REVIEW ARTICLE

Measurement of Maximum Occlusal Force Using Digital Occlusal Force Measurement Device: A Scoping Review

Mohd Khairul Firdaus Mazlan[1], Melati Mahmud[1], Rohana Ahmad[1,2], Tong Wah Lim[3]

[1] Centre of Restorative Dentistry Studies, Faculty of Dentistry, Universiti Teknologi MARA, Malaysia.
[2] Integrative Pharmacogenomics Institute, Puncak Alam, Selangor, Malaysia.
[3] Division of Restorative Dental Sciences, Faculty of Dentistry, the University of Hong Kong, Prince Philip Dental Hospital, Sai Ying Pun, Hong Kong, Hong Kong SAR.

ABSTRACT

The aim of this review was to provide an update on the current status of digital occlusal force measurement devices, as well as clinical and research applications in complete arch maximum occlusal force measurement. SCOPUS, ScienceDirect, and PubMed databases were used to conduct a literature search from January 2001 to January 2021. Identification and screening of literature were done independently according to published guidelines and selection criteria. The electronic searches turned up 394 articles, 16 of which met the inclusion and exclusion criteria and were selected for study analysis. All of these studies used T-scan and Dental Prescale digital occlusal analysis system with pressure-sensitive foils as occlusal force measurement devices. The devices showed a promising potential for identifying and comprehending maximum occlusal forces objectively. According to the current review, maximum occlusal force measured with digital occlusal force devices can be used as a prosthodontic adjunct to address issues that arise during the treatment of occlusal disorders, temporomandibular disorders, and complete dentures. It is also useful in predicting cognitive and functional decline in the elderly.
Malaysian Journal of Medicine and Health Sciences (2023) 19(2):71-277. doi:10.47836/mjmhs19.2.38

Keywords: Bite force, Dental stress analysis, Dental occlusion

Corresponding Author:
Tong Wah Lim, MClinDent
Email: tongwah@hku.hk
Tel: +85228590296

INTRODUCTION

Oral physiologists have been studying maximum occlusal force (MOF) for years because it is a good indicator of how well the masticatory system works (1). It is caused by the mastication muscles' closing action, which is influenced by the mechanical reflexes of the jaw. MOF assessment has a long history in dentistry, with the goal of improving understanding of mastication mechanics in order to assess the clinical impact of prosthetic devices and establish comparison merit for prosthetic biomechanics research. Maximum occlusal force is influenced by the skeletal, muscular, dental, and nervous systems (2). Previous studies have discovered that these influential factors have an impact on the MOF's values and measurements. In addition to these biological considerations, mechanical determinants such as various recording devices must be considered. Several studies have been conducted to investigate the role of the muscular system in maximum occlusal force (3), the role of parafunctions, particularly bruxism (4), the prognosis of oral prostheses (5-7), and the evaluation of temporomandibular disorders (TMD) (8,9). These studies had a significant impact on the development of occlusal force measuring devices.

The evaluation of MOF for the complete arch is required for an accurate occlusal analysis. Waxes, alginate impression, occlusal sonography, transparent acetate sheets, mylar paper strips, articulating papers, foils, occlusal sprays, and silicone bite registration materials have all previously been used for occlusal analysis. However, these methods have yet to demonstrate their ability to accurately reproduce occlusal contacts (10). Qadeer et al. reported that the size of the marking area on the articulating papers was unrelated to the applied occlusal force (11). Another study also reported that dentists were unable to differentiate between high and low occlusal force by inspecting the articulating paper marks and suggested that an objective method be used (12). As a result, occlusal contacts or occlusal forces are always subjectively interpreted in routine clinical practices.

Mechanical, electrical, or a combination of the two are the different types of occlusal force devices. The electronic or digital type is now the most commonly used occlusal force device nowadays due to its accuracy and precision in measurement (13,14). In digital devices,

the transducer or load cells use the strain-gauge, piezoelectric, or pressure transducer working principle to convert occlusal force to electrical energy (15). Furthermore, occlusal force quantification and occlusal contact area assessment are now possible with digital occlusal analysis systems. Because the masticatory muscles exert the same force on the prosthesis in this position, the MOF and occlusal contact area must be checked in the maximal intercuspal position (16).

As a result, pressure-sensitive foils for digital occlusal analysis systems including the T-Scan system (Tekscan, Inc., South Boston, USA) and the Prescale system (Dental Prescale, Fuji Film Co., Tokyo, Japan) have been developed. Despite the fact that there are many occlusal force measurement devices on the market, their designs and methods of recording MOF differ. As a result, clinicians or researchers may struggle to find an appropriate device that is accurate and reliable enough to meet the aim of recording MOF in a clinical or research setting. Occlusal analysis, particularly MOF determination, is becoming increasingly important due to the increased demand for long-term oral health and optimal clinical outcomes. Therefore, the goal of this review is to provide an overview of current digital occlusal force measurement devices with pressure-sensitive foils, as well as clinical and research applications in complete arch MOF measurement.

METHODOLOGY

Study protocol and search method

This review was conducted in accordance with previously published guidance on the conduct and reporting of scoping reviews studies evaluating healthcare interventions (17). The adopted guidelines were as follows:

i. Identify the problem statement and link it to the aims of the review.
ii. Identify the potential studies to answer the aims of the review.
iii. Select the studies according to the inclusion criteria and extract the data accordingly.
iv. Document and analyse the extracted data.
v. Summarise and report the results.

Electronic searches were conducted using 3 English healthcare databases, including PubMed, SCOPUS, and Science Direct, from January 2001 to January 2021. The following keywords were used: “maximum bite force” or “maximum occlusal force” or “bite force” or “occlusal force” or “bite force measurement”.

Selection of studies

The three-stage process consists of title-reading, abstract-reading, and full-text reading to determine the potential studies that meet the selection criteria. The study’s flowchart is shown in Fig.1. The identified titles and abstracts were independently screened by the two

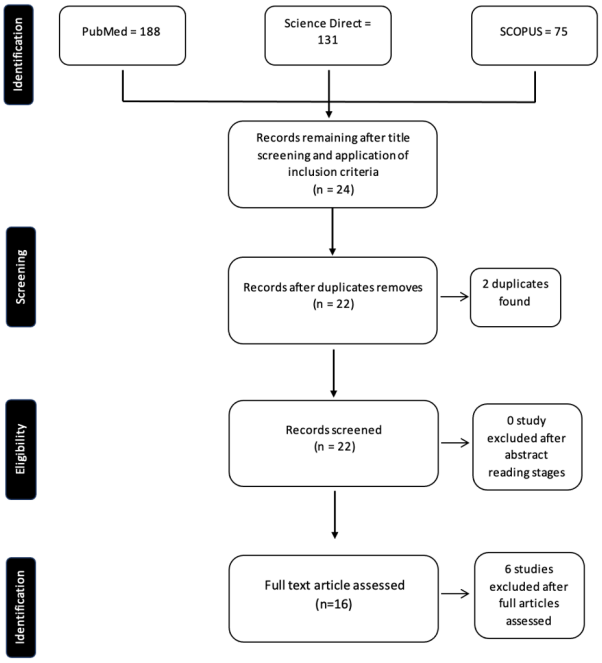

Figure 1: Flowchart of the selection mechanism schedule of records relevant to the present study.

reviewers in accordance with the inclusion and exclusion criteria. Agreement between the reviewers during this stage was assessed using Cohen’s kappa statistics, with a kappa value of 0.81. The full-text articles were then retrieved for further analysis from the selected abstracts. The selected studies were evaluated for the quality of their reporting. Any dissents were deliberated upon and resolved through discussion and consultation with the third reviewer. Studies were considered eligible and were included according to the following criteria:

i. Complete arch evaluation of MOF, excluding studies that evaluated single teeth or unilateral occlusal force.
ii. Patients of all age groups who have had the MOF measured.
iii. At least one type of digital occlusal force measurement devices used in the studies was mentioned or compared, excluding the conventional occlusal force measurement devices.
iv. Both clinical trials and prospective or retrospective cohort studies were allowed, excluding reviews, in vitro studies, and case reports.
v. There is a restriction on articles published in English and excluding grey literature.

Data procurement and management

The first two reviewers collected data independently. A customised data assembling form was used to document the study characteristics, including the name of the first author, title, year of study, aims of the study, number of participants, type of digital MOF device used in the study, intervention, and outcome of the study. The completed data sets were then compared and discussed to achieve a consensus.

RESULTS

The electronic searches yielded a total of 394 articles, with 16 full publications meeting the study's inclusion and exclusion criteria (18-33). A final number of 13 randomised control trials and 3 prospective cohort studies were selected for this review. A summary of these studies, including their methodologies and devices used, is presented in Table I. The digital occlusal analysis systems with pressure-sensitive foils were used in all 16 studies; two of them used the T-scan system, and the remaining used the Dental Prescale system. Four recent studies from the years 2018 to 2019 investigated the association of the masticatory performance with the geriatric health and cognitive function in elderly patients (27-30). Four studies evaluated the masticatory performance of complete denture patients (20,23,26,32). Another 4 selected studies evaluated the relationship of MOF and the treatment of the masticatory system or bone diseases (18,19,22,25). One study compared the MOF of resin-bonded fixed partial dental prostheses cemented at an increased occlusal vertical dimension (OVD) prior to, during, and 12 weeks after cementation (33). Another study evaluated the relationship between masticatory performance and MOF for both genders (31). The remaining 2 studies compared the MOF between 2 digital devices (21,24).

DISCUSSION

Digital occlusal force measurement devices

In all 16 studies, the MOF was measured using digital occlusal force measurement devices, either T-scan or the Dental Prescale system. Each has its own set of benefits and drawbacks. Clinical performance, research data and findings, cost, reliability, and a thorough understanding

Table I: Summary of the selected studies for whole arch maximum occlusal force measurement

Authors, year	*n*	Device	Aims of the study	Intervention	Outcome
Miyawaki *et al.,* 2005 (18)	54	Dental Prescale system	To test the hypothesis that both pre-pubertal and adult orthodontic patients with open bite show a weak occlusal force and/or abnormal condylar motion compared with normal individuals.	• Prepubertal subjects: Open bite group vs Normal group • Adult subjects: Open bite group vs Normal group	Prepubertal open bite patients showed a normal value of MOF, whereas adult patients showed a value lower than normal.
Narita et *al.,* 2009 (19)	6	Dental Prescale system	To investigate the effects of jaw clenching with soft and hard occlusal splints on the awareness of tiredness, bite force, and EEG activity.	6 healthy adults performed maximal voluntary clenching under 3 kinds of clenching conditions: with natural dentition, and with soft and hard occlusal splints	Jaw clenching with a soft occlusal splint caused a significant increase in awareness of tiredness, as well as significant decreases in bite force and Electroencephalography alpha 2 power spectrum values
Jofre´ et *al.,* 2010 (20)	45	Dental Prescale system	To evaluate the effect of maximum bite force (MBF) on marginal bone loss (MBL) around mini-implants in edentulous patients wearing mandibular overdentures with two retention systems: ball and bar.	• Group I (n= 22) received 2 single ball-type mini-implants • Group II (n= 23) received two mini-implants splinted with a prefabricated bar	No relationship was found between MOF and marginal bone loss for patients wearing overdentures retained on mini-implants using bar or ball attachment systems
Shiga *et al.,* 2012 (21)	60	Dental Prescale system	To clarify whether there might be a gender difference in masticatory performance in dentate adults	30 male and 30 female subjects were asked to chew gummy jelly on their habitual chewing side for 10, 15 and 20 s and the amounts of glucose extraction were measured. The amount of glucose extracted and maximum bite force was compared between 2 groups	The maximum occlusal force was significantly larger for males.
Misirlioglu *et al.,* 2014 (22)	21	T-Scan system	To determine the relationship between idiopathic osteosclerotic lesions and occlusal forces using the T-Scan II computerized occlusal analysis device, and to test the sensitivity of the system in occlusal analysis.	7 male and 14 female patients diagnosed with Idiopathic Osteosclerosis, aged between 17 - 62 years old	High occlusal forces at an osteosclerotic lesion area accounted for 20% of the maximum total force and a possible relationship between Idiopathic Osteosclerosis and occlusal forces and primary contacts
Niwatcharoenchaikul *et al.,* 2014 (23)	10	Dental Prescale system	To evaluate the effect of 2 complete denture occlusal schemes on masticatory performance and maximum occlusal force.	6 male and 4 female patients with a mean age of 67.3 years were given 2 complete denture occlusal scheme: bilateral balanced occlusion and neutrocentric occlusion	No difference was found in masticatory performance or maximum occlusal force between the occlusal schemes
Imamura Y *et al.,* 2015 (24)	10	Dental Prescale system	To clarify the effects of occlusal loading force on occlusal contact in natural dentition by comparing measured values for occlusal loading and occlusal contact area.	2 male and 8 female subjects with a mean age of 27 years were recruited for measurement of masseter muscle activity, occlusal contact point and accuracy fit with natural dentition.	The combination used of Occluzer and BiteEye gives an accurate picture of occlusion from weak to strong clenching strength of masseter muscle
Zhang *et al.,* 2016 (25)	30	T-Scan system	To evaluate the occlusal force and therapeutic efficacy of the masseteric muscles after intramuscular injection of botulinum toxin A (BTX-A) for the treatment of patients with concurrent TMD and bruxism.	• Patients with a temporomandibular disorder associated with bruxism were randomised into three groups • Test group treated by bilateral intramuscular injection of BTX-A into the masseter • Placebo group • Control group	There was a significant difference between the BTX- A and placebo groups but not between the control group and the other two.

Table I: Summary of the selected studies for whole arch maximum occlusal force measurement (continue

Authors, year	*n*	Device	Aims of the study	Intervention	Outcome
Komagamine *et al.,* 2019 (26)	27	Dental Prescale system	To compare the effect of conventional complete dentures fabricated using two different impression methods on masticatory performance and factors relating to masticatory performance in a randomized controlled trial.	• Participants were randomly divided • Conventional-Simplified group: the conventional method was used first, followed by the simplified method • Simplified-Conventional group: the simplified method was used first, followed by the conventional method	No significant differences were observed between the two methods regarding mixing ability, maximum occlusal force, and perceived chewing ability
Ohi *et al.,* 2018 (27)	815	Dental Prescale system	To investigate the association between maximum occlusal force, which is an objective predictor of masticatory performance, and incident functional disability in an elderly Japanese population.	Community-dwelling older adults aged was identified and invited. Incident of functional disability was recorded	A lower MOF was significantly associated with an increased risk of functional disability independently of possible confounders, including the number of remaining teeth
Hara *et al.,* 2020 (28)	117	Dental Prescale system	To verify the association between masseter muscle myotono-metric assessment results and MBF.	A community-dwelling > 65-year-old individuals were assessed. Masseter muscle stiffness on the dominant side during forceful biting and MOF was measured	Masseter muscle stiffness possibly reflects a force generated by the masseter muscle during forceful biting. Therefore, masseter muscle stiffness is effective to assess tooth loss as well as an index of masseter muscle strength when evaluating MOF.
Hatta *et al.,* 2020 (29)	860	Dental Prescale system	To investigate the impact of oral health on the decline of cognitive function over 3 years among Japanese people aged 70 and 80 years.	A community-dwelling older adults were examined the number of teeth, number of functional teeth, number of periodontal teeth, and occlusal force at baseline and follow-up surveys	Number of teeth and occlusal force predict cognitive decline over 3 subsequent years in Japanese older adults aged 70 and 80 years.
Ohi *et al.,* 2020 (30)	815	Dental Prescale system	To investigate the relationship between the bilateral MOF of full dental arches and all-cause mortality in a group of community-dwelling older males and females in Japan.	395 males and 420 females with a mean age of 75.1 years were assessed in demographic variables, chronicity, comorbidity, physical status, cognitive and psychological status, social functioning, and blood chemistry data in relation to maximum occlusal force	There was a significant and independent association of bilateral MOF with all-cause mortality in community-dwelling elderly males and females in Japan. These findings suggested that maintenance of oral functioning contributes to general health.
Shiga *et al.,* 2020 (31)	40	Dental Prescale system	To clarify the relationship between two types of dental prescale systems.	Forty healthy subjects were asked to maximally clench for about 3 s, and the maximum occlusal force before and after cleaning was calculated using an Occluzer FPD707 for dental prescale (P1) and a bite force analyzing system for dental prescale II (P2).	There was a certain relationship between the maximum occlusal forces measured by dental prescale and dental prescale II, suggesting that it is possible to compare the results of both by applying corrections using a regression equation.
Limpuangthip *et al.,* 2021 (32)	130	Dental Prescale system	To identify subjective and objective measures that better reflect the masticatory ability of complete denture wearers and to investigate their associating factors.	Complete denture wearers were assessed based on eating or mastication ability and MOF and occlusal contact area were determined	Unacceptable complete denture quality was significantly associated with oral impact on eating, eating dissatisfaction, and larger peanut particle size. Peanut particle size increased with lower maximum occlusal force, which was related to fewer occlusal contacts and the female subjects.
Idris *et al.,* 2021 (33)	28	Dental Prescale system	To investigate the occlusal force and occlusal contact reestablishment of RBFPDPs cemented at an increased occlusal vertical dimension (the Dahl concept) and to evaluate the factors affecting them.	28 participants receiving cantilevered resin-bonded fixed partial dental prostheses at an increased occlusal vertical dimension and maximum occlusal forces were recorded at precementation, postcementation, and 12-week review visit	Significant differences were found for the maximum occlusal force between the precementation and the postcementation and between the postcementation and the 12-week review of resin-bonded fixed partial dental prostheses.

MOF, maximum occlusal force.

of the hardware and software components all influence device selection (34). The T-scan system was used in only two studies to measure occlusal forces. Both studies agreed that this device was precise and durable, with neither foil conversion nor repeated readings having a significant impact on the measured MOFs (22,25). Nonetheless, because there were only two studies that used T-scan as the primary device to register MOF, drawing conclusions about the device's effectiveness is inadequate. Furthermore, no analytical methods were used in a clinical setting to validate the device.

In contrast, the Dental Prescale system is a promising occlusal device that has been used clinically to

assess masticatory performance (18-21,23,24,26-33). This system has been demonstrated to be capable of registering the MOF at the maximum intercuspal position, measuring bite force for each tooth even when there is an occlusal discrepancy, registering the occlusal contact area, and repeatedly replicating the maximum occlusal force value. It is also simple to use because measuring the MOF requires only one step. The main disadvantages are the thickness and rigidity of the pressure-sensitive sheet, the technical limitations of the computerised scanning system, the inability to register a prolonged bite, and the time-consuming and complicated photo-occlusion method (35,36).

A digital occlusal analysis device is preferred over conventional occlusal assessment techniques because it offers objective data (34) and data generated by analytical technology advancement may aid in the investigation of the factors affecting MOF. Idris et al. (33) reported that after cementation of resin-bonded fixed partial dental prostheses with an increased OVD, the device's pressure-sensitive films detected fewer occlusal contacts and decreased colour intensities, indicating that MOF was reduced as a result of the fewer occlusal contacts. According to Imamura et al. (24), the digital occlusal analysis device demonstrated excellent reproducibility and revealed that the masseter muscles' clenching strength increased with occlusal force and contact area. Using multivariate linear regression analysis, Hara et al. (28) discovered that the stiffness of the masseter muscles was strongly related to MOF and the number of teeth but not to age or gender. In addition, three clinical trials discovered that males with complete dentition had a considerably greater MOF than females (21,30,31). Males with a higher MOF, according to one of them, have the superior masticatory ability (21). Thus, digital equipment can be used to investigate the effects of various factors on occlusal forces, such as the masticatory system and demographic factors, as well as to decipher the underlying dynamics of the masticatory process and masticatory performances. Overall, the research found that both devices can accurately measure occlusal forces. Shiga et al. (31) also found a link between the MOF of early and later versions of the Dental Prescale systems. By applying a formula, the outcomes of both systems can be compared. The authors, however, are unaware of any clinical investigation comparing these two systems or different T-scan system versions. Furthermore, unlike the T-Scan System, the Prescale system was designed to be used in larger sample size investigations.

Clinical and research applications of occlusal force measurement devices

MOF in the masticatory system and bone diseases

Multiple clinical trials used digital occlusal force devices to assess occlusal force in order to diagnose and manage the masticatory system and bone diseases. Premature contacts, excessive forces, occlusal surface interrelationships, and temporomandibular joint-related disorders can all be diagnosed using the data from the digital programme long before they become a painful problem. Misirlioglu et al. (22) investigated the relationship between excessive occlusal forces and idiopathic osteosclerosis in a pilot study. Eighteen of the 21 subjects were found to have lesions located around the teeth with high occlusal force. They suggested that idiopathic osteosclerosis may be caused by high occlusal forces, but the association was unclear. Removing excess occlusal forces was also proposed as a treatment for Idiopathic Osteosclerosis. One randomised control trial evaluated the occlusal forces of 30 individuals diagnosed with TMD following injection of botulinum toxin A into their masseter muscles. They found that the occlusal forces were significantly reduced following the intervention. However, the study also reported that the psychological intervention might have influenced the treatment outcome (25). According to Miyawaki et al., adult subjects with open bites had lower occlusal force than subjects with normal bites, but not pre-pubertal subjects (18). For the treatment of TMDs, bruxism, and occlusal problems, various types of occlusal splints are recommended. However, the effect of soft and hard occlusal splints on MOFs has not been elucidated. Therefore, Narita et al. (19) evaluated the effect of these splints and found that the soft splint reduced occlusal force and increased awareness of muscles' tiredness. However, the findings need to be interpreted with caution because only healthy subjects were recruited. In conclusion, these devices have great potential as a clinical diagnostic tool for occlusal problems as well as a prosthodontic adjunct to address issues that arise during the treatment of occlusal disorders and TMD.

MOF and masticatory performances in complete denture
In order to assess masticatory performance and ability, the MOFs of complete denture patients were objectively measured using a digital occlusal force device. In a clinical study, MOFs were measured in two occlusal schemes of complete denture patients (23). There were no significant differences in masticatory performances or MOF between bilateral balanced and neutrocentric occlusion if the complete denture quality was good. There are no significant differences in MOF between patients wearing mini-implant retained bar and ball complete overdentures, according to Jofrй et al. (20), and both groups have more than 200 N MOF. In addition, Komagamine et al. (26) compared the MOFs of complete dentures made with a custom tray and a silicone impression to complete dentures made with a stock tray with an alginate impression. Although they found no differences in MOF between the two groups, the silicone impression group required fewer insertion adjustments. Another clinical study discovered that complete denture patients with low MOF had poor masticatory performance and that the MOF increased significantly with the number of occlusal contacts (32). As a result, regardless of the type of occlusion, implant

overdenture attachments, or impression materials used, high-quality complete dentures may potentially contribute to high MOFs.

MOF and general health of the elderly population

The remaining selected studies used digital occlusal force devices to investigate the association of MOF with incident functional disability, cognitive function, and geriatric health in the elderly population. Ohi et al. (27) studied 815 Japanese adults over the age of 70 and discovered that MOF was significantly related to oral function and overall health. They proposed that MOF be used as a parameter to assess the risk of functional disability in elderly patients. The same authors (30) studied the relationship between MOF and all-cause mortality among the community-dwelling elderly population. The MOF decreased during the study period, but male all-cause mortality increased. In the first half of the follow-up period, however, they found no differences in female survival rates. Another study on MOF in elderly patients found that stiffness of the masseter muscles was related to MOF and tooth loss (28). Hatta et al. (29) also reported the number of teeth and occlusal force influenced cognitive function in people aged 70 to 80. They proposed using both indicators to predict cognitive decline in the elderly for 3 years.

CONCLUSION

Based on the findings of this scoping review, the following conclusions were drawn. The T–Scan and Dental Prescale systems devices demonstrated promising potential for objectively identifying and comprehending MOF. The way these devices are made has changed over time to make them easier to use while keeping their accuracy and reliability as sensors. The current literature revealed that MOF measured using digital occlusal force devices can be used as a prosthodontic adjunct to address issues that arise during the treatment of occlusal disorders, TMD, and complete dentures. It can also be used as an indicator to predict the cognitive and functional decline in the elderly. More clinical studies are needed to figure out how digital occlusal force devices can be used to measure MOF as a diagnostic tool in dentistry.

ACKNOWLEDGEMENTS

This study was supported by MyRA Research Grant 600-RMC/MyRA 5/3/LESTARI (087/2020). The authors thank the Faculty of Dentistry, Universiti Teknologi MARA and UiTM library for their assistance in data collection and analysis.

REFERENCES

1. Hagberg C. Assessment of bite force: a review. J Craniomandib Disord. 1987;1(3):162-9. Available from: https://pubmed.ncbi.nlm.nih.gov/3325528/
2. Koc D, Dogan A, Bek B. Bite force and influential factors on bite force measurements: a literature review. Eur J Dent. 2010;4(2): 223-32. doi:10.1055/s-0039-1697833.
3. Sasaki K, Hannam AG, Wood WW. Relationships between the size, position, and angulation of human jaw muscles and unilateral first molar bite force. J Dent Res. 1989;68(3):499-503. doi: 10.1177/00220345890680031401.
4. Kogawa EM, Calderon PS, Lauris JR, Araujo CR, Conti PC. Evaluation of maximal bite force in temporomandibular disorders patients. J Oral Rehabil. 2006;33(8):559-65. doi: 10.1111/j.1365-2842.2006.01619.x.
5. Haraldson T, Karlsson U, Carlsson GE. Bite force and oral function in complete denture wearers. J Oral Rehabil. 1979;6(1):41-8. doi: 10.1111/j.1365-2842.1979.tb00403.x.
6. Lassila V, Holmlund I, Koivumaa KK. Bite force and its correlations in different denture types. Acta Odontol Scand. 1985;43(3):127-32. doi: 10.3109/00016358509064142.
7. Mьller F, Heath MR, Ott R. Maximum bite force after the replacement of complete dentures. Gerodontology. 2001;18(1):58-62. doi: 10.1111/j.1741-2358.2001.00058.x.
8. Helkimo E, Carlsson GE, Carmeli Y. Bite force in patients with functional disturbances of the masticatory system. J Oral Rehabil. 1975;2(4):397-406. doi:10.1111/j.1365-2842.1975.tb01539.x.
9. Pereira LJ, Pastore MG, Bonjardim LR, Castelo PM, Gaviro MB. Molar bite force and its correlation with signs of temporomandibular dysfunction in mixed and permanent dentition. J Oral Rehabil. 2007;34(10):759-66. doi:10.1111/j.1365-2842.2006.01697.x.
10. Dawson PE, Arcan M. Attaining harmonic occlusion through visualized strain analysis. J Prosthet Dent. 1981;46:615-22. doi:10.1016/0022-3913(81)90067-6.
11. Qadeer S, Kerstein R, Kim RJ, Huh JB, Shin SW. Relationship between articulation paper mark size and percentage of force measured with computerized occlusal analysis. J Adv Prosthodont. 2012;4:7-12. doi: 10.4047/jap.2012.4.1.7.
12. Kerstein RB, Radke J. Clinician accuracy when subjectively interpreting articulating paper markings. CRANIO. 2014;32(1):13-23. doi:10.1179/0886963413Z.0000000001.
13. Roffie J, Lim TW, Ab Patar MNA, Abdullah SA, Abd Ghani H. Wireless Sensor Network for a Bite Force Recorder. J Int Dent Med Res. 2020;13(4):1592-7. Available from: http://www.jidmr.com/journal/wp-content/uploads/2020/12/60-D20_1164_Juzailah_Roffie_Malaysia-1.pdf.
14. Iffendi Idris R, Tasri NI, Yusof SF, Lim TW, Shoji Y. Reliability of The Pressure Indicating Film for Occlusal Force Analysis: A Pilot Study. Compendium

Oral Sci. 2019;6:9-14. Available from: https://ir.uitm.edu.my/id/eprint/49723/1/49723.pdf.
15. Verma TP, Kumathalli KI, Jain V, Kumar R. Bite Force Recording Devices - A Review. J Clin Diagn Res. 2017;11(9):ZE01-5. doi: 10.7860/JCDR/2017/27379.10450.
16. Pameijer JH, Glickman I, Roeber FW. Intraoral occlusal telemetry. 3. Tooth contacts in chewing, swallowing and bruxism. J Periodontol. 1969;40(5):253-8. doi:10.1902/jop.1969.40.5.253.
17. Tricco AC, Lillie E, Zarin W, O'Brien K, et al. A scoping review on the conduct and reporting of scoping reviews. BMC Med Res Methodol. 2016;16:15. doi: 10.1186/s12874-016-0116-4.
18. Miyawaki S, Araki Y, Tanimoto Y, Katayama A, Fujii A, Imai M, et al. Occlusal force and condylar motion in patients with anterior open bite. J Dent Res. 2005;84(2):133-7. doi:10.1177/154405910508400205.
19. Narita N, Funato M, Ishii T, Kamiya K, Matsumoto T. Effects of jaw clenching while wearing an occlusal splint on awareness of tiredness, bite force, and EEG power spectrum. J Prosthodont Res. 2009;53(3):120-5. doi: 10.1016/j.jpor.2009.02.006.
20. Jofrй J, Hamada T, Nishimura M, Klattenhoff C. The effect of maximum bite force on marginal bone loss of mini-implants supporting a mandibular overdenture: a randomized controlled trial. Clin Oral Implants Res. 2010;21(2):243-9. doi: 10.1111/j.1600-0501.2009.01834.x.
21. Shiga H, Kobayashi Y, Katsuyama H, Yokoyama M, Arakawa I. Gender difference in masticatory performance in dentate adults. J Prosthodont Res. 2012;56(3):166-9. doi:10.1016/j.jpor.2012.02.001.
22. Misirlioglu M, Nalcaci R, Baran I, Adisen MZ, Yilmaz S. A possible association of idiopathic osteosclerosis with excessive occlusal forces. Quintessence Int. 2014;45(3):251-8. doi: 10.3290/j.qi.a31210.
23. Niwatcharoenchaikul W, Tumrasvin W, Arksornnukit M. Effect of complete denture occlusal schemes on masticatory performance and maximum occlusal force. J Prosthet Dent. 2014;112(6):1337-42. doi: 10.1016/j.prosdent.2014.06.003.
24. Imamura Y, Sato Y, Kitagawa N, et al. Influence of occlusal loading force on occlusal contacts in natural dentition. J Prosthodont Res. 2015;59(2):113-20. doi:10.1016/j.jpor.2014.07.001.
25. Zhang LD, Liu Q, Zou DR, Yu LF. Occlusal force characteristics of masseteric muscles after intramuscular injection of botulinum toxin A (BTX - A) for treatment of temporomandibular disorder. Br J Oral Maxillofac Surg. 2016;54(7):736-40. doi:10.1016/j.bjoms.2016.04.008.
26. Komagamine Y, Kanazawa M, Sato Y, Iwaki M, Jo A, Minakuchi S. Masticatory performance of different impression methods for complete denture fabrication: A randomized controlled trial. J Dent. 2019;83:7-11. doi:10.1016/j.jdent.2019.01.009.
27. Ohi T, Komiyama T, Miyoshi Y, Murakami T, Tsuboi A, Tomata Y, et al. Maximum Occlusal Force and Incident Functional Disability in Older Adults: The Tsurugaya Project. JDR Clin Trans Res. 2018;3(2):195-202. doi: 10.1177/2380084418761329.
28. Hara K, Chizuru N, Yamaguchi K, Kobayashi K, Saito T, Nakagawa K, et al. Association between myotonometric measurement of masseter muscle stiffness and maximum bite force in healthy elders. J Oral Rehabil. 2020;47:750-6. doi: 10.1111/joor.12968.
29. Hatta K, Gondo Y, Kamide K, Masui Y, Inagaki H, Nakagawa T, et al. Occlusal force predicted cognitive decline among 70- and 80-year-old Japanese: A 3-year prospective cohort study. J Prosthodont Res. 2020;64(2):175-81. doi:10.1016/j.jpor.2019.07.002.
30. Ohi T, Komiyama T, Miyoshi Y, Murakami T, Tsuboi A, Tomata Y, et al. The association between bilateral maximum occlusal force and all-cause mortality among community-dwelling older adults: The Tsurugaya project. J Prosthodont Res. 2020;64(3):289-95. doi:10.1016/j.jpor.2019.08.005.
31. Shiga H, Komino M, Uesugi H, Sano M, Yokoyama M, Nakajima K, et al. Comparison of two dental prescale systems used for the measurement of occlusal force. Odontology. 2020;108(4):676-80. doi:10.1007/s10266-020-00509-9.
32. Limpuangthip N, Somkotra T, Arksornnukit M. Subjective and objective measures for evaluating masticatory ability and associating factors of complete denture wearers: A clinical study. J Prosthet Dent. 2021;125(2):287-93. doi:10.1016/j.prosdent.2020.01.001.
33. Idris RI, Shoji Y, Lim TW. Occlusal force and occlusal contact reestablishment with resin-bonded fixed partial dental prostheses using the Dahl concept: A clinical study. J Prosthet Dent. 2021;14:S0022-3913(20)30764-2. doi:10.1016/j.prosdent.2020.11.035.
34. Sutter B. Digital Occlusion Analyzers: A Product Review of T-Scan 10 and Occlusense. Adv Dent Tech. 2019;20:11079. Available from: https://adtt.scholasticahq.com/article/11079-digital-occlusion-analyzers-a-product-review-of-t-scan-10-and-occlusense.
35. Kerstein RB, Lowe M, Harty M, Radke J. A force reproduction analysis of two recording sensors of a computerized occlusal analysis system. Cranio. 2006;24(1):15-24. doi: 10.1179/crn.2006.004.
36. Ando K, Fuwa Y, Kurosawa M, et al. Bite force measurement system using pressure-sensitive sheet and silicone impression material. Dent Mater J. 2009;28:212-8. doi: 10.4012/dmj.28.212.