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Review Article

Bite Force: A Contemporary Narrative Review

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ABSTRACT

Bite force is one of the indicators of the masticatory apparatus's functioning status, as determined by the activation of the jaw's elevator muscles as a result of craniomandibular biomechanics.
Bite force is used to investigate the activity related to the dentition, occlusal factor, dentures and implant therapy, temporomandibular diseases, orthognathic surgery, and neuromuscular modifications. Masticatory functions are determined by muscular forces and the total number of functioning teeth. The goal of calculating maximal biting force is to assess the force generated by the mandible's elevator muscles. The biting force is generated by the action of muscles in the maxilla and mandible, which is then disseminated to the thing being chewed via the teeth. The forces which result essentially while during chewing activity performance on the jaw bones in varying dimensions which depends on activity of musculature that cause an unambiguous action.

Keywords: Bite force, muscles, teeth, jaws, factors

INTRODUCTION

Bite force is one of the indices of the masticatory complex's functional condition, as determined by the activation of the jaw's elevator muscles as a result of craniomandibular biomechanics. Estimation of a certain biting force level is widely used in dental practise, as is understanding the mechanics of mastication for interpreting the useful effects of prosthetic equipment, and contributing reference codes for biomechanics of prosthetic devices research. Aside from that, biting force may be important in determining the severity of stomatognathic system disturbance.[1]

The biting force analysis may be done immediately with the help of a suitable transducer placed between a pair of teeth. This basic approach to force evaluation appears to be a good way to determine the submaximal force. Indirect measurement of the biting force using other physiologic variables known to be functionally relevant to force production is a viable alternative. The cutaneous projection of the muscular belly can take up electromyographic activity of the mandibular surface elevator musculature. The data obtained as a consequence of these considerations offers a concept of biting force.[1]

Various studies found a linear relationship between electromyographic activity potentials and direct biting force measurements, particularly at the submaximal level. The explicit measures of biting force are influenced by a number of factors. As a result, multiple researches discovered a wide range of maximal biting force levels. The huge disparity in biting force estimates is due to a variety of factors relating to the participants' anatomical and physiologic characteristics. Away from these variables, the mechanical parameters of the biting force recording device impact the validity and definiteness of the bite force levels. Significant variables that impact bite force measures have been discussed in this review, including age, sex, craniofacial morphology, periodontal apparatus, temporomandibular disorders and discomfort, and dentition status. Mechanical elements consisting of various recording devices, placement of recording devices in maxillary or mandibular arch, unilateral or bilateral measurements with the aid of acrylic splints, and wide opening of mouth were emphasised in addition to a review of previous studies related to implants and bite force.[2]

Physiologic and morphologic variables affecting bite force values

Age Factor

The routine aging course may lead to the depletion of oro-facial musculature force. Certainly, the jaw closing force elevates with age factors and growth factors, halts reasonably consistent from 20 to 50 years of age, and then depletes. In children between the ages of 6 and 18, having permanent dentition, the bite force has been positively correlated with age factor. It has been reported that bite force decreases significantly with age, especially in women and bite force will downturn with age after 45 years in males and after 25 years in females. The influence of age on maximum bites force, magnitudes of pressure, and occlusal contact areas in young and elderly Japanese subjects have been evaluated. The occlusal contact areas and maximum bite force were observed to be much greater in the elder group than in the younger group. The other observation was the minimal average occlusal pressure values in the elder group. However, no diversity has been revealed in combined occlusal force and occlusal force sharing among the younger and elder age groups because of the wider contact areas of the teeth. Albeit the interrelationship among age and bite force implies to be compelling in these researches, it can be pretended that the influence of age on bite force is comparatively minimal.[3,4]

Relation to Gender

Higher levels of maximum bite force were noted in males compared to females. The higher muscular potential of the males is credited to the anatomic divergences. The masseter muscles in males constitute type 2 fibers with increased diameter and maximal sectional area when compared in females. Hormonal diversity in females and males can grant to the content of the muscle fibers. Apart from this, the interaction of maximum bite force and gender is not revealed till 18 years of age. It is credible that maximum bite force surge all over the growth and development period without gender distinction. Amid the post-pubertal phase, maximum bite force surges at a increased levels in males in comparison to females and thus can be related to gender. Some researchers documented greater bite force levels in males and attributed this outcome by their greater dental size. As the larger dental size confers maximum periodontal ligament areas, it can contribute a maximum bite force. Whereas, other authors did not find compelling divergence in bite force among females and males. It is implied that it can be because of the minimal number of subjects incorporated in their research and to the analysis of functional forces arising during sleeping period. Even some researchers have observed a non-significant gender influence; most studies have affirmed the diversity in the values of bite force between females and male gender.[5]

Cranio-facial anatomy

Variation is noted in maximum bite force with skeletal measures of the craniofacial morphology which includes the ratio of anterior and posterior facial height, inclination of the mandible and mandibular angle. It has been explained that bite force reflects the geometry of lever system of mandible. In cases where the ramus of the mandible is more vertical and acute gonial angle, elevator muscles of the mandible show added mechanical benefits. A negative relation between bite force and mandibular inclination was observed in a study. This result was proposed to be consistent with the other similar researches in which the long-faced type of the craniofacial morphology has been correlated with limited values of the bite force. The same authors also implied a positive association among bite force and muscle thicknesses and between masseter-temporal muscle thickness and facial morphology. It has been also observed that that masseter muscles are thicker in short- faced people when compared to normal or long-faced people and that short-faced subjects may exhibit stronger bite force.[6,7]

Periodontal status

Loading forces during masticatory phase which were generated by the masticatory muscles were controlled by the mechanoreceptors located in the periodontal ligament. So, decreased support from periodontal tissue can reduce the threshold level of the mechanoreceptors activity. This state may lead to alterations in the biting. It has been mentioned that subjects observed with loss of attachment may show altered sensory function which may result in decreased regulation of biting force. It has been stated that the biting capacities of the persons with healthy periodontium were notably higher than those of person with chronic periodontal diseases. This was in accordance with those of another study in which a positive association between compromised periodontal support and reduced biting force has been revealed. In a study a positive correlation has been observed between biting ability and periodontal status; however, the authors observed minimal influence of periodontal conditions on biting ability. In contrast to these observations, it has been observed that compromised periodontal tissue support did not restrict the bite force with maximal strength in subjects having natural dentition. Apart from this, it has been also noted that reduced amount of periodontal neural receptors may be sufficient for proper feedback action restricting bite force and chewing forces. The disparity between these researches may be because of the variation of measurement areas and devices used for recording the bite forces.[8]

Some authors estimated the bite force in dentition restored with cross-arch bilateral end abutment bridges and observed that the degree of the chewing force was significantly associated to the areas of the periodontal ligament aiding the bridge abutments. These observations may be elucidated by the actuality that the teeth were splinted as a whole in a comparatively rigid assembly. An investigation of the relation among local biting force and local residual periodontal ligament area of a single unsplinted teeth may head to altered results.[9,10]

Disorders of the temporomandibular joint

The masticatory system is a perplexing system devised to achieve fundamental actions, such as mastication, deglutition and vocal functions. An in coordination in this apparatus that extends outside limits of the individual’s physiological limitations, heads to brawling the masticatory apparatus. This process may further lead to various functional disorders involving the system, known as temporomandibular disorder (TMD). Temporomandibular disorder is a unified term comprising various clinical complications involving the muscles of mastication, the temporomandibular joint and orofacial system emerging from a debilitation of the stomatognathic system. Pain and discomfort in the joint area and the musculature is the prime is the complaint among the patients which will results and exaggerates while masticatory movements. Patients having temporomandibular disorders were noted with non-symmetric and restricted jaw movements and sounds in the joint area. Numerous aetiological factors are known to cause TMD. Bite force influence the efficiency of the musculature and the masticatory function; therefore evaluation of bite force may be a beneficial additional mode of perceiving masticatory activity in subjects with orofacial disorders. So, many practitioners have concentrated on bite force to actuate if or not is there any effect of bite force among patients with temporomandibular disorders. A significantly lower bite force for the patients with TMDs patients when compared to healthy control subjects was observed in various studies. The authors considered that existence of pain in masticatory muscles along with coexistence of inflammation of temporomandibular joint can lead to limitation of maximum bite force. It has been stated that TMJ pain was the common etiologic factor for the limiting bite force. In confirmation with these observations, a significant correlation between reduced bite force and tenderness of musculature, and pain in TMJ was revealed.[11]In disagreement with these findings, few authors found no significant difference in maximal bite force results between healthy control subjects and patients with TMDs. These alterations in observations may arise from the acerbity of the TMDs in subjects or contrasting recording techniques.[12]

Bruxism is a significant causative factor leading to TMDs, usually represented by clenching and grinding the teeth. Few authors compared the bite strength in bruxists using a gnathodynamometer 12 mm of height in the molar region and observed that bite strength in some bruxists was nearly six times higher when compared to that of non-bruxists. However, some other authors have estimated bite force value using a load transducer with 14 mm distance in molar region in bruxists and non-bruxists. They noted that both the subjects had no alterations in maximal bite force values. In both these researches, although the height and properties of transducers were same, the intensity of bruxism and diagnostic procedures may be contrasting.[13]

Dentition

Dentition composed of restorations, fixed and removal dentures, number and position of existing teeth are important determining factors of bite force. A positive correlation among number and position of the teeth at both maximal and submaximal bite force has been observed. The number of existing dentition and their contact seems to be a significant criterion influencing the maximum bite force. The larger bite force in the posterior aspect of the dental arch may also be reliant on the heightened occlusal contact number of premolar and molar teeth loaded while biting action. For instance, occlusal contact areas double when maximum bite force level increased from 30% to 100%. It has been suggested that the number of occlusal contacts is a substantial determinant of muscular activity and bite force than the number of teeth.[14]Few authors evaluated measurements of occlusal bite force in population with and without restorations in incisors and molars. The subjects with restorations revealed significantly minimal bite force in the incisor region when compared to molars. As per the data observed in that research, the authors proposed that it may be conceivably due to the adaptive alteration lead by the reestorations.[15] Some investigators compared maximum bite force levels in persons with removable partial denture, complete dentures and fixed partial denture and those having full natural dentition. The subjects having natural dentition revealed maximum bite force levels, the biting forces observed were 80, 35 and 11% for fixed partial dentures, removable partial denture and complete denture subjects respectively, when characterized as a percentage of the natural dentition group.[16] Bite force in subjects having, partial dentures, and natural dentition and it was observed that found the maximum bite force was exhibited by the subjects having natural dentition. Decreased bite force was observed in the areas of negative alveolar process and a significant correlation between the height of the alveolar process and the bite force.[17]Some researchers have compared bite force levels in subjects having implant-supported and root-retained over dentures, complete dentures and those having existing natural dentition. At the maximum bite force level, persons with dental implant-supported over denture revealed forces much higher when compared with the subjects having complete dentures and root-retained over dentures. Nonetheless, maximum bite forces exerted by the implant group was still minimal than those of the subjects with natural dentition.[18]

Recording devices and techniques

The interest regarding on the intraoral force has been widely discussed in the literature since very long time from past. In the associated studies, a wide variety of techniques and equipments for the estimation of bite forces has been mentioned. These devices differ from a simple spring to a wide variety of complex electronic appliances. Borelli in 1681 carried out the first experimental study defining the intraoral forces was performed by those who designed a gnathodynamometer. He attached various weights to a cable that spanned over the open mandible's molar teeth, and with the closing of the jaw, up to 200 kg could be elevated. Black conducted the first scientific analysis of forces in 1893. He arrived at his conclusions by inventing a new sort of gnathodynamometer. Various scientists went on to do more research and develop the lever-spring, manometer-spring and lever, and micrometered appliances. In today's practise, sensitive electronic equipment that are both legitimate and exact are routinely employed for routine load assessments. The action of all latest equipments is based on the electrical resistance action of the strain-gages and the most of them are capable of recording force levels in 50- 800 N range with an accuracy level of 10 N and 80% precision.[19]

Gnathodynamometers are been routinely used for measuring the bite force for a long period and some researchers use strain ages mounted dynamometer for bite force recordings. A digital dynamometer is a latest version which uses electronic technology and is composed of the digital body and a bite fork. Its increased precision load cell and electronic circuit for indicating the force will provide accurate values. The maximal bite force in the temporomandibular disorder subjects employing a digital dynamometer with a capacity of 100 kg and a 14.6 mm of height was evaluated, and note that the mean maximal bite force in control group has been found as 338 N which was parallel to that of other researches.[20]Newly, a deformation-sensitive piezoelectric film has been used as a force sensing recording system. Deformation of piezoelectric film induces an electrical signal, which differs with the force induced to the film. An amplifier is designed to amplify the piezoelectrical signal because the generated electrical signal is a very small electrical current. This device is used in a study in which the current was brought to a digital recorder, and the level could be recorded either directly or with the aid of a graphic recorder. The detector was directly commented to an amplifier and then to a threshold-detection circuit in which the output signal was delivered to a computer system. [21]A novel miniature bite force recorder was later introduced; it was a semiconductor in the form of a silicon beam that apportioned as a sensory unit. A load on the sensor induces corresponding amendments in the two resistors and advances to electric modifications in the circuit. Its calibration test has revealed an acceptable reliability with the bite forces in the range of 10 to 1000 N.47 A conductive polymer pressure-sensing resistors with a diameter of 12 mm and the thickness of 0.25 mm was used, it was composed of two conducting interdigitated electrodes on a thermoplastic sheet facing a second sheet coated with a semi-conductive polyetherimide ink.[22] The quartz force transducer has also furnished as a sensory assemblage on which the values of clenching action are revealed on a liquid crystal display. It has been also stated that the bite forces in the 113-1692 N range can be registered with acceptable accuracy with this equipment; this appliance has been portrayed as a best device for recording the bite force.

Strain-gage bite force transducer is the utmost universally adapted recording appliance and it is available in different heights and widths. Bite force was measured using a 4 mm height and 5x7 mm wide strain-gaged transducer, calibration of the this device was carried out at room temperature between the force of 0 and 350 N, with a ± 2% error. The aberration from linearity with load of 300 N was ± 7.3% and with load of 350 N was ± 9%. A maximum variability of bite force was been noted to be ranked between 446 N and 1221 N.

Dental prescale system consisting of a horse-shoe shaped bite foil of a pressure-sensitive film and a computerized scanning system was used for analyzing the load. When the forces were applied to occlusal contact, a chemical reaction occurred which produced a graded colour. The exposed pressure-sensitive foils were scrutinized in the occlusal scanner, which interprets the area and colour intensity of the red dots to determine occlusal contact area and pressure. It can also measure occlusal loads automatically. Two different varieties of pressure sensitive sheets exist: Type R with 97 µm thickness and type W having 800µm thickness. Each of these sheets is further classified as two sub-types, 30 H and 50 H. The 30 H sheet is adopted for a range of 30 to130 kgf/cm^2, and the 50 H sheet is used for a range of 50 to 1200 kgf/cm^2. The total occlusal load measured with PSF and conventional unilateral strain-gage transducer has been compared. A maximum bite force was registered with strain-gage transducer positioned on mandibular first molar teeth in 6-7 mm bite opening. Horse-shoe shaped pressure-sensitive foil is having a thickness of 0.097 mm and maximum bite forces are registered in intercuspal position. The thin pressure sensitive foil grants the chance of estimating the bite force from each tooth in recordings with little brawl to the occlusion. In the conventional type of this recording system which adopts the analysis of the combined jaw closing at specific points over the dentition, the occlusion is altered by the inevitable jaw separation and limits the occlusal support lead by the device. The diversification between total maximum UT force and maximum PSF force have been elucidated by a technical constraint in computerized scanning device of the dental prescale unit. Even though the changes in absolute values of closing force, the combined maximum PSF force and the UT force have been noted to be associated; the mean PSF combined force, PSF force at first mandibular and UT force have been recorded as 1109 N, 148 N, 553 N, respectively. A bite force analyzing system such as the dental prescale system adopting thin pressure-sensitive film is known to be superior than ordinary measuring systems which uses strain-gage transducer. This result may be explained by two factors; first, bite force can be recorded close to intercuspal position, which contributes a good chance to estimate bite force under natural circumstances. The second one is the load sharing along the dentition can be analyzed at the same time.[23]

The bite force applying a strain-gaged bite fork and a conductive polymer pressure-sensing resistor (force-sensing resistor) was compared. The bite force values retrieved from these two systems have revealed statistically significant differences in bite force levels in the range of 50 to 300 N. The authenticity of the sensor to register a reproducible force level amid two different loading series was noted about 93%. The observations of in situ loading tests have revealed that the novel bite force sensor is capable to document intraoral forces with satisfactory clinical precision and veracity. The researches have expressed out some challenges related to bite force sensor. The significant one is the nonlinear and load-rate dependent characteristics of the sensor that may be interpreted slightly by an assertive extent of nonlinearity of the force sensing resistor and devastation of the surface material related to the sensor. [22]

Location of recording device

Bite force differs in various locations of the oral cavity, the greater the bite force were recorded when the transducer is placed posteriorly. This may be attributed to the mechanical lever system of the jaw. Greater bite force can be beard well in the posterior teeth, due to their larger area and periodontal ligament at the roots of the posterior teeth. Transducer located at different positions in dental arch may impact the various muscles that are participating in the production of the force. When the transducer is positioned in the anterior region between the incisors, with an aftermath mandibular protrusion, the masseter muscle will generate majority of the force combined with the medial pterygoid muscle. If the bite force transducer is more posteriorly placed, the anterior fibres of the temporalis muscle will become more active making a greater contribution to the effort in cases when the transducer is placed at the posterior region. [24]

Measurements at different sites

Recording at the unilateral or bilateral application is another factor that determines the value of the bite force. Majority of the researches revealed that bite force while bilateral clenching is greater when compared to unilateral clenching. Conventional force transducers were applied in healthy persons during both unilateral and bilateral clenching, bilateral total bite force was estimated in healthy subjects and force noted 40% larger than unilateral clenching. Bilateral and unilateral bite force analysis was compared using different transducers, employing a 0.1 mm thick pressure-sensitive foil for bilateral clenching and a 6 to 7 mm thick conventional force transducer for unilateral clenching. 100 % acceleration in bite force and 50 % increase in massteric actions during bilateral clenching in comparison to unilateral clenching were observed. Bite force and jaw muscle activity was analyzed using strain-gage transducer during bilateral and unilateral maximum clenching and a 30% larger bilaterally measured bite force was observed. In bilateral measurement, 30% larger right and left masseter muscles and anterior temporal muscular actions have been reported than unilateral measurement. No significant differences in the activity of masseter muscles in the unilateral clenching experiments was observed, where as difference in the activities of right and left temporal muscles during unilateral clenching and the loaded side showed significantly more muscle activity.

The muscles of the jaw should synthesize a unilateral bite force which is equivalent to the resultant force generated during bilateral clenching. The force per side is more when analyzed unilaterally, in comparison to half of the force when recorded bilaterally. The mandibular muscle actions and bite force retrieved while unilateral clenching as correlated with bilateral clenching may be a product of reticence from periodontal and joint receptors. To minimize the trauma to the teeth, inhibition by periodontal receptors will limit the extremely strong bite forces and increased muscular activities. The force at the balancing side joint would be larger during unilateral clenching in comparison with forces at the working side. Thus, inhibition by joint receptors at the non-loaded side might limit joint forces.[25]

Role of Acrylic splints

Acrylic appliances were adopted for safeguarding cusps of the teeth and to avert dental fracture while maximum clenching. Acrylic appliances were used in contact with the metal faces of the strain-gage transducers to limit the possibility of fracturing teeth while chewing hard on the transducer. When the subject bites the hard metal surface of transducer, the irregular movements were generated by the neuromuscular reaction preventing the maximum bite force. In such case, a complacent surface for maximum bite force was provided by acrylic splints. Along with this, these devices can lend a standard position of the transducer for every subject, and for every session. Acrylic splints were used to correlate bite forces among a single tooth and multiple teeth. As occlusal splint is continued over the molars, escalation of maximum biting force is because of the appended force from the molar teeth disseminated to the strain-gage via the splint. It is hypothecated that the greater surface area of the periodontium and the increased bite force can be accomplished. The bite force values in patients with and without splinting by using a strain-gage transducer was compared and it was revealed that bite force levels are increased by using acrylic splints. [26]

Opening of Jaw

Alterations in the orofacial structures were observed from increase in the vertical dimensions altering the length of the main jaw elevator muscles and the position of the mandibular head. When biting force values were held constant, a reduction in electromyographic activity of the masseter muscle with greater jaw opening was observed. When the masseter muscle activity levels were held constant, maximal biting force magnitudes were measured between 15 and 20 mm of anterior vertical jaw opening. At the incisal aperture of 17 mm, the maximal incising force was discovered to be at its greatest. From this optimal opening, there was a drop or rise in jaw separation, as well as a decrease in the power of the maximum incising. A study was conducted to see how variations in vertical jaw opening alter the relative contributions of masticatory muscles to bite force output. The increase in electromyographic activity per unit of force produced under consistent biting forces was comparatively larger at the restricted range of jaw opening; EMG activity was lowered in the range of 9 and 11 mm of opening, and increased in the range of 12 mm of opening. In one experiment, minimum activity was measured between 15 and 20 mm at anterior jaw openings and between 9–11 mm at molar sites. According to the findings of these investigations, the population average for producing the strongest bite force is between 14 and 20 mm of jaw spacing.[27]

CONCLUSION

Bite force measurement has shown to be a reliable means of evaluating the biomechanical characteristics of the masticatory system as well as prosthetic therapy. When comparing biting force measurement in study, however, additional important parameters should be considered.

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