it. Protrusion of the tongue may also give impression of macroglossia in these patients(Macho *et al.*, 2014).

**Development of Occlusion in Down Syndrome**

The insufficient bone development associated with muscle hypotonicity may become more heightened with age and lead to a greater incidence of malocclusions in comparison to the general population. Dentition and oral cavity are morphological deviated causing vertical and transverse alterations, such as anterior open bite and anterior/posterior cross-bite (Oliveira *et al*., 2010). Initially, the disparity between the alveolar arches may be insignificant at birth but this swiftly becomes noticeable and obvious with growth. The primary teeth may not erupt into a position without a stable resting occlusion due to reduced maxillary growth. It is often the incisors which are in an edge to edge relationship or with a reverse overjet(Faulks *et al*., 2008). Although the mandible measurements are not remarkably changed from normal subjects, however, due to lingual pressure a transverse expansion may occur(de Moura *et al*., 2005). Malocclusion has a profound consequences in terms of exerting a substantial negative effect on the quality of life. The problems related to the performance of daily activities, such as speech, swallowing, and chewing are also affected. Above all, discrimination based on physical appearance, and its psychosocial consequences because of the unacceptable dental esthetics(Hennequin *et al*., 1999).

**Mastication**

Proper orofacial function results from complex integrated activities of the central nervous system and the neuromuscular system. The stomatognathic system is comprised of neuromuscular system, temporomandibular joint, teeth and other soft tissues of the oral cavity including the tongue.Stomatognathic system is responsible for a number of vital actions such as breathing, mastication and swallowing. Proper stomatognathic system warrants proper social interaction in terms of speech, emotional communication, facial expression and appearance (Khosravanifard *et al.*, 2012). Mastication is one of the essential functions of the stomatognathic system. Mastication helps in mechanically broken down food to mix with saliva so to create a bolus that can be easily swallowed and digested. The rhythmic opening and closing of the jaw breaks down the food in small digestible pieces (Ohira *et al.*, 2012). Mastication materialize due to coordinative movements between muscles and nerves. It is a learning process that takes place in the central nervous system (Gavião *et al.*, 2007; Ohira *et al.*, 2012). Due to inadequate development of mastication in DS patients, proper function and normal development of the maxilla and mandible is severely affected. The coordinative movements between muscles and nerves is well established by 12 months of age but continues to be refined during early development (Gavião *et al*., 2007). Human mastication process is a sophisticated interaction of several muscle groups. It is believed that more than twenty muscles are responsible for the motion profile, helping in clenching and grinding motions(Conserva *et al.*, 2008). In many simulations, the complex muscular interaction is simplified due to the major three muscles involved in mastication, i.e. the temporal, the masseter, and the pterygoid muscles (Conserva *et al.*, 2008). The temporalis muscle helps in elevating the mandible and also retract it back with the action of its posterior fibers. The pterygoid muscles assist to depress the mandible (externus), and to lift the mandible (internus). Both these muscle groups are utilized to generate lateral movements of the mandible. However, much of the masticatory force is generated by the masseter, which can raise and protrude the mandible. The amalgamated actions of these three muscles generate the motion profiles that are accountable for masticatory function. The knowledge of this concept has guided several investigators to emphasis on the masticatory muscle role as a measure of the patient's capability to chew(Conserva *et al.*, 2008).

Clenching materializes due to the vertical motion of the jaw. Clenching involves shearing and compression of the food with the incisors and the molars, respectively. Grinding is a merging action of both compression and shearing with the molars. Due to clenching and grinding, any food that adhere to the teeth may also come in tension when the occlusal surfaces separate from each other(Ohira *et al.*, 2012). Interactive actions of morphological and functional growth of the craniofacial complex are involved in the development of a matured mastication process (Yonemitsu *et al*., 2007). Besides, the coordinative movements between muscles and nerves that takes place in the central nervous system develop a learning process (Ohira *et al*., 2012), masticatory performance is governed by several factors, e.g. loss and/or fixing of posterior teeth, bite force, malocclusion, body size, facial symmetry, occlusal relationship, and other motor tasks (Tripathi *et al*., 2014). Orofacial abnormality and oral health of the mentally disabled patients, particularly children agonizing from DS or cerebral palsy are usually masked by symptoms of the main disease (Pilinová *et al*., 2006). DS patients have poor muscle tonicity and oromotor incoordination due to which open mouth, protruding tongue, difficulties while chewing/swallowing and speaking, drooling, and mouth breathing are common symptoms (Macho *et al*., 2014). All these factors rely on both genetic vulnerability, and on interaction between muscle function and skeletal development during growth (Faulks *et al*., 2008).

## Improving Masticatory Function in Down Syndrome

It is imperative to improve the oral health of DS population and for that health programs must integrate intervention approaches to control oral hygiene, and make fluoride and sealants application to avert and treat malocclusions at the earliest(Macho *et al.*, 2014). Treatments for DS patients may include prevention, interception or correction of the abnormalities. It is possible to take prior actions during the different phases of growth; in early ages without any teeth, during mixed dentition phase, in the definite phase of teething, and up to the adult age. Orthodontic, orthopedic and surgical interventions are possible. With some interventions, masticatory function may be improved. These interventions may include reduction of the size of the tongue, variation from its position and increase of the space for the tongue and increase of the maxilla. Although the maxilla may be increased, we may need special techniques that first fabricate the bone growth or we amend the position of the muscles for orientation of the bone growth (Ohira *et al*., 2012). In order to improve suction, drooling, chewing ability, and to help in developing language and speech skills, the researcher Castillo-Morales(Limbrock *et al.*, 1993), developed an acrylic plate with many strategically placed accessories, stimulating different areas of the tongue, cheeks and lips, arousing reflexes that changed positions of different muscle groups. With this plate, secondary conditions such as pseudo-prognathism, dental disease, malocclusion, open mouth and pseudo-macroglossia can also be prevented. The advantages of this acrylic plate are manifold. It gives better respiratory characteristics, reduction in respiratory infections, reduced disturbance during sleep, and reduction in bruxism. The lingual re-establishment of plate not only permits a better pronunciation of words but also helps in aesthetics. The plate could be used for extended period of the time compared to other stimulation methods (Limbrock *et al.*, 1993). The problem with the initial plate introduced by Castillo-Morales was fear of swallowing and child choking. The plate couldn't be used for a prolonged period of time without any adult supervision. The subsequent modified pacifier-shaped device provides greater safety, prolonged usage time, even at night, less apprehension by caregivers, and better acceptance by society (Pilinová *et al*., 2006). Fixed appliances are ideal for modifying the orofacial problems, if the child is cooperative. Complications such as anterior or posterior cross-bites must be corrected at early growing age. The Fixed appliances have superior outcomes because of a greater control of their use, which is not possible with removable appliances since they might be used or not. With a fixed appliance, expansion of maxilla is possible at early age to gain more space for the tongue. For individuals with DS, it is usually preferable to expand the maxilla from the apical base, in order to obtain an orthopedic effect (de Moura *et al*., 2005). It is essential to have an appropriate fixed orthodontic appliance for individuals with DS. With the help of an orthodontic appliances, unwanted dental movements can be avoided and orofacial growth may be guided in right direction. A fixed orthodontic appliance is essential throughout life for DS individuals because of hypotonia and other harmful habits for the stability of the correction (de Moura *et al.*, 2005).

## Factors Affecting Masticatory Function

The investigators have correlated age with the bite force. Studies have shown that bite force value significantly increase with age (Owais *et al*., 2013). On the other hand, correlation between gender and bite force seems to be controversial. Some studies suggest no difference in the measurement, while others suggest that the bite force in males is higher than in females (Singh *et al.*, 2012). The available literature suggest that hormonal difference among male and female could be related to this disparity in muscular potential. Another reason could be the size of a masseter muscle among males, which is larger in in diameter and cross-sectional area compared to female counterparts(Koc *et al*., 2010). Moreover, the jaw dimensions, which are usually larger in male than females, could also be the reason. Regardless of this disparity, the correlation between gender and bite force is not evident up to the age of eighteen (Koc *et al.*, 2010). Many studies have also correlated bite force with height and weight of an individual. A positive correlation could be found between a body mass index (BMI) and a bite force (Owais *et al*., 2013).

Studies have also shown variation in maximum bite force with craniofacial morphology. In general, there are three basic facial types: short (brachyfacial), average (mesofacial), and long (dolichofacial). Studies have also demonstrated that people with short face usually have the greatest bite force followed by the people with average face. Whereas, the long face documents the weaker value (Abu Alhaija *et al*., 2010). Farella *et al*.,(2003) demonstrated that the short face people have thicker and stronger masseter muscle, hence they have greater bite force. However, this relationship cannot be established correlation among the children. Malocclusion is considered as one of pivotal factor on evaluating the bite force in adults. It has been reported in many studies that the bite force is directly dependent on occlusal relationship. Bite force is weaker in adults with open bite. However, this relationship in children is difficult to establish (Gavião *et al*., 2007). There are some studies that have shown significant relationship between dental status and bite force(Koc *et al.*, 2010). Loss of a tooth in molar region has more negative effect on the bite force than the loss of a tooth in anterior region. The first and second molars contribute more than half of the total bite force(Shinogaya *et al.*, 2000). However, the bite force is subjective to the number of teeth which are occlusally in contacts(Hatch *et al*., 2001).

## Human Bite Force

Human bite force is defined as maximum capacity of the mandibular elevator muscles to clench the lower teeth against the upper teeth under favorable conditions (Calderon *et al.*, 2006).It is an indicator of the functional state of the masticatory system (van der Bilt *et al.*, 2008). Researchers have proposed that the bite force depends on muscle volume, jaw muscle activity, and the harmonization of the various chewing muscles (van der Bilt *et al*., 2006). It is widely accepted that better masticatory systems would result in stronger bite forces. Besides, bite force can also be used as a diagnostic tool in case of stomatognathic system disturbance (Koc *et al.*, 2010). Since early, researchers have been interested in evaluating bite force. Borelli; an Italian scientist in 1681, was the first to quantify intraoral forces. He performed an experimental study using a self-designed gnathodynamometer. A cord over the mandibular molar teeth with different weights were attached to evaluate the bite force. In 1893, an investigator named Black also invented a new type of gnathodynamometer. At present, investigators are interested in studying bite force with a variety of techniques and devices, ranging from conventional mechanical devices to more advanced electronic transducers (Koc *et al.*, 2010).

Several authors have proposed a wide range of techniques for evaluating the bite forces. Measuring the bite force is a valuable indicator for masticatory performance among normal individuals, and among the individuals with disturbances in the stomatognathic system. Researchers have also used bite force to compute the effect of prosthetic devices fixed in the mouth of individuals (Koc *et al*., 2010). Furthermore, the bite force can also be used to measure the load on implants(Rismanchian *et al*., 2009), as well as to investigate cases of bruxism among adults (Calderon *et al.*, 2006). In addition, the researchers have tried to determine the effectiveness of the replacement dentures among children by measuring the bite force with dentures (Serra *et al*., 2007).

**Occlusion**

Understanding the occlusion dynamics is pivotal and vital for clinical practice in dentistry. The clinicians of all disciplines of dentistry require to understand the articulation of the teeth and prosthesis with respect to simultaneous contacts, biting time and biting force. However, calculating dental occlusal forces is a science, often requiring complex and subjective decisions (Rues *et al.*, 2008). For proper functioning, occlusal contacts or relationship need to be in harmony with the stomatognathic system. The concept of occlusion is not just restricted to morphological contact between the teeth of the two jaws. It is actually a dynamic morpho-functional interactions among all the teeth, periodontium, neuromuscular system, temporomandibular joint and the craniofacial bones (Rues *et al*., 2008). For an ideal occlusion, all posterior teeth should contact concurrently and the occlusal force should be evenly distributed. For an ideal occlusion, there should be contact between the opposing teeth with an inter-occlusal distance of less than 50 microns. Whereas, near occlusal contacts follow when the distance between the opposing teeth is in the range of 50-350 microns(Owens *et al.*, 2002).

**Occlusal Analysis**

Unevenly shared load or pressure on occluding teeth may result into occlusal trauma. Occlusal trauma may initiate due to unusual occlusal contacts, and excessive occlusal height of a restoration by which stress concentrate on an area (Eliyas and Martin, 2013). Studies have demonstrated that dental and periodontal tissues often undergo from occlusal trauma (Ishigaki *et al*., 2006). Premature or hindering occlusal points such as contacts deviating on the non-working side often lead to destructive forces during mastication, and could even result in parafunctional habit such as clenching. The consequences may lead to sore neck and trauma of facial muscles and nerves within the TMJ, as has been seen in various temporomandibular disorders (TMDs) (Baba *et al.*, 1996). On the contrary, a low occlusal height may result in conditions such as disuse osseous atrophy and/or unstable centric occlusion (Afrashtehfar *et al.*, 2012). Furthermore, disturbances in the occlusal relationship of the teeth may lead to crowding of teeth due to mesial drift of the teeth (Acar *et al*., 2002).

**Methods of Occlusal Analysis**

To identify the occlusal contact points, numerous materials have been employed. The conventional methods for analyzing occlusal relationship include articulating paper, waxes, silicone impressions and photocclusion. Nevertheless, none of them have demonstrated ideal characteristics. Regarding articulating paper marks, there is no scientific evidence available that justify the relationship between the depth of the color and the mark. The surface area, amount of force, and the contact timing sequence are not inter related. For these reasons, this was considered as inadequate occlusion analysis method (Qadeer *et al.*, 2012). Also, the use of occlusal waxes and silicone pastes do not demonstrate accurate reproduction of occlusal contacts. The validity and reliability of these methods is greatly susceptible to error because of the width, strength and elasticity of the materials, and the oral cavity environment. The validity of occlusal analysis using these methods greatly relies on the clinician's interpretation (Millstein and Maya, 2001). On the contrary, a digital occlusal analyzer system known as T-Scan which was introduced in 1987, has been claimed to be highly reliable occlusal registration system. With this digital analyzer quantitative measurement of occlusal forces and occlusal contact timing are possible. The good thing about this digital occlusal analyzer is that when repeated measurements in the same subjects were performed, there was no significant difference between the results, proving sufficient validity and reproducibility of this method (Koos *et al*., 2010).

**T-Scan System**

Digital occlusal analysis of bite is a novel concept and has become popular among prosthodontics to appraise bite pattern in individuals. Digital occlusal analysis estimates the bite pattern by computing distribution of force, time of occlusion, the center and trajectory of force. In 1987, Professor William L. Maness in partnership with M.I.T. institute developed The T-Scan 8 occlusal analysis system, manufactured by (Tekscan, Inc., Boston, MA, USA). The system is consists of a hand-held device having a USB port connected with a Windows-based PC. The hand-held appliance comprises of a U-shaped pressure monitoring sensors, fits into the patient's mouth between the occluding teeth. The pressure-monitoring sensor with 1122 compressible sensitive receptor points is usually a grid-based, mylar-encased recording sensor that is 0.1mm thick. Due to the biting pressure on the sensor, the electrical resistance of the conductive sensor is reduced. The applied force squeezes the particles together; and a recorded quantitative force data is available. Apart from recording the applied force, this device can also record the series of occlusal contacts, i.e., from the first point of contact to maximum intercuspation position (Kerstein and Grundset, 2001). The relative occlusal force is scanned in time increments of 0.01 sec to simultaneously analyze the occlusal contacts, teeth with excessive forces, and occlusal contact timing sequences. These applied forces are represented as bars and columns on three-dimensional window in different ranges, i.e. from blue, which is the optimum force, to ascending order: green, yellow, orange, red and pink as the force increases. The output display the percentage force per tooth and a two-dimensional arch view that can be divided into quadrants.The T-Scan electronic digital occlusal analysis system has been used extensively showing evidence of its efficacy and reliability (Koos *et al.*, 2010).

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