

FUNCTIONAL EVALUATION OF IMPLANT SUPPORTED PROSTHESES

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Abstract

Purpose: Surface electromyography is currently considered a useful tool for dentistry allowing the validation of conventional morphological evaluations with an accurate and objective quantification of the functional activity. An evaluation of full mouth resin prostheses on implants was performed including both a morphological evaluation of occlusion and a measurement of the actual impact of morphology on stomatognathic function.

Methodology: The measurement was performed using masticatory muscle electromyographic recordings with ad-hoc software algorithms. In the present study, five patients with full mouth resin prostheses on implants have been evaluated at the beginning of their prosthetic reconstructions and after one year using surface electromyography. To verify the static neuromuscular equilibrium of occlusion, functional evaluation of the left and right masseter and temporalis anterior muscles was performed in all patients, and a set of indices was computed: the Percentage Overlapping Coefficient - POC (an index of the symmetric distribution of the muscular activity determined by the occlusion), the Torque Coefficient - TC (an index of the possible presence of a mandibular torque) and the antero-posterior coefficient (an index of the possible relative position of the occlusal center of gravity).

Results: One year after surgery during the maximum voluntary clench, all patients had symmetric standardized potentials (POC values between 80% and 100%, and TC values larger than 90%).

Conclusions: Surface electromyography indices were well super imposable to the values found in healthy subjects with natural and normal occlusion, thus indicating that, at short time follow up, a functionally stable occlusion could protect from resin prosthodontic fractures.

Keywords: electromyography, prostheses, implants

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Introduction

Today, several clinical tools can support the daily clinical practice in dentistry with a quantitative support helpful for diagnosis, measuring the effects of therapy, and timely detection of the possible failures or relapses.

Surface electromyography (EMG) is able to support conventional morphological evaluations with an accurate and objective quantification of functional activity and it is currently considered a useful tool for dentistry. Engineers, biological and dental researchers have developed useful EMG protocols that couple the scientific accuracy, indispensable in all instrumental evaluations (1), with the simplicity necessary for daily use in dental practice. Therefore, starting from the multiple information collected during the computerized analysis, a selection of simple and well reproducible indices (with a clear biological and clinical significance, and easily comprehensible), should be made. Moreover, the quantitative data should be coupled with a graphic support allowing an easier and more efficient communication between the clinician and the patient. In other words, diagnosis should be supported "at a glance" (1,3).

A correct evaluation of prostheses should include both the morphological evaluation of occlusion, and the measurement of the impact of customized morphology of dental contacts on stomatognathic function in each single patient. Among the various clinical protocols currently used in prosthodontics, the immediate loading of implants with full mouth resin restorations has been proposed as simpler, less time and money consuming than delayed loading of implants.

In our prosthodontic practice, we tried to develop a practical application of well-standardized sEMG protocols developed in research laboratories (1-7) to help clinical work. A quantitative clinical tool may reduce complications in implant supported, all-

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acrylic resin prostheses, with immediate load. These measurements can be well performed using surface EMG recordings of the main masticatory muscles, such as the temporalis anterior and the masseter (1,4,5,8). For instance, occlusal stability has been found to be related to muscular performance, significant associations may exist among dentition status, chewing ability, muscle strength and balance both in the young and the elderly population (9,10)

EMG allows not only to measure the electric potentials produced by the single masticatory muscles (values that are somehow related to the developed masticatory forces) (1,4,5,8), but it also allows the verification and quantification of muscular balance, between couples of muscles of the two sides of the body (symmetry), between couples of muscles with a possible later deviant effect on the mandible (torque) (1), and between couples of muscles with an action line positioned more forward or more backward to identify a hypothetical center of gravity of occlusion. Indeed, occlusion both on natural teeth and on prostheses with premature or sliding contacts can provoke a mandibular torque (4) or an unfavorable center of gravity. The consequent altered muscular activity is not macroscopically evident, but, in the medium-long time, it could cause alterations in the bone.

In the present study, patients with full-mouth prostheses on implants have been evaluated at the end of their prosthetic reconstructions and after one year with surface EMG.

Methods

Patients

On September 2013, five male patients were selected from a dental practice in Milan during dental hygiene clinical recall appointments. These patients had received full mouth rehabilitation on 4 implants (Milde® implants) in each dental arch from the same private practice between June 2012 and September 2012. All the patients were in good health and edentulous in both arches. All of them have presented severe atrophy in the posterior regions of the arches. Clinical and radiographic diagnoses were performed, using preoperative panoramic radiographs and Cone Beam CT scans. All patients gave their informed consent to the immediate loading procedure. Immediately after the surgery (Fig 1), full-resin prosthesis with a resin CAD-CAM framework (Fig 2) was placed with distal cantilever extension - first molar area (12 teeth).

To avoid the incidence of prosthetic complications, the neuromuscular equilibrium of occlusion in static conditions was evaluated in all patients with a surface EMG (TMJoint, BTS, Italy) of the masseter (MM) and temporalis anterior (TA) muscles of both sides (left and right) one week after the surgery. In all patients, dental



Figure 1. Immediately post-operative x-ray

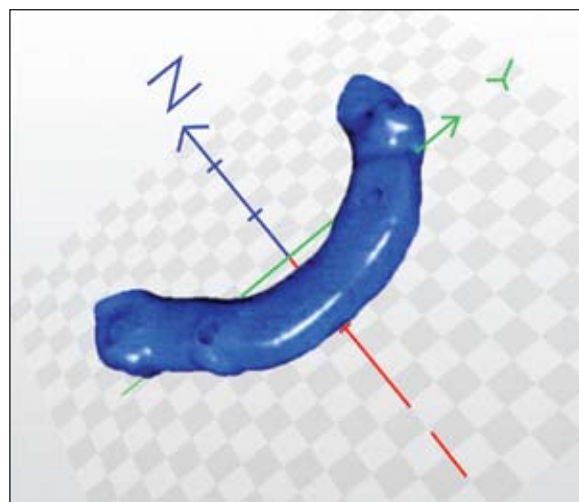


Figure 2. Digitized prosthetic CAM Framework

contacts and vertical dimensions were adjusted to obtain normal values of the EMG standardized indices (see below). Articulating paper (Bausch, Germany) was used to morphologically finalize the occlusion and adjust it with respect to the functional parameters (Fig 3 a-b). Morphological occlusion consisted of central contacts on all the masticatory units. Dynamic occlusion consisted of group function guidance regardless of the opposite arch settings. This stereotyped occlusion was functionalized in each patient by means of the patient-specific neuromuscular response on rehabilitation. The EMG test was repeated during the recall appointment one year after the surgery (Fig 4).

EMG analysis

Details on the protocol have been reported by Ferrario et al. (1,4). In brief, four disposable bipolar surface electrodes (Duo-Trode; Myo-Tronics Inc., Seattle, WA, USA) were positioned on the muscular bellies identified by palpation during a voluntary clench. EMG potentials were detected, amplified, digitized, digitally filtered and recorded using four of the six channels of the above mentioned computerized electromyography (1,2,4).

During the test, all the patients sat with their head unsupported, the feet flat on the floor and the arms resting on the legs; they were asked to maintain a natural upright position. They performed both a standardization test and a 3 seconds maximum

Table 1. Maximum voluntary teeth clenching in patients one week after surgery (prosthesis delivery).

Patient	Age	POC masseter %	POC Temporalis %	TC %	APC %	Activity standardized $\mu V/\mu V s$ %
1	71	88	89	91	91	105
2	57	84	82	88	90	92
3	71	85	87	88	85	95
4	65	86	85	90	78	93
5	70	88	87	89	87	92

POC, percentage overlapping coefficient (index of left-right muscular symmetry); TC, torque coefficient (potential lateral displacing component); APC, antero-posterior coefficient (relative activities of masseter and temporalis muscles).

voluntary clench test. During the standardization test (lasting 3 seconds), a maximum voluntary clench performed on two cotton rolls positioned on the mandibular second premolar and molars was recorded. This record obtains a series of reference values to standardize all further EMG potentials recorded during the maximum clench performed directly on the occlusal surfaces (1). All values were expressed as a percentage of the standardization recordings ($mV/mV \times 100$), and indices were computed as follows.

The Percentage Overlapping Coefficient (POC, %) was computed to quantify the muscular symmetry. Its value ranges between 0% and 100%. When two paired muscles contract with perfect symmetry, a POC of 100% is obtained (normal values >83%) (6). TA and MM POCs were obtained for each patient.

To compare the standardized muscular activities of masseter and temporalis muscles, an antero-posterior coefficient (APC, unit %) was obtained as the ratio between the non-overlapped and the overlapped masseter and temporalis muscle areas of both sides (normal values > 90%) (6). When the standardized masseter and temporalis potentials are well comparable, the index is equal to 100%; when the patients have unbalanced standardized masseter and temporalis potentials, the index is equal to 0%. When standardized muscular potentials are not balanced between the masseter and temporalis muscles, the occlusal center of gravity (MVC on the occlusal surfaces as compared to MVC on the cotton rolls) might be displaced backwards (masseter prevalent) or onwards (temporalis prevalent).

The Torque Coefficient (TC,%) was used to measure the tendency of the mandible to move toward one side during a symmetric bilateral clenching, given by unbalanced contractile activity of contralateral masseter and temporalis muscles

(righttemporalis and leftmasseter vs. lefttemporalis and right masseter). Its value ranges between 0% (complete presence of lateral displacing effect) and 100% (no lateral displacing effect) (normal values >90%) (6).

The Impact Coefficient (IC, $\mu V/\mu V s$; 14) was used to measure the global muscular activity computed as the mean EMG standardized potentials over time (normal values range between 87 $\mu V/\mu V s$ and 107 $\mu V/\mu V s$) (6).

Results

The EMG evaluation allowed us to measure the good functional impact of the dental contacts on the full mouth prosthetic reconstructions. Normal values of all EMG indices were obtained in each patient adjusting the occlusal contacts; a well harmonized contraction of the masticatory muscles allowed the force imbalance over the resin prosthesis and the bone. During the maximum voluntary clench one week after surgery, all patients had symmetric standardized potentials (POC values between 80% and 100%, and TC values larger than 90%, as shown in Table 1). None of the fixed prostheses (Fig. 5) were lost during the observation time, yielding a survival rate of 100%. Only one of the all-acrylic resin prosthesis displayed fracture of the resin material (Fig. 6). No occlusal screw loosening was observed. At the 1-year recall appointments, all the patients still had symmetric standardized potentials (POC values between 80% and 100%, and TC values larger than 90%, Table 2). In general, at the second visit, we observed larger values on the standardized Activity than at the first one.

Discussion

In the current investigation, patients with full mouth resin rehabilitation on implants were analyzed. All patients were satisfied with their prostheses, and reported an adequate stability on swallow and

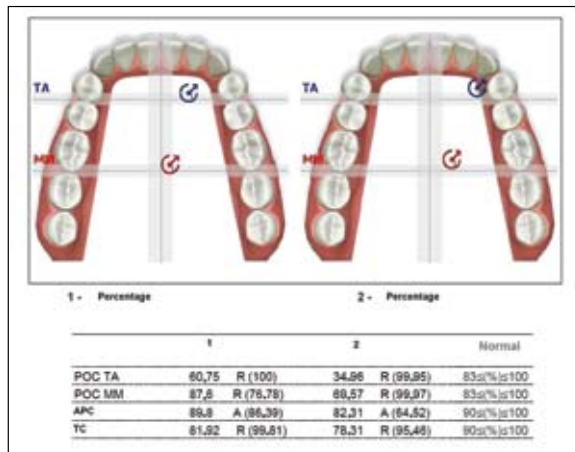


Figure 3a. Results of two sEMG functional tests obtained during the procedure of occlusal adjustment at prosthesis delivery (patient 1) TA: Temporalis anterior; MM: Masseter; POC TA: Standardized muscular symmetry for temporalis anterior muscles; POC MM: Standardized muscular symmetry for masseter muscles; APC: Standardized overlapped muscular activity between masseter vs. temporalis; TC: Standardized overlapped activity between right temporalis and left masseter vs. left temporalis and right masseter; R: Displacing static effect toward right - in brackets the correspondent percentage of muscular asymmetry component; L: Displacing static effect toward left side; A: Displacing onwards static effect (temporalis prevalent); P: Displacing backwards static effect (masseter prevalent); Normal, Normal range of indices (gray areas in the graphical view)

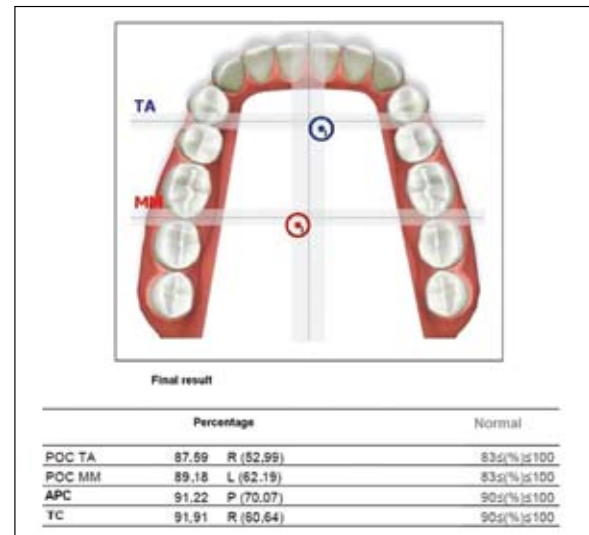


Figure 3b. sEMG test results at the end of the procedure of customized occlusal adjustment (patient 1). For abbreviations, see Figure 3a

masticatory efficiency. The EMG tests were performed one week and one year after the completion of their prosthetic reconstructions, a time considered more than sufficient for the development of good muscle activity and force generation (7,11).

It has to be underlined that the current five patients were not randomly selected, and their prosthetic

rehabilitations were chosen independently from the present investigations. Only well-satisfied patients in private practice were asked to undergo the present protocol. Therefore, the extrapolation of the present results to a wider population should be done with caution (12-14).

The detection of the relationship between function and its morphological substrates has always been one of the most intriguing matters in dentistry. In particular, one still debated question is the relationship between dental contacts, and the function of jaw elevator muscles (15,16). In clinical practice, values recorded in healthy subjects with a full natural dentition are considered the reference norm (1,6).

In the patients analyzed in the present study, the EMG indices computed from the electrical potentials recorded during the maximum voluntary clench test were well super imposable to the values found in healthy subjects with

Table 2. Maximum voluntary teeth clenching in patients at the 1-year recall appointment.

Patient	Age	POC masseter %	POC Temporalis %	TC %	APC %	Activity standardized $\mu V/\mu V s$ %
1	71	85	83	91	88	95
2	57	83	85	90	88	97
3	71	82	86	87	82	95
4	65	83	84	89	83	98
5	70	85	86	88	91	95

POC, percentage overlapping coefficient (index of left-right muscular symmetry); TC, torque coefficient (potential lateral displacing component); APC, antero-posterior coefficient (relative activities of masseter and temporalis muscles).

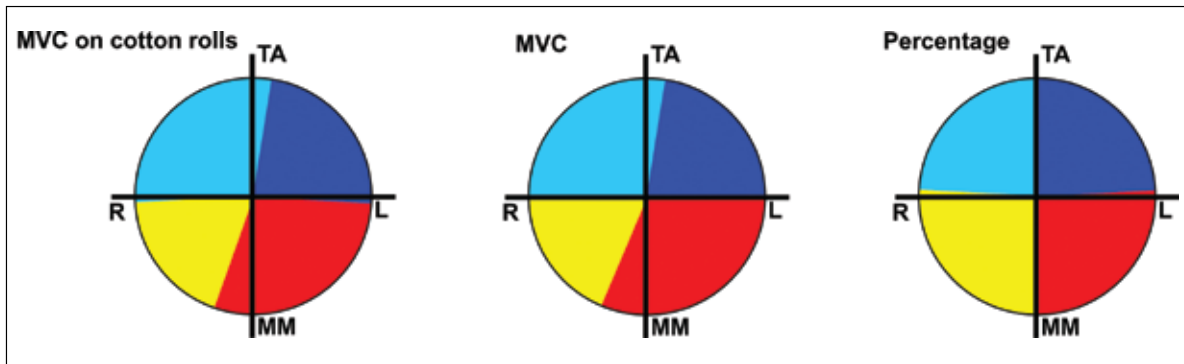


Figure 4. One year functional test results, “at a glance” view (patient 1)

MVC on cotton rolls pie chart: non-standardized EMG average amplitude activity (raw data) during a 3 s maximum voluntary clench on cotton rolls between R = right L = left TA (temporalis anterior) muscles, and R = right L = left MM muscles. The higher the raw value, the wider the chart sector.

MVC pie chart: non-standardized EMG average amplitude activity (raw data) during a 3 s maximum voluntary clench on dental surfaces.

Percentage pie chart: ratios between raw data on dental surfaces and raw data on cotton rolls (standardized EMG average amplitude activity). Graph sectors with equal area and centered on the origin axis indicate a normal functional occlusal equilibrium



Figure 5. Final prosthetic result



Figure 6. Particular of prosthesis fracture

natural and normal occlusion (1,6), and they could be useful to clinically address some of the aforementioned questions. In a situation of perfect symmetry, the POC, TC and APC indices should be 100%. Of course, this hypothesis is only theoretical, and, starting from the statistical evaluation of data collected in healthy individuals, POC values larger than 83%, TC larger than 90%, APC larger than 90% and EMG standardized potentials over time between $87 \mu\text{V}/\mu\text{V s\%}$ and $107 \mu\text{V}/\mu\text{V s\%}$ are considered to be normal (6).

The limited TC values show that patients had no premature and sliding contacts due to the natural and prosthetic occlusal surfaces. Morphological alterations of the occlusal surfaces can generate a mandibular torsion (4). Indeed, even if an actual mandibular torsion has already been observed in several experimental models (17-19), in most cases this phenomenon is not macroscopically appreciable, because several other muscles (the medial pterygoid, for instance) could counterbalance the torque effect provoked by the masseter and temporal

muscles. Nevertheless, continuous microstresses can be dangerous for the muscles themselves, the temporomandibular joint (20), and the bone, with altered load patterns.

The increased standardized activity recorded in the second assessment can be explained with the effect of one year “training”: the patients regained confidence with their stomatognathic system and used well their masticatory muscles and their new occlusal surfaces.

Surface EMG of the masseter and temporal muscles, therefore, allowed an objective quantification of the good functional characteristics of the new occlusal equilibrium of the patients’ prosthesis analyzed in the current study.

The results are also in accord with literature findings: a correct prosthetic reconstruction on implants can restore a good functional situation. The relevant static characteristics are not obviously superimposable to those measured in subjects with a natural dentition, but are better than those that can be obtained with removable dentures (21).

Conclusions

A dentist should be able to control and detect occlusal alterations produced by a non-equilibrated rehabilitation using the most correct methods. The method used in the present investigation allows a static evaluation of occlusion and can detect mandibular torsions and alterations between the two sides that cannot be controlled only with qualitative or purely morphological methods (articulation paper).

The present surface EMG analysis of a static (clenching) task showed that the analyzed prostheses need stable dental contacts between the opposing dental arches.

This functional condition could be protective for full-mouth prosthetic resin complications over implants. It should be underlined that the simplicity of the current tests with a minimal effort could provide useful clinical information for the day-to-day clinical practice.

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CV

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Questions

What should be included in a correct evaluation of prostheses:

- a. the stomatognathic function;
- b. the morphological evaluation of the occlusion is not required;
- c. the measurement of the actual impact of the morphology on the stomatognathic function;
- d. the previous prosthetic reconstruction.

The values for the EMG indices in the five study patients were:

- a. abnormal;
- b. normal;
- c. unusually high;
- d. unusually low.

How many patients were followed in this study and for how long:

- a. 5 patients for 10 years;
- b. 50 patients for 1 year;
- c. 5 patients for 1 year;
- d. 50 patients for 10 years.

In what interval was the TC (torque coefficient) for the study patients:

- a. 25-50%
- b. 50-75%
- c. 85-95%
- d. 25-75%