

# REPEATABILITY OF THE CALIBRATION PROTOCOL FOR EMG EVALUATION OF THE OCCLUSION WITH THE TEETHAN DEVICE

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**Abstract. Objective.** The aim of the study was to investigate the repeatability of the calibration protocol performed by the Teethan® device (Teethan S.p.A. Italy) for surface electromyography (sEMG) when biting on cotton rolls to eliminate the effect of occlusal contacts. **Materials and methods.** Thirty-three fully dentate subjects aged 13-43 years (mean 21.33 years) of which 15 men and 18 women were enrolled in the study. All subjects had a good state of dental and periodontal health without temporomandibular disorders (TMDs). Each examined participant performed two distinct maximal voluntary clenches on cotton rolls: the first one for calibration of the device and the second one for recording of the signals. The results were presented as the indices: Percentage overlapping coefficient (POC), Barycenter (BAR), Torsion (TORS), Impact (IMPACT), Global index and Asymmetry (ASIM). **Results.** All the examined indices showed good repeatability during the test, compared with the normal values, determined by the manufacturer of the device. Some of the recorded indices were insignificantly lower than the norm (POC TA, POC MM, BAR and TORS). Global index and IMPACT were within the reference values and showed highest repeatability in this study. **Conclusion.** Instrument calibration is an important prerequisite for exact testing. The indices, recorded by this device are rather repeatable, with Global index and Impact found to be the most repeatable ones. The values of the measured indices show that the process of calibration is highly reliable.

**Key words:** surface EMG, Teethan, calibration, standardization of EMG signal

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**Received:** 08 March 2024; **Revised/Accepted:** 20 May 2024

## INTRODUCTION

Surface electromyography is used to make an objective recording of the myoelectric signals that are generated during muscle activation and for evaluation of the muscle function and dysfunction [1-5]. Recording of the activity of masticatory muscles provides information about the occlusion and its relation to the balance of the masticatory muscles. Surface EMG (sEMG) is a non-invasive,

painless examination method that can be performed in the dental office to evaluate changes in the masticatory system, without the necessity of sending the patient to specialized diagnostic centers [1, 2, 4, 6-8].

It is an important tool for analysis of muscular physiopathological changes during orofacial static and dynamic activities [9]; changes in sEMG characteristics may indicate a modification in the occlusion parameters [10, 11]. Several fundamental and more recent

studies, where occlusal parameters have been analyzed, suggest that the activity of the masticatory muscles at maximum efforts depends on occlusal factors such as the number of posterior occlusal contacts [11-14]. A higher number of posterior contacts gives a stable intercusp support that allows elevator muscles to achieve higher levels of muscular activity during clenching and chewing [13, 14]. Moreover, alteration of the activity of the temporalis and masseter muscles was observed during clenching and chewing in the presence of experimental occlusal interferences. For example, Christensen and Rassouli reported motor facilitation on the masseter muscle on the side of a rigid unilateral interference and motor inhibition on the opposite side during forceful clenching. [15] According to Baba et al., increase in the activity of anterior temporalis ipsilateral muscle will also occur, when an interference is placed [16].

The absolute values in microvolts during the EMG assessment provide an inaccurate basis for result comparison of muscle function during different activities both in consecutive trials on one person and when different individuals are examined. For this reason, comparing the EMG activities between subjects and under different conditions requires a process known as "standardization". It is suggested that ideally the standardization procedure should be in the same position or activity as the muscle is acting. For the amplitude domain, some authors recommend the use of the maximum voluntary clenching (MVC) as a parameter of standardization [17].

Standardization of the EMG data allows elimination of the influence of occlusion contacts on the neuromuscular balance, avoiding individual variability (anatomical variations, physiological and psychological status, etc.) and technical variations (muscle crosstalk, electrode position, skin impedance etc.) [18].

Clenching teeth on cotton rolls eliminates the effect of occlusal contacts on muscle balance, which provides basis for individualization of the norm for every patient. This process of standardization of the results is called calibration. With the Teethan device, the calibration process can be done more than once, and it is possible to choose which of the trials will be used to standardize the results. Usually this is the recording with the most even distribution of the muscle activity of the four tested muscles, i.e. 25% each.

The aim of the present study was to examine the accuracy and repeatability of the calibration test with the electromyographic device Teethan®, designed for sEMG examination of the effect of the occlusion on masticatory muscles.

## MATERIALS AND METHODS

### **Sample**

Thirty-three participants aged 13-43 (mean 21.33) years, of which 15 men and 18 women, were included in the study. All subjects had a good state of dental and periodontal health and complete permanent dentition (with the exclusion of third molars).

Exclusion criteria were: temporomandibular disorders; neurological disorders; fixed or removable prostheses; current orthodontic or dental treatment. All eligible for the study signed informed consent forms.

### **sEMG recordings**

The examined persons were seated in a dental chair without headrest, with the feet resting on the chair and arms resting on the lap. The head was positioned upright and the Frankfort plane parallel to the floor was used as a positioning parameter as described by De Felicio et al [19]. The subjects were informed about the tests with the EMG device and the procedures preceding the tests had been conducted.

Masseter and anterior temporal muscles of both sides were examined. The skin over the muscles was cleaned with alcohol to eliminate any residues. Circular silver/silver chloride bipolar pre-gelled disposable electrodes (Kendall™ H124SG Covidien™ Electrodes) were applied to the muscle belly, determined through palpation, parallel to the fiber direction according to the recommendations of SENIAM (Surface EMG for Non-Invasive Assessment of Muscles) [20]. On the anterior temporalis muscle, in particular, the electrodes were positioned vertically along the anterior muscular margin, parallel to the coronal suture. On the masseter muscles, the electrodes were parallel to muscular fibers, positioned on the maximal bulk of the masseter and the anterior temporalis muscle, which was determined by palpation while the subject clenched. For each subject, the electrodes were positioned at the beginning of the session, and all trials were performed without any modification of the electrodes and/or their position. Electromyographic activity was recorded using a wireless computerized instrument Teethan.

### **Devices**

The Teethan® electromyographic device (Teethan S. p A., Milan, Italy) is a wireless device, composed of four probes. The probes communicate via Wi-Fi with a USB receiver and the transmitted data are made available in real time, through the interface of the specific software. Muscle activity is measured in microvolts ( $\mu V$ ). The protocol adopted in this study is based on standardization procedure before the

actual evaluation of the occlusion as in the study by Ferrario et al [7]. This protocol allows the calculation of the indices of EMG activity by using standardized signals recorded during the MVC, with cotton rolls between posterior teeth on both sides. This test allows assessing the maximum muscle activity in the absence of dental contact. The method reduces both technical and biological noise and allows to compare the activity of paired jaw muscles by providing information about any possible asymmetry in masticatory muscle activity.

For calibration of the device, each subject performed a 5-second maximum voluntary clenching (MVC) on cotton rolls. The distance between teeth is negligible when the roll is clenched and modifies the vertical dimensions slightly. In this way, the EMG activity of the masticatory muscles is evaluated without the influence of occlusal contacts. This record is presented as a pie chart (Figures 1 and 2). After the calibration, the device is ready for evaluation of the occlusion. For this test, the subject was asked to perform MVC again on the same cotton rolls, without removing them, after a pause of 1 minute. The cotton rolls were left between the teeth in order not to change their position. Specialized software converts the data (standardization procedure) and presents them as percentages as described by Ferrario et al [21]. All examined subjects served as a control group because the test result was compared with the individual norm for each one of the examined. The values of the second measurement represent the standardized indices of the assessment of the muscle activity balance.

The indices as described in the user manual of the device are:

**Percent Overlapping Coefficient (POC):** This index was introduced by Ferrario et al. [21] and is used to assess the symmetry of contraction standardized within the same muscle pair. It indicates the imbalance (right/left) within the examined muscle pair: in particular, the POC calculates the predominance of the right or left temporalis anterior (POC TA) and that of the right or left masseter muscle (POC MM). If the two muscles of the same muscle pair contract symmetrically, the expected theoretical result of POC is close to 100%; instead, if the two muscles have standardized values with a different percentage, the POC is considerably less than 100%. If POC exceeds

83%, there is a normal muscular symmetry induced by teeth contacts.

**Barycenter (BAR):** It assesses the position of the occlusal barycenter [7]. It is obtained by calculating the percentage of overlapping coefficient between the activities of the two temporalis and the activities of the two masseters (unlike the POC index that compares individual analogous muscles). The normal value of the BAR index is greater than 90%.

**Torsion (TORS):** It assesses the torsion attitude of the mandible in the horizontal plane when it is in occlusion with the upper jaw [7]. It is the result of the comparison of the force couple of crossed muscle pairs: comparison between the right temporal and left masseter pair and between the left temporal and the right masseter pair. When this index is > 90%, there are no force couples on the jaw.

**Impact (IMP):** It indicates the muscular activity of masticatory muscles and is proportional to the bite force [22]. The normal values of the index are over the range of 100%-115%.

**Global index:** The mean value of the four mentioned above indices.

**Asymmetry (ASIM):** this index compares the activity of the right muscles with that of the left ones [23]. A positive value indicates a greater activation of the right-hand side, while a negative value indicates a greater activation of the left-hand side. Normal values range from -10 to +10.

Figure 1 presents the calibration screen of the device software. Three calibrations are shown on the left, from which the clinician chooses the one with the most symmetrical distribution of muscle activity.

Figure 2 presents the pie charts of the muscle activity of the four masticatory muscles.

The quadrants of the pie chart represent the muscle activity of the four masticatory muscles examined.

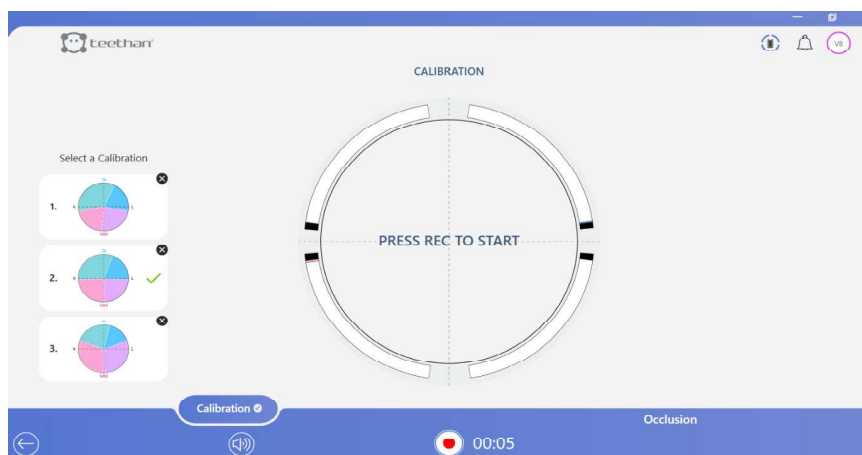


Fig. 1. Calibration screen

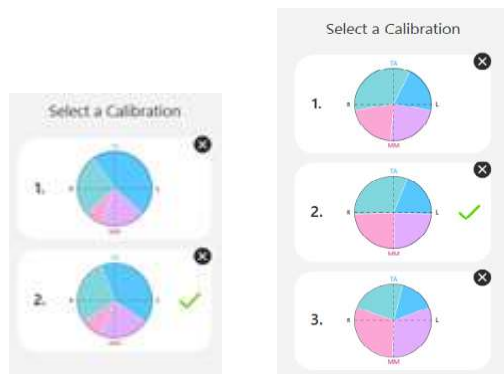


Fig. 2. Muscle activity of the masticatory muscles

The presented calibrations are of two different people, the first of whom has pronounced muscle asymmetry. More than one calibration tests are usually necessary to pick the most symmetrical one.

**Statistical Analysis.** The IBM SPSS Statistics, 23.0 was used for the statistical analysis. The mean values, standard deviation, minimal and maximal values and coefficient of variation (CV) were calcu-

lated for the outcome variables. The distribution of the indices within the reference intervals was presented in histograms.

## RESULTS

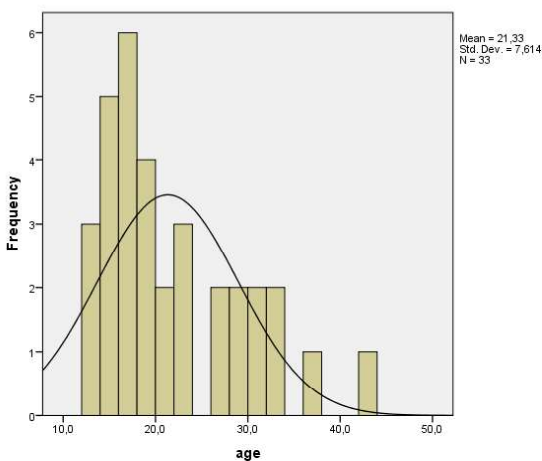
Table 1 shows the reference values, provided by the device manual, the values of the tested indices in this study and coefficient of variation.

All reported indices showed good-to-excellent reproducibility. Global index and IMPACT, although with a significant standard deviation are within normal values, while POC TA, POC MM, BAR and TORS show values above 80%, which are slightly lower, compared to normal values. Histograms show that most of the studied individuals are near the norm. The summarizing Global index is found to be more reproducible than its component indices.

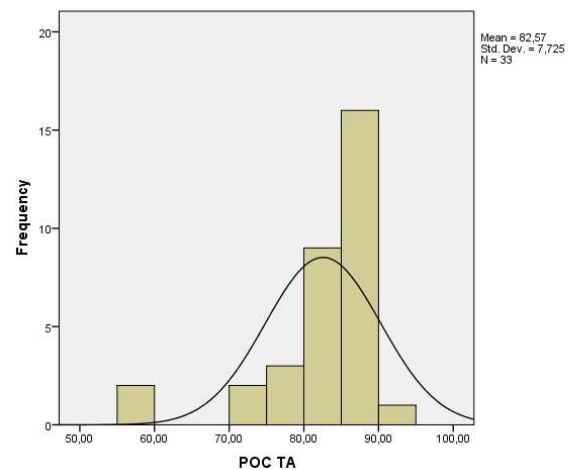
Asymmetry index (ASIM) values are interpreted as an absolute value (not as positive value for right prevalence and negative value for left prevalence), since the norm is zero.

**Table 1.** Indices, measured in the study, including coefficient of variation, compared with the reference values, provided by the device manual

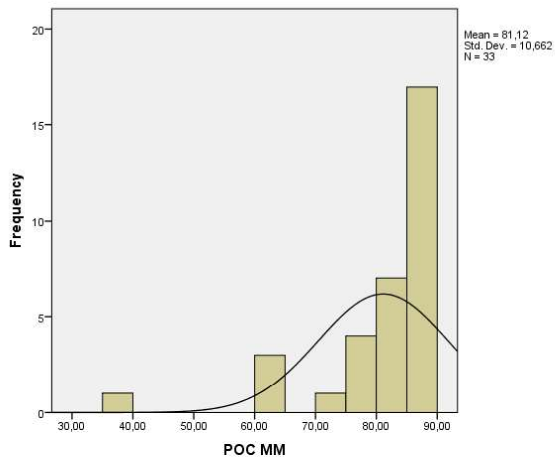
Index	Reference values	Results				
		mean		Min	Max	CV %
POC TA	83-100%	82.57	7.73	56.67	90.26	9.4
POC MM	83-100%	81.12	10.66	36.39	89.58	13.1
BAR	90-100%	84.91	10.62	46.44	92.50	12.51
TORS	90-100%	87.16	8.92	41.53	92.73	10.25
Global Index	83-100%	84.15	8.25	47	91	31.9
IMPACT	85-115%	98.77	31.49	57.8	214.53	85.14
ASIM	0-10	10.50	8.94	0.79	37.45	9.8



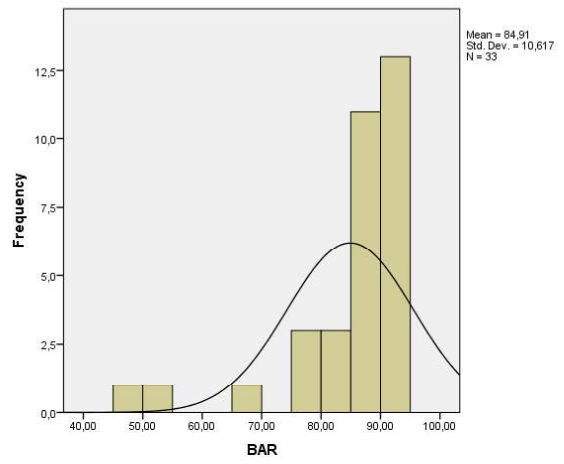
a)



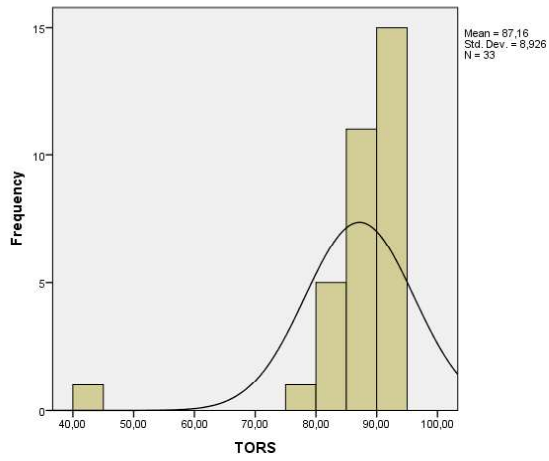
b)



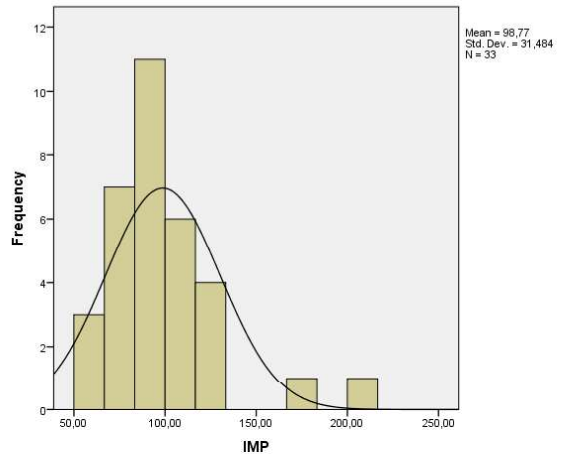
c)



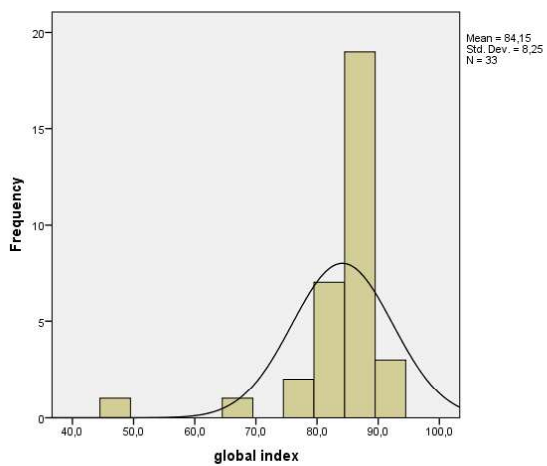
d)



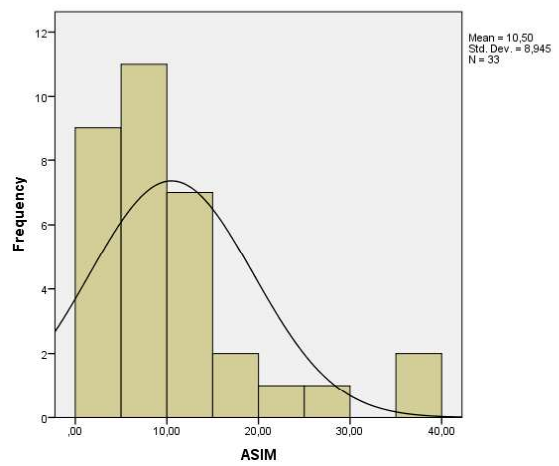
e)



f)



g)



h)

**Fig. 3.** Histograms of the age and examined indices (a, b, c, d, e, f, g, h)

Figure 3 (a, b, c, d, e, f, g, h) presents the histograms of the frequency and distribution of the registered indices and the age of the examined participants in this study.

Histogram (a) presents the age distribution of the participants. Most of the examined persons are within the age interval between 15 and 25 years.

As for POC TA and POC MM (b and c), most of the examined persons showed percentage overlapping coefficient between 85-90%, which is within normal range both for the temporalis and masseter muscles.

Barycenter (d) and Torsion (e) also show near-normal values, with most of tested individuals being within the normal range.

Although the vertical size of the muscles is increased, the muscle work (impact) (f) is normal. Most of the examined individuals showed asymmetry of up to 10, which is within normal limits. The mean values of the global index (g) are within normal limits. As to the asymmetry index during the second test, some of the examined subjects showed values above 10 (ASIM, h). The ASIM index shows large variations in the study group. Overall, the study demonstrates that although there is no 100% reproducibility of the results, in most of the individuals, the results are within the reference values.

## DISCUSSION

The usefulness of surface EMG as an additional tool for clinical evaluation was considered under question by some authors [24, 25]. However, most clinical studies proved the use of sEMG of temporalis and masseter muscles as a fundamental tool for precise diagnose and especially for discrimination of TMD from other pathology [4, 7]. One of the main questions to answer is the repeatability and hence, the reliability of the results acquired by this method in various patients with different pathology. For the purpose, many studies were performed both on healthy subjects and patients with different disorders.

Electromyographic evaluation of the masticatory muscles in relation with the occlusion has proven to be highly reproducible in healthy people [3, 19, 26-30]. Best results were obtained in MVC in centric occlusion.

It is expected that after the first clench on the rolls and calibration of the device, the second clench will give results close to 100%, as the first clench provides individual norm. Our results show that during the second clench, POC TA, POC MM, BAR and TORS are slightly below the normal reference values. The indices, giving the result of the second MVC on rolls in percentages, actually indicate the percent-

age of reproducibility for two consecutive clenches of the teeth. Im YG et al. [28] in a study concerning the ASIM index and the Activity index (similar to the BAR index) found that both indices are highly reproducible in a two-day trial. Their examination of the indices during the MVC was performed on cotton rolls as well.

In our study, the highest repeatability was found for the Global Index and the Impact. The ASIM showed the least repeatability of the results with the highest standard deviation. In a recent pilot study on the repeatability of Teethan indexes of the masseter and anterior temporalis muscles during maximum clenching, O. Saracutu et al. [26] found that the indices provided by device have a wide range of variability and repeatability and some are more repeatable than others. They found that Global Index, that summarizes all the recorded results and defined as the main index, shows one of the highest degrees of repeatability.

The difference in the results may be due to the difference in the texture of the cotton roll. During the first MVC, the cotton rolls are soft until compressed and not soaked in saliva. When asked to bite again on the same rolls, the height is smaller, and the rolls are harder. On the other hand, Global Index and IMPACT are within normal range, which makes them the most repeatable indices during the MVC on cotton rolls. Moreover, it is necessary to underline, that the reliability of the results depends on several factors as the correct posture of the patient, the cleaning of the skin, the precise location of the electrodes. The elimination of these factors is achieved by the process of standardization. Muscle fatigue can impair muscle contraction and also should be taken in consideration if repeated tests are performed on the same patient.

## CONCLUSIONS

The calibration of the device is the basis on which the occlusion assessment is subsequently made. This study showed that the indices, recorded by the Teethan device, when the patient clenches teeth on rolls, are rather repeatable, with the Global index and the Impact found to be the most repeatable and thus most reliable indices. The high degree of reproducibility found, is possibly due to the fact that the cotton rolls are the same and their position remained the same during two consecutive times of patients' voluntary clenching.

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**Disclosure Summary:** *The authors have nothing to disclose.*

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