Development and Clinical Reliability of a Measuring Device for Bite Force

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CONTENTS

Ⅰ. INTRODUCTION

The technical development of strain gauge dynamometers during the 1950s encouraged the measurement of bite force.[1-3] Bite forces can help the clinician to understand and successfully treat patients with disturbances in the stomatognathic system that involve overloading of the masticatory muscles and/or the temporomandibular joints as well as damage to natural teeth or prosthetic restorations. Therefore, many efforts have been made to investigate the normal chewing force[4-8] as well as maximal bite forces in man.[7,9-20] Mean values of molar region for the maximal bite force in these studies have varied from 25 to 127 kgf.[7,16,21,22) For the incisal region smaller values, 13.2 to 29.3 kgf, have been reported.[14,16] Bite forces which greatly differ in magnitude and direction, result from different combinations of action of various masticatory muscles and status of teeth including periodontal tissue.[23]

Today different methods are available for the measurement of bite force.[24-27] Regardless of the method used, distortions are likely to affect the bite-force values since some technical equipment always has to be used which disrupts the biological system to a greater or lesser extent.

A modern apparatus usually used for bite-force measurements is constructed as a strain gauge dynamometer.[9,14,24,28,29] One such representative strain gauge construction was described by Linderholm and Wennstrom.[9] The device consisted of steel bridge and a potentiometer writer.

Floystrand, Kleven, and Oilo[30] constructed a miniature bite fork 3.4 mm thick. The sensory unit was a semiconductor with planar resistors diffused on both sides mounted in a metal housing. Waltimo and Kononen developed a bite force recorder, which a quartz force transducer serves as a sensory unit. In this device, several teeth bite upon the housing. Stress analysis in dental restorations has been performed with methods such as photoelastic analysis,[31-33] brittle lacquer technique[27] and telemetric devices built in to the restorations.[33-35] Photoelastic stress analysis has been restricted to laboratory tests. The two other methods may be used under clinical conditions and interfere only to a small extent with the functional pattern of the masticatory system, but the measuring equipment has to be custom made.

The aim of the present study was to develop a new feasible device measuring bite force without needs of individual adjustment. The new equipment, compact and easy to use, was designed to allow recording of unilateral maximal bite force for one tooth. Further, the reliability for this measuring device was investigated for clinical application in dental fields calculating inter- and intra-examiner correlation in this study.

Ⅱ. MATERIALS AND METHODS

1. The measuring device for bite force

The instrument was designed in cooperation with Seokwang Co. Ltd., which is a leading manufacture and supplier of load cell, universal testing machine for a wide varity of industries and laboratories in Korea. The device consisted of steel bars(SNCM8) that were supplied with strain gauges connected in a Wheatstone bridge and a liquid crystal display(LCD). The device is shown in Fig. 1 and 2. The results of clenching action are shown on a LCD. Loads on the bite site produced proportional alterations of the resistance in the resister. When applying DC voltage, loading of the bite site resulted in electric changes in the circuit. The changes in the electric potential were transformed to force variable (kg) in a LCD panel.

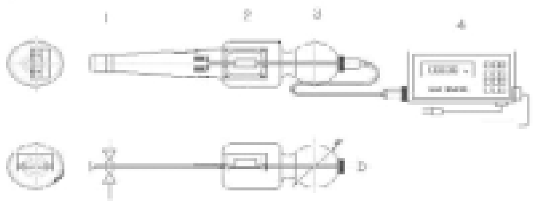

Fig. 1. A Design of the measuring device for bite force.1.load site; 2.strain gauge; 3.handle; 4.LCD

The strain gauge was placed between two bite plates of device with a thickness of 8 mm and width of 20 mm. It was made for unilateral use. To reduce metallic impact on the teeth, the bite sites of both sides are covered with 3.55 mm-thick silicon plates mounted with one-sided adhesive tape. The overall thickness at a bite site of the device is 15.1 mm.

2. Calibration test

To test the stability of the device, a calibration procedure was performed in the Laboratory of Seokwang Co. Ltd.. The device was loaded with a compression-test machine with a load gauge (Maekawa testing machine Mfg, Japan). The device was tested at loads of 50 and 100 kg at room temperature. The arithmetic mean value and standard deviation were calculated by 5 recordings of each of the loads given. On the basis of these measurements, the correlation coefficient was calculated for the device: $r=1.00$, $p=.000$. These coefficients were used to calculate actual bite force values. During these laboratory calibration tests, no protective rubber plates were used.

3. Clinical test

In the present study, 10 male dental students showing normal TMJ and masticatory functions,

Fig. 2. A photograph for a primary model of the measuring device for bite force

aged from 24 to 26 years (mean age 25.2), volunteered as test subjects. All subjects had continuous dental arches (28-32 teeth) with stable jaw relationship in intercuspal position and multidirectional freedom of contact movements. The subjects with simple amalgam restorations (O cavity) were included, but the subjects with complex amalgam restorations (MO, MOD cavities etc.) or prosthetic restorations were excluded. All subjects were accepted for the investigation after informed consent.

To measure the bite force of the right first molar, we placed the device cross the dental arch, so that the load site of device was situated in the first molar (Fig 3). To record incisal force, we placed the load site of device between the central incisors while teeth were in the interincisal position. At the beginning of the test, each subject was asked to bite on the load site of device without any measurements being made in order to become familiar with the equipment. Each subject made two attempts in each region (right first molar and incisal region) to bite as hard as possible with 10 minutes of interval. After recordings, the higher value was selected as a maximal bite force.

Inter-examiner and intra-examiner reliability was tested by the use of multiple examinations of subjects on the same and on different days. For determination of inter-examiner reliability, all subjects were investigated in one day by two examiners, each blind to the other examiner's results. Two examiners were chosen among dentists of Dept. of Oral Medicine, Dental Hospital, Dankook University based on their experience in

Fig. 3. The views of measuring anterior and posterior bite force.

evaluating the bite force with the device. For testing of intra-examiner reliability, all subjects were investigated twice by examiners blind to their first score. Seven days separated the first and second investigations by examiners, in order to minimize the memory of the first results

4. Statistical analysis

Statistical analysis of differences between results of two investigations by one examiner and results of investigations by two examiners was performed by the paired t-test. Correlation coefficient was performed to investigate a reliability of clinical use for a new developed bite force device. The level of statistical significance is given when $P \leq 0.05$; otherwise, differences are rated as no significant (NS).

Ⅲ. RESULTS

1. Calibration test for bite force device

The bite force device is able to record with good reliability in the range of 50 to 100 kg (Table 1). The corresponding SD ranged from 0.72 to 0.37.

2. Clinical test

As seen in table 2 and 4, the mean maximal bite forces of the subjects, examiner A measured two times, were 31.85 kg (SD=9.18) and 30.61 kg (SD=9.17) in the incisor. The corresponding values for examiner B were 31.36 kg (SD=9.13) and 29.96 kg (SD=7.95).

In table 3 and 5, the mean maximal bite forces of the subjects, examiner A measured two times, were 68.33 kg(SD=11.29) and 68.96 kg (SD=18.15) in the right first molar. The corresponding values for examiner B were 70.09 kg (SD=10.69) and 68.50 kg (SD=19.06).

Table 2 showed high correlations between two examiners for the maximal bite force of the incisor in the first (r=0.919 p=0.000) and the second examinations (r=0.894 p=0.000). There was no difference between the results of the maximal bite forces measured by two examiners (p>0.05). Table 3 showed also high correlations between two examiners for the maximal bite force of the first molar in both examinations (r=0.950, r=0.966, p=0.000). There was no difference between the maximal bite forces measured by two examiners (p>0.05).

In Table 4, two examiners showed significant correlations between the results of bite forces in the first and second examinations of the incisors(r=0.939 p=0.000, r=0.827 p=0.003). However, in Table 5, one examiner showed significant correlation between the first and the second examinations of the first molar (r=0.706 p=0.023) and the other examiner showed no significant correlation between two examinations (r=0.546 p>0.05).

Table 1. The calibraton results of the bite for the device in the laboratory

Load	Mean ± SD	Correlation coefficient
50kgf	50.1 ±0.72	r = 1.00
100kgf	100.9 ±0.37	(p=0.000)

Table 2. Interexaminer reliability of a developed measuring device for anterior bite force: Mean and standard deviations of measurements and results of paired t-test and correlation between 2 examiners at 2 different examinations

Examiner	Examination	
	1st (n=10)	2nd (n=10)
A	31.85 ± 9.18	30.61 ± 9.17
B	31.36 ± 9.13	29.96 ± 7.95
Paired t-test(p-value)	0.684	0.629
Correlation coefficient(r)	0.919	0.894
(p-value)	(0.000)	(0.000)

Table 3. Interexaminer reliability of a developed measuring device for molar bite force: mean and standard deviations of measurements and results of paired t-test and correlation between 2 examiners at 2 different examinations

Examiner	Examination	
	1st (n=10)	2nd (n=10)
A	68.33 ± 11.29	68.96 ± 18.15
B	70.09± 10.69	68.50 ± 19.06
Paired t-test(p-value)	0.149	0.773
Correlation coefficient(r)	0.950	0.966
(p-value)	(0.000)	(0.000)

Table 4. Intraexaminer reliability of the measuring device developed for anterior bite force : Mean and standard deviations of measurements and results of paired t-test and correlation between 2 examinations

Examiner	Examination	
	1st (n=10)	2nd (n=10)
1st	31.85 ± 9.18	31.36 ± 9.13
2nd	30.61± 9.17	29.96 ± 7.95
Paired t-test(p-value)	0.250	0.412
Correlation coefficient(r)	0.939	0.827
(p-value)	(0.000)	(0.003)

Table 5. Intraexaminer reliability of the measuring device developed for molar bite force : Mean and standard deviations of measurements and results of paired t-test and correlation between 2 examinations

Examiner	Examination	
	1st (n=10)	2nd (n=10)
1st	68.33 ± 11.29	70.09 ± 10.69
2nd	68.96 ± 18.15	68.50 ± 19.06
Paired t-test(p-value)	0.899	0.724
Correlation coefficient(r)	0.546	0.706
(p-value)	(0.102)	(0.023)

Ⅳ. DISCUSSION

The human bite forces registered in this study lay within the calibration range. The reliability and validity of the method are as good as those of previous developed device (r=.90, .89).[16] The measuring range for the bite-force recorder is similar with previously reported equipment with unilateral housings.[11,13,16,36] This device, however, is able to increase the range of bite force measurement through a proportional alteration of the electric changes in the circuit. Some subjects in this study showed maximal bite force of molar more than 100 kg (100.4 and 102.5 kg) and an increase in the range of force for this device should be followed up to at least 200 kg. In the report of Gibbs et al.[21] the greatest bite strength, 443 kg, was recorded from a 37-year-old man, R.H. of Lake City, Florida. The bite strength of 443 kg found in their study exceeded that measured in this study by a factor of 6.2. The bite strength Gibbs et al. reported couldn't be comparing with that of this study, because they measured bilateral force, but unilateral force (only first molar) in this study.

Proffit et al.[7] reported a mean maximum unilateral first molar bite force of 31 ± 20 kg. The mean unilateral molar bite force recorded in Sasaki et al.'s study[37] (189 ± 78 N) is similar to that reported by Lundgren and Laurell[5] for randomly chosen subjects biting on a preferred side (211 ± 77 N), but less than that recorded in this study (68.33 ± 11.29 kg to 70.09 ± 10.69 kg).

When the load site of a device was placed between the first molar teeth of both jaws, subjects had a tendency, as in normal chewing, to move the mandible laterally to the side of device before the maximal bite force effort.[38] It should be considered that the teeth could be fractured on biting maximally onto the metal device. A round silicon plate (12.7 mm diameter, 3.55 mm thickness), therefore, was attached onto the both load sites of device respectively for each subject. The interocclusal separation became only 15.1 mm in this study. This is in the range of the suggested favorable clearance of 9-20 mm.[28,39] The silicone plates not only prevent teeth from biting directly on the rather uncomfortable and dangerous metal surface, but also provide sagittal and lateral support to the cusps. The silicone plates attached on both sides of the device may, therefore, partly explain the high bite force values recorded in this study.

Solid state components were used to construct a miniature bite force recorder suitable for registrations in large study groups. A semiconductor was chosen as the sensory unit to be applied in the range from 10 to 1000 N.[13] This unit is also convenient bite force device. However, it was possible to measure bite forces only in the range of 10 to 1000 N and there wasn't compensatory function for temperature changes. The measuring device for bite force developed in this study has a compensatory function for temperature changes and it is possible to measure a maximal bite force at any room temperature.

As seen in Table 1, the findings showed that bite forces within 100 kg could be registered with good reliability. This equipment proved stable and easy to handle. The high resolution of the instrument made possible a distinct notion of the recorded values in the total measuring area. In theory, this ability should make the instrument feasible also for other kinds of registrations, such as the registration of bite forces for a tooth with periodontal disease, an implant or a patient with temporomandibular disorders.

The instrument could be conveniently positioned between a single pair of antagonizing cusps. The dimension of the bite area is relatively adequate compared with other types of equipment used for the same purpose.[11,13,24,33,40] These properties make the equipment highly applicable for screening tests in large study groups.

The maximal bite forces measured in this study should probably not be interpreted as representing maximum muscular potential. All molars should be included in the study of bite force representing a maximal muscular potential and a more likely correlate would be the level at which the individual is protected against injury by the alarm function of the pain receptors.[41,42]

This device would be helpful for the evaluation of treatment and prognosis of TMD patients if the vertical height of this device is determined in a further study. In addition, it could be very helpful to estimate masticatory function for subjects with TMJ dysfunction by traffic accident and so on.

Ⅴ. CONCLUSIONS

A new measuring device for maximal bite force was developed using a strain gauge. The device had a good intra- and inter examiner reliabilities for maximal bite force. This device was proved stable and easy to handle. Therefore, it would be highly applicable for screening tests in large study groups, and feasible also for taking other kinds of registrations, such as the registration of bite forces for a tooth with periodontal disease, an implant or a patient with temporomandibular disorders.

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국문초록

교합력 측정기기의 개발과 임상적 신뢰도에 관한 연구

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지금까지 여러 가지 형태의 기기를 이용하여 보고된 사람의 교합력은 그 최대치가 매우 다양하다. 본 연구에서는, 교합력을 측정하기 위하여 새로운 측정기기를 개발하였다. 본 기기를 이용하여 전치부 교합력 측정 시에는 대칭적으로 최대한 물도록 하악을 유도하여 최대 교합력을 측정하였고, 구치부는 편측으로 물도록 하악을 유도하여 최대 교합력을 측정하였다. 교합 시 치아간 수직고경은 15.1mm 였다. 측정기기 내 strain gauge를 사용하여 전기저항의 변화를 힘으로 전환하였다. 마이크로 프로세서가 수치를 계산하면 액정화면에 수치가 표시된다. 실험실 내 기기교정 검사에서는 50kg과 100kg의 부하를 가하였다. 개발된 교합력 측정기기의 임상적 신뢰도를 시험하기 위해 건강한 치과대학 재학생 10명을 대상으로 최대 교합력을 측정 하였다. 이 새로운 측정기기로 측정된 교합력은 이전연구에서 기록되었던 것보다 더 높은 수치가 나왔다. 또한 제1대구치와 전치부에서 최대 교합력을 측정한 경우 실험자 내와 실험자 간에 통계적으로 유의한 신뢰성을 얻을 수 있었다. 본 기기는 안정적이고 조작성이 쉽다고 판명되었다. 그러므로, 본 기기는 더 큰 연구 집단의 선별검사에 매우 유용하게 사용할 수 있을 것이며, 또한 치주질환이 있는 치아나 임플란트, 악관절 장애를 가진 환자의 교합력 측정과 같이 특정된 경우의 교합력 측정에도 유용할 것이다.