Bite Force and Diet:

How Bite Force Impacts Quality of Life

Helping patients understand the limits of their diet through bite force

Prepared by **Chris Sitaras**, B.Sc., M. Eng.; **Jocelyn Vignaola**, D.D.; **Philippe Bertrand**, DMD

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Background

The masticatory system is an integral part of a healthy diet in humans, as a dysfunctional masticatory system can limit the dietary choices available to a person.[1] One crucial component of this system is a person's state of dentition, which is directly related to the amount of force that can be applied to ingested foods.[1,2] In order to properly ingest food, the dentition must tear, shred, and crush the food morsels, as well as help integrate an adequate amount of saliva into the bolus.[3] Pain and/or missing teeth can limit the number of mastication cycles applied to the bolus and ultimately increase the food particle size.[3] As the food particle size has been shown to be inversely proportional to the nutrition derived from the food,[4–7] the state of dentition and thus bite force is directly linked to nutrient availability.

> "In order to properly ingest food, the dentition must tear, shred, and crush the food morsels, as well as help integrate an adequate amount of saliva into the bolus"

Clinicians currently rely on a qualitative evaluation of a patient's bite force in order to provide a restoration treatment plan. However, this subjective measure does not adequately characterize the magnitude of force outputted by a patient, since bite force can vary widely within a population[8] even in patients with complete dentition.[8–10] A clear objective understanding of this value will assist the dental clinician in designing a personalized solution that adequately considers the dietary limitations of the patient's occlusal loads.

How Much Force is Needed?

The important question with regard to bite force is: How much is enough? This question can be linked to the person's dietary choice; however, a moderate amount is recommended for bone homeostasis.

Within an individual's dietary choices, a clear requirement for macro- and micro-nutrient rich foods is needed to maintain a healthy diet.[11] Although sustenance can be acquired by liquid nutrition (requiring no bite force),[12] a desire to eat a slice of cake, a steak, or a carrot may give a more subjectively pleasurable experience during a meal and maintain the oral health.[13] When diets lack fresh fruits and vegetables, or similar foods requiring significant force to fragment, there may be a limited amount of nutrients available. This limit of bioavailable nutrients could lead to an increase in gastrointestinal problems.[14] Additionally, the loss of dentition, significant oral disease, and pain can further complicate the oral health of patients, which can cause a cascade effect of restricted dietary choices that ultimately leads to sarcopenia, and frailty.[15] This is seen in the elderly who experience significant negative affect on their quality of life due to limited bite force from a dysfunctional or compromised masticatory system, xerostomia, pain, and malnutrition (poor diet).[16–22]

Although a healthy diet helps to maintain nutrient homeostasis,[23] a significant factor in bone homeostasis is occlusal force. The stress from the forces applied to each antagonist teeth is transferred to the jaw bones by way of micro-

Table 1. Estimation of the maximum bite force required to break specific foods into smaller, more digestible components.

FOODS	SINGLE TOOTH BITE FORCE (N)[a]	FULL-ARCH BITE FORCE (N)[b]
SOFT BREAD	2±1 (Premolar), 5±1 (Molars)	25
CHEESE	17±4 (Molar)	90
COOKIES	9±2 (Incisor), 13±2 (Molar)	95
CRACKERS	20±6 (Molar)	100
CHEWING GUM(SOFT)	23±6 (Molar)	120
PEANUT	18±4 (Incisor)	180
WALNUT	36±6 (MTS-Molar)	190
IMITATION CRAB	17±12 (Incisor), 16±10 (Molars)	210
CHEWING GUM (HARD)	75±3 (Molar)	390
RAW CARROT	39±28 (Incisor), 50±26 (Molar)	450
BEEF JERKY	95±51 (Premolar)	715
COOKED STEAK	78±17 (MTS-Incisor)	780

a. Single tooth bite forces (Molar, Premolar, Incisor), or Universal Testing Machines forces (MTS-Molar, MTS-Incisor).
b. Total Force based from load partitioning discussed below: percentage of total force per anterior tooth and posterior tooth[9,33–37]. Values are estimates of whole arch bite force as measured by the Innobyte™.

strain, the minute three-dimensional deformation of the living material. This micro-strain from masticatory forces acts on the alveolar processes of the mandible and maxilla, where it promotes and maintains healthy bone structure around the dentition.[14,24–28] The partial or full loss of dentition, where the masticatory forces are no longer transferred, has been shown to contribute to residual ridge resorption due to the lack of any amount of micro-strain from the missing teeth.[29–32] Thus, a moderate amount of bite force is recommended to assure a healthy masticatory system as well as a healthy diet.

Table 1 illustrates the estimated bite force required to break sections from a selection of 12 foods, as determined by empirical single tooth bite forces or Universal Testing machines simulating human teeth.[9,33–37] The force required to break off sections of each food item range from 2 N to 95 N and depend on which tooth antagonist is doing the sectioning, and the cross-sectional area of the morsel.[33,34,38–46] The reason for variability between the required force is dominated by the complex fracture mode implemented by each set of antagonist teeth; the Incisors and Canines impart a scissor-like fracture mode in food, while the Molars and Premolars impart a wedge-like fracture mode.[47]Also, within the fracture mode of each food there is a complex interplay of cohesive forces, toughness, fiber direction and length, and hardness, which further varies required fractioning forces.[33,39,40] Despite the complex material science of food, one certainty is that some measure of force is required to disrupt the integrity of each food morsel for subsequent consumption. Although each food morsel requires successive chewing cycles prior to ingesting, the peak bite forces listed in the **Table 1** are the forces that were found to break apart the largest sections of these particles. Other structures of the masticatory system can be used to apply force to a morsel of food, but solely the dentition can apply the sharp crushing or severing forces needed to break apart most food.[47]

To estimate the whole arch bite force necessary to achieve these individual tooth antagonist forces seen in **Table 1**, a repartition of the forces must be understood. Researchers have found that each antagonist tooth accounts for a portion of the whole arch bite force.[9,33–37] The distribution of forces along the full arch has been shown to be between 67-80% for posterior teeth, with the remainder being at the anterior teeth.[9,35] Specifically, the approximate average portion of force per anterior tooth antagonist would be 10% and 18% per posterior antagonist teeth. As such, the total arch bite force can be estimated by this repartition of force. The third column of **Table 1** shows the mean full arch bite force required to break apart each food item using this estimated repartition of force.

The table can be used as a reference for the approximate range of bite forces required to break a particular food item into smaller, more digestible fragments. Falling within these bite force ranges indicates that a person can most likely masticate the specific foods to fragments necessary for ingestion and subsequent digestion, in order to obtain significant nutrition.[3] Failing to be within these bite force ranges means that a person may not be masticating the specific foods to a size that allows for proper digestion,[4,6,48] or alternatively avoids difficult to break down foods altogether.[15] This data is corroborated by previous studies on chewing efficiency in patients with a range of bite forces and states of dentition.[49–52] As the bite force increases through improvements to state of dentition and toning of the masticatory muscles, the patient is better able to fractionate a larger range of foods into digestible particles, leading to potentially more bioavailable nutrients and a positive affect on their quality of life.[1,15,16,52–55]

What Does My Bite Force Say About Me?

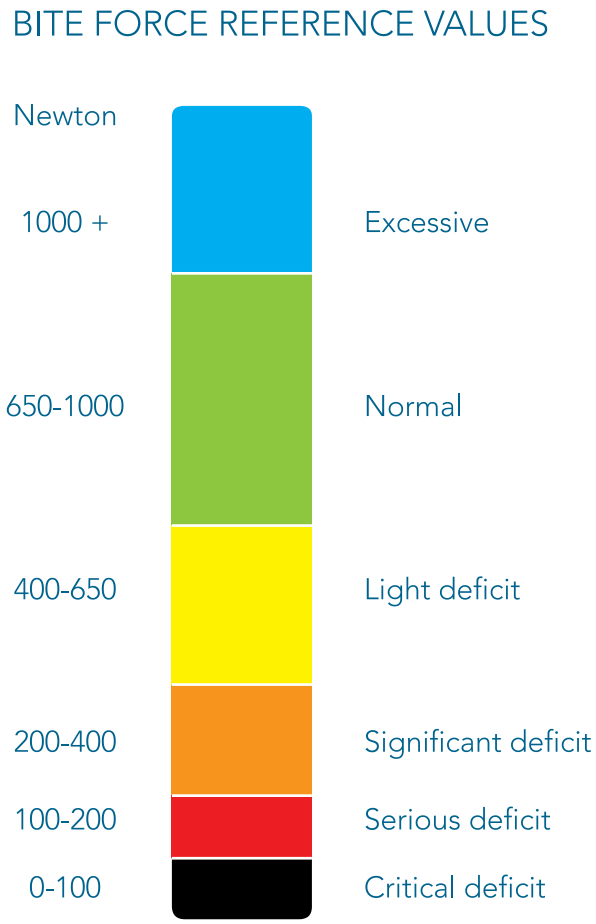

Figure 1. Bite force reference chart. The ranges of forces and what that means for oral health.

Figure 1 shows the ranges of bite forces in the general public as previously presented,[2,9,10,56] and as determined with the Innobyte™. The normal or average range of bite force in adults with their full dentition is between 650 and 1000N. Patients presenting with forces in the range of Normal to Excessive (1000N+), are not expected to have dietary restrictions related to their bite force. Patients presenting with a Light Deficit (400 – 650N), begin to experience a difficulty or inability to chew certain foods, but can maintain a healthy and balanced diet through conscious dietary choices.[2] When patients present with a Significant Deficit (200 – 400N), there is a noted inability to chew several types of foods that are needed to maintain a healthy diet (fruits and vegetables, meats, nuts, etc.),[56] and health problems may arise that are related to diet. Patients presenting with a Serious Deficit (100 – 200N) or Critical Deficit (0 – 100N) have limited chewing ability and can only chew foods with low strength.[56] Frequent health problems arise that are related to diets deficient or limited in macro- and micro-nutrients, leading to negative effect on their quality of life. These deficiencies in bite forces may be due to missing teeth, decreased musculature, mobile teeth, and/or pain. A restorative treatment for these issues may allow the patient to increase their bite force, thus allowing them to maintain a healthy diet and positively affect their quality of life.

Personalized Bite Force Assessment

The Innobyte™ is the first quantitative total bite force measurement device on the market measuring the magnitude in Newtons.[c] With the Innobyte's patented technology, the clinician is able to measure the full-arch loading using an easy-to-read, easy-to-interpret, digital read-out of the calibrated force in Newtons (1 Newton is equal to 0.225-pound force) with a range from 0 to 3,000 Newtons. The system is calibrated with high precision standards that results in less than 5% variation from industry calibrated measurement of force. This translates to a maximum variation of 20 Newtons or 5-pound force, or less than the force required to tap a key on a keyboard, which is quite impressive when the average human bite is well over 650 Newtons of force.[9] Due to the soft nature of the medical-grade silicone of the bite surface, patients do not risk pain or damage to teeth or gingiva, allowing them to apply their maximal load.[57] The intermolar separation of the Innobyte's Mouthpiece is specially designed to minimize elevator muscle bias, where fewer muscle fibers are recruited during large jaw separations,[44,58] as well as simulating the clinically relevant average food morsel size. The Innobyte's Mouthpiece is a one-size-fits-most flexible unit. Additionally, the Mouthpiece has four carefully designed guides for precise placement that allows the clinician to obtain reproducible results every time.[d] Differences in the measured bite force can be confidently associated with a successful treatment plan. The Innobyte is streamlined in design and operation, with an intuitive user interface and no complex accessories or components. It has never been so easy to quantitatively assess the maximum voluntary bite force of a patient.

c. Health Canada Medical Device License 10155. United States FDA listing number D447457.
d. 1000 bite force measurements per Mouthpiece (>60 N per cycle)

5524 rue St-Patrick, suite 540
Montréal, QC
H4E 14B, Canada
info@kubeinnovation.com

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1-800-511-8792
www.kubeinnovation.com

Conclusions

Bite force is an important part of a healthy digestive system, where a deficiency can be implicated in limited bioavailability of nutrients, amongst other complications, which can negatively affect a patient's quality of life. In order to properly masticate foods during normal digestion, one must apply an adequate force to break the item into easily digestible particles. The force required varies depending on the antagonist teeth performing the breaking, however the tougher the food item, the higher the force required to break. Foods such as tough meats and raw vegetables require an elevated value of force to break them into easily digestible particle sizes allowing the gut to extract their nutritional content, thus maintaining a nutritional homeostasis. In addition, the micro-strain provided by mastication of foods maintains healthy supporting bone of the dentition through bone homeostasis. Therefore, to maintain optimum nutrition and healthy dentition, an adequate level of bite force is essential, and understanding this force allows clinicians to provide a treatment plan that can improve the overall quality of life of their patients. The Innobyte™ can quickly and accurately show the patient how their bite force may be limiting their dietary choices and how providing the adequate treatment plan may positively affect their quality of life.

Innobyte™

> “To maintain optimum nutrition and healthy dentition, an adequate level of bite force is essential”

5524 rue St-Patrick, suite 540
Montréal, QC
H4E 14B, Canada
info@kubeinnovation.com

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5524 rue St-Patrick, suite 540
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