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ssEMG assessment of a new tool for the management of 3D vertical dimension of occlusion in prosthetic dental rehabilitations: A case report

Riccardo Rosati[1], Redento Peretta[2], Francesco Rosati[3], Federica Musto[1], Claudia Dellavia[4]

SUMMARY

In oral rehabilitation the new dental morphology requires changes in the occlusal relations and in case of whole dental arch restoration also the mandibular position can undergo three-dimensional spatial modifications. Overloads and/or altered distributions of the stresses on the temporomandibular joint, teeth and bones may therefore result with not clearly understood consequences. In the present case report a new tool -Vertical Tester- designed to manage the 3D vertical occlusion during an implant retained full mouth rehabilitation was combined with standardized surface electromyographic (ssEMG) analysis in order to respect the masticatory muscle symmetry and coordination.

The Authors conclude that the standardized surface electromyography of the masticatory muscles coupled with custom made centric relation registration device is an easy to use procedure to reduce torsional strains on the oral hard structures.

Key words: dental occlusion, prosthetic rehabilitation, electromyography, dental implant.

INTRODUCTION

During adulthood, after childhood and adolescent development, all parts of the face continue to modify (1-3) and the masticatory performance too (4, 5). If physical and chemical mechanism like stress, friction, and corrosion exceed the adaptation capacity of the system, a pathological process can occur causing extensive destruction of patient's natural tooth morphology and its supporting structures (6). Altered dentition due to traumas, caries, tilted, drifted, rotated or malpositioned teeth results in compromised aesthetics, phonetics and mastication (7).

When an oral rehabilitation is approached, prosthetic dental reconstructions are often used to restore lost masticatory units, recreate compromised dental structures or replace incongruous prostheses. The new morphology requires changes in the occlusal relations and in case of whole dental arch restoration also the mandibular position can undergo 3D spatial modifications (8, 9). Occlusal morphologies that are not adequately designed and positioned may therefore alter the muscle generated forces distribution causing changes on temporomandibular joint, teeth and bones loads (10, 11) with not clearly understood consequences. Also neck muscles recruitment can suffer changes in teeth-perio-bone proprioception (12-14). These iatrogenic changes are perceived by the proprioceptive system requiring a functional adaptation to reduce the overload to the hard structures. If the posterior occlusal areas are not sufficiently sized (Fig. 1), an overload of the temporomandibular joint may occur together with a reduction of some masticatory muscle performance. This functional adaptation pattern is not proven to remain stable over time and during the day- and night-time parafunctional activities and the consequences of altered muscles behaviour on facial morphology are not completely understood (15). It should also be underlined that the selective (non-uniform and homogeneous) inhibitions of the masticatory muscles can establish the onset of torsional stresses during maximum clenching, reaching not easily evaluable forces. Indeed, as reported by Koyano *et al*. (16), the "'indirect' methods, that is, improving function by providing an appropriate morphology, are nevertheless superior to other prostheses, such as eye prostheses, that are

[1]University of Milan, Milan, Italy
[2]Private practice, Vicenza, Italy
[3]Private practice, Udine, Italy
[4]Department of biomedical, surgical and dental sciences, University of Milan, Milan, Italy

Address correspondence to Riccardo Rosati, via Luigi Mangiagalli 31, 20133 Milano, Italy.
E-mail address: riccardo@riccardorosati.eu

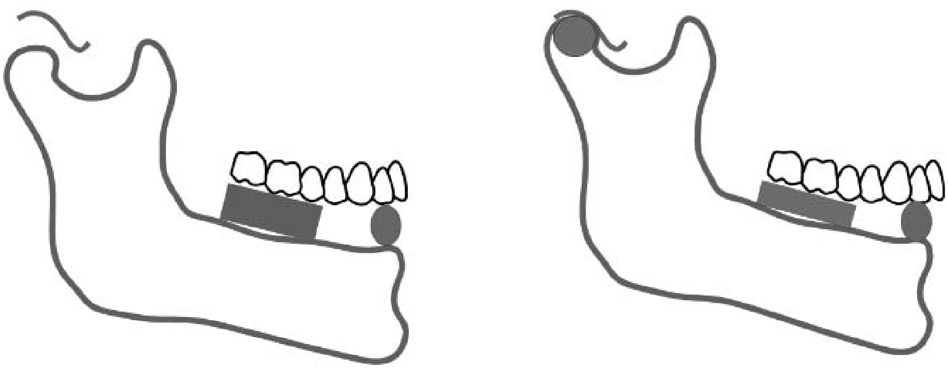

Fig 1. In case of insufficiently sized posterior occlusal areas a temporomandibular joint overload could result

Fig 2. Patient's initial clinical condition

Fig 3. Patient's dental orthopantomography

monitor the main changes in the masticatory and neck muscles recruitment pattern due to the dental contact (teeth-perio-bone proprioception) (17, 18). An effective measurement of the muscular consequences of dental treatment can support the clinician to design a rehabilitation without abnormal stress transmission on the hard structures. The following case report represents an example of standardized electromyography application in a full arch dental rehabilitation.

CASE REPORT

Ms. Marisa (Fig. 2 and 3), aged 55 years, presented to the clinical observation to restore the lost chewing function. Chronic infectious phenomena caused loss of teeth and periodontal support in several sites with alteration in the survived teeth position. Marisa was informed about the first choice and most conservative treatment plan that included infection control procedures, lost bone volume reconstruction and replacement of hopeless teeth using dental prostheses supported by prosthetic-guided osseointegrated implants. Since the patient declined bone restoration treatment, the Author RR proceeded with the alternative therapy that comprises implant supported alveolar-teeth prostheses. That alternative treatment plan included the extractions of the elements 14, 22, 23, 24, 25 and their replacement with prostheses supported by implants positioned at 16, 14, 22, 24, 25 sites, for the maxillary arch. The treatment plan for the lower arch comprised all teeth extraction and the subsequent restoration of the mandibular dental arch with a fixed prosthesis

morphologically correct and have adequate aesthetics but cannot improve function (e.g. vision)". In addition, the Authors state "A method of occlusal rehabilitation that certainly improves function is not yet available" (16). In that perspective, the surface electromyography of the masticatory muscles (adequately standardized according to the most modern methodological standards), allows the clinician to supported by 6 osseointegrated implants. The patient gave her consent to all the therapies. Before the definitive prostheses production, it was decided to verify the three-dimensional posture of the jaw by means of a standardized surface electromyography of the masseter (MM) and anterior fibers of temporal (TA) muscles.

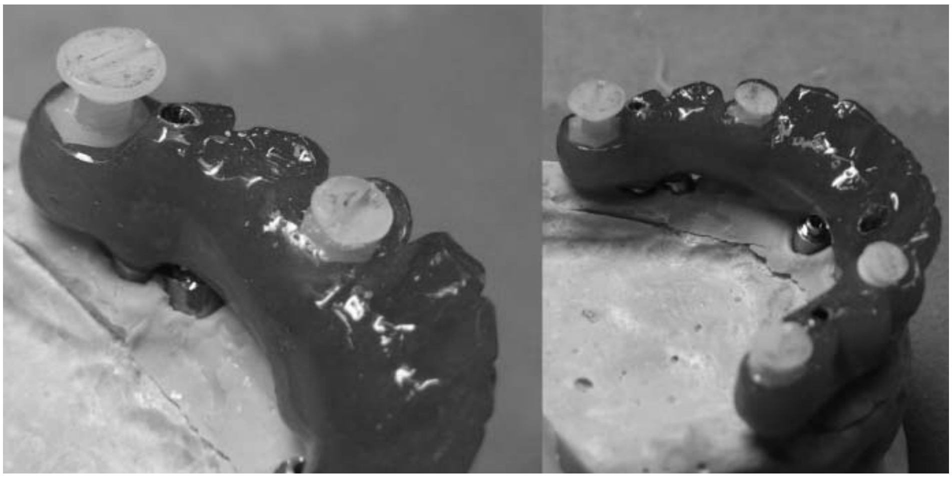

Fig 4. Vertical Tester on the gypsum model

Fig 5. Vertical Tester installed in the mouth

Electromyographic procedures

The electromyographic procedures was performed as previously described by Ferrario *et al.* (17, 19). On each muscle a disposable pre-gelled silver/silver chloride bipolar surface electrodes (21×41 mm, 20 mm inter-electrode distance) (F3010, Fiab, Firenze, Italy) were positioned on the muscular bellies parallel to muscular fibers as follows (17):

- MM. The electrodes were fixed parallel to the exocanthion-gonion line and with the upper pole of the electrode under the tragus-labial commissural line.
- TA. The electrodes were fixed vertically along the anterior margin of the muscle (corresponding to the fronto-parietal suture).

A disposable reference electrode was applied to the forehead. To reduce skin impedance, the skin was carefully cleaned prior to electrode placement, allowing the conductive paste to adequately moisten the skin.

Surface EMG activity was recorded using a computerized instrument (Easymyo, 3 Technology S.r.l., Udine, Italy). The analogue sEMG signal was amplified (gain 100, bandwidth 0-1000 Hz, peak-to-peak input range from 0 to 3600 mVpp) using a differential amplifier with a high common mode rejection ratio (CMRR 100 db in the range 0-60 Hz, input impedance 100 Gohm), digitized (24 bit resolution, 4000 Hz A/D sampling frequency), and digitally filtered (high-pass filter set at 30 Hz, low-pass filter set at 400Hz, band-stop for common 50–60 Hz noise). The signals were averaged 25 ms, with muscle activity assessed as the root mean square (RMS) of the amplitude. sEMG signals were recorded for further analysis. Before acquisition session, the subjects were properly trained to elicit true teeth maximal voluntary contraction using an on-time sEMG signal visualization.

Fig 6. Vertical Tester in maximum intercuspation

Electromyographic signal standardization

The electromyographic signal normalization is a procedure that allows to reduce the raw signal inter-appointment and between subject's variability linked to technical aspects (electrode position, changes in the soft tissue conductivity above the muscle, cross-talk effect, alterations in the patient body composition etc.).

In order to reduce raw signal variability and isolate the dento-perio-bone proprioceptive component and understand its role in the organization of masticatory muscles two acquisitions are performed:

Reference test asking the subject to clench at maximum two cotton rolls interposed between

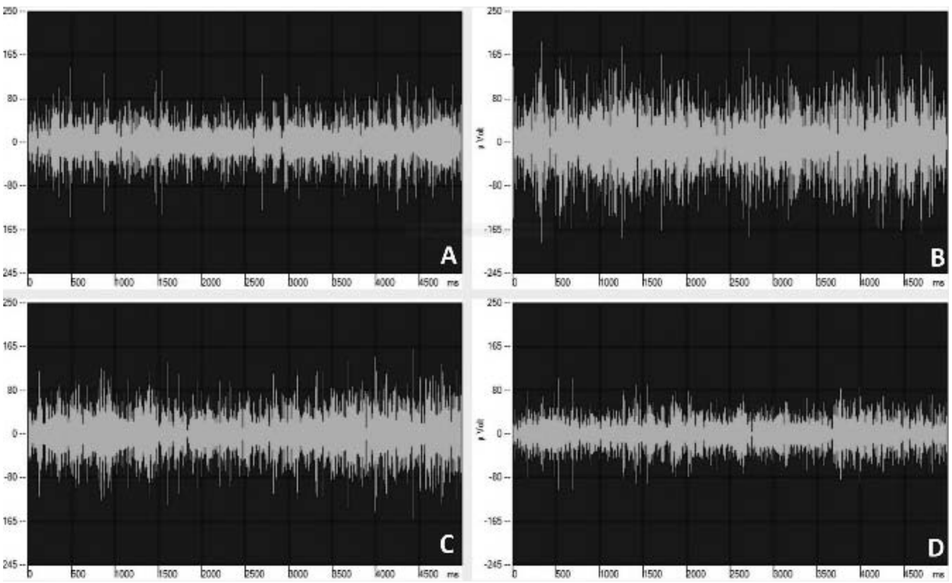

Fig 7. The normalization test clenching on cotton rolls. A right anterior Temporal, B left anterior Temporal, C right Masseter, D left Masseter.

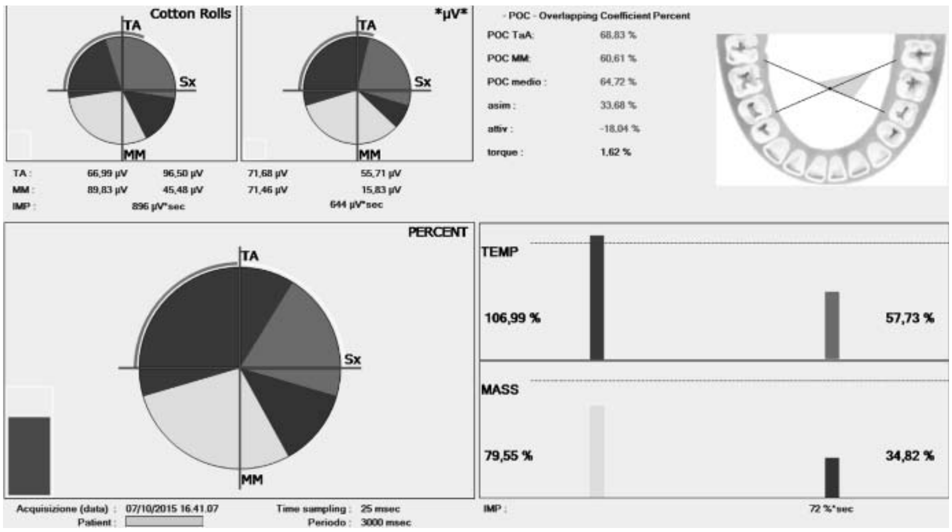

Fig 8. The first test normalized output quantifying the muscular coordination indexes with the Vertical Tester. The bigger pie represents the periodontal proprioception (dental occlusion) effect on masticatory muscles (Temporals in red and purple, Masseters in dark and light blue, left and right respectively). In an ideal situation no periodontal effect on masticatory muscles should be obtained with a relative graph consisting of 4 slices of the same size. In this example the left side vertical dimension of occlusion is causing an overload in the left side TMJ then the left side muscles reduced their performance protecting the hard tissues. Normalized electromyography indexes are Anterior Temporal Percentage Overlapping Coefficient (POC), Masseter POC, Asymmetry, Activity, Torque and Impact.

the dental arches (with temporary prosthesis in this case). During this task the dento-perio-bone proprioception is reduced at minimum since the occlusal surfaces are not in contact.

Patient occlusion test clenching at maximum with the arches in maximum intercuspation; in this case with a device called Vertical Tester aimed to simplify the muscles guided intermaxillary relationship registration (see below in the text).

A differential analysis allows to quantify the differences between the two acquisitions – that are acquired under the same conditions – attributable to the dento-perio-proprioception.

Young healthy subjects perform very similar contractions in the two conditions with a percentage overlapping coefficient POC (of the two acquisitions) greater than 80%.

Muscle performance differences during the two tests are therefore attributable to the proprioception of the tooth complex or prosthesis-osseointegrated implant-supporting bone (i.e. dental occlusion).

Before the definitive prosthesis production, the three-dimensional position of Marisa's mandible was tested using the described differential electromyographic procedure. To facilitate the achievement of an occlusal structure that allows a symmetrical muscle performance, a special tool called Vertical Tester (Fig. 4 to 6) has been designed and produced (ideated and realized by Authors RP and FR). The Vertical Tester consists of a resin reproduction of the temporary prosthesis with integrated four plastic screws in contact with the first premolar and first molar antagonist teeth. Working on the screws, separately and with different rotation magnitude, the clinician can change the vertical dimension of the anterior, posterior, right and left mandibular arch sectors selectively in a simple and fast way adjusting the mandible position in a three-dimensional way compensating the lateral side shift due to tooth displacement secondary to periodontal support and/or tooth loss. The device is designed orienting the screw plate perpendicular to the palatal maxillary cusp allowing a stable maximal clenching avoiding screw fracture. With sequential normalized electromyographic tests (Fig. 7 and

8) a maxilla-mandibular relationship allowing symmetric, contemporary and not subject to protective inhibitions muscle function can be easily achieved (Fig 9). Through that tool, a three-dimensional alveolodental arch position allowing symmetric muscle recruitment without selective or generalized muscular inhibitions avoiding torsional strain on articular, dental and bone structures could be obtained.

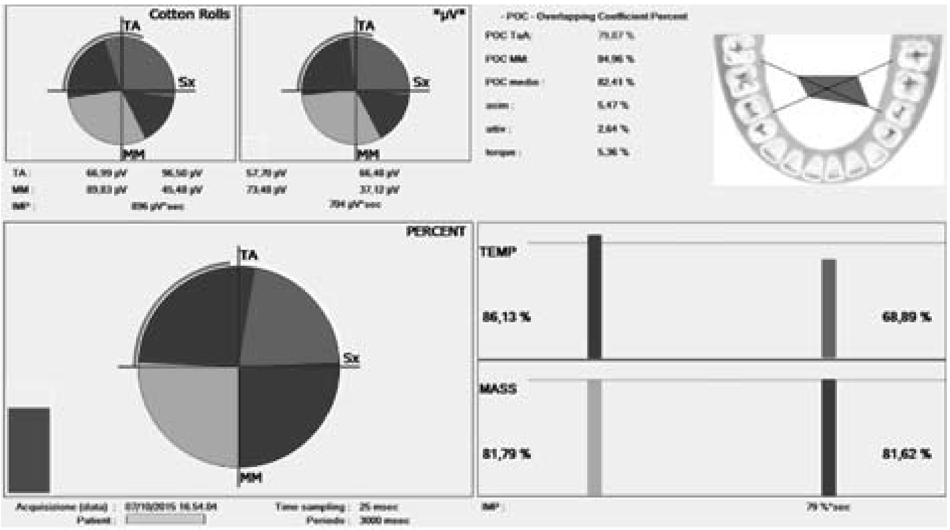

Fig 9. The last test normalized output with the regulated Vertical Tester. No relevant muscle asymmetry or torsional effects were found (standardized muscles indexes are all normal and the pie graph consist in 4 similar slices).

Reached an ideal muscular function, the mandibular position was recorded fixing the screws with light-curable resin (Fig. 10) and a silicone occlusal register. The laboratory technician then proceeded to produce the final prosthesis reproducing the morphology of the previously tested temporaries respecting the three-dimensional setting defined with the electromyographic test (Fig. 11 to 13).

Fig 10. The 3D muscular defined cranio—mandibular position was fixed and transferred to the articulator

DISCUSSION

The advantages of this device basically consist in the best management of oral biomechanics since it allows fast and easy area-specific changes in vertical dimension of occlusion coupled with muscles recruitment evaluation (ssEMG). In addition, the standardized sEMG procedures permit a repeatable and reliable muscles evaluation (20) reducing the well-known limitation of surface EMG acquisition technique (21). All tests are performed in maximum voluntary clenching, a condition of high mechanical stress. Symmetrizing the muscular forces distribution on the biological and prosthetic hard structures plausibly reduces torsional stress; in cases of full arch implants supported rehabilitations, reducing torsional strain probably increases prosthetic survival rate. Indeed, balancing the Masseter versus Temporals and right versus left side muscular work, also the TMJ structures benefit from reduced mechanical stresses. The main disadvantages of the proposed method are linked to the increase of clinical steps and therefore costs compared to the registration without instrumental evaluation. Furthermore, in the case of implant supported full arch rehabilitation it is relatively easy to design and produce the Vertical Tester which allows to modify the vertical dimension of occlusion selectively in each arch sec-

Fig 11. The final result: an intraoral view

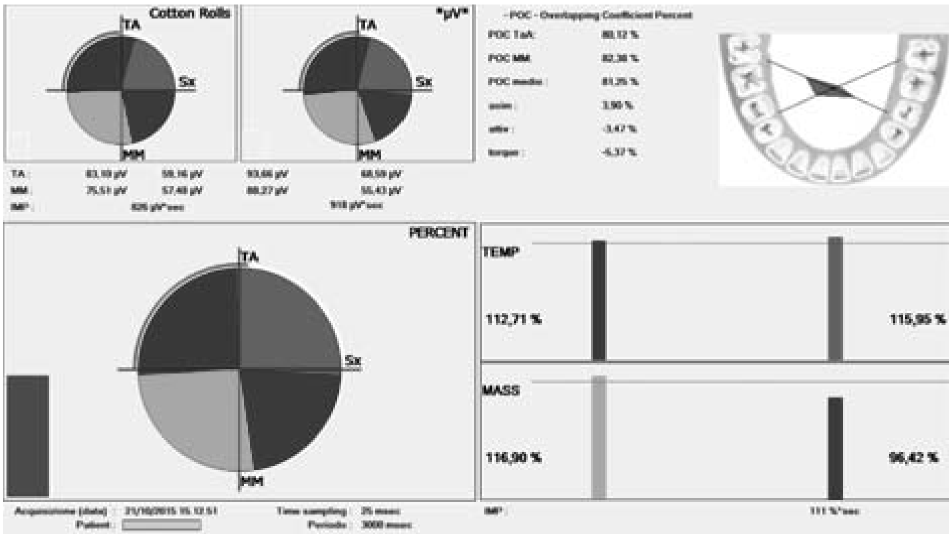

Fig 12. The last test normalized output with the definitive rehabilitation

Fig 13. The final result: an extraoral view

tor in a simple and fast way. In the case of natural teeth prosthesis, it is not possible to incorporate the screws so the verticality should be tested milling or increasing resin occlusal splints, which is a more time-consuming procedure.

CONCLUSIONS

The standardized surface electromyography of the masticatory muscles coupled with a custom made device for centric relation registration is an effective and easy to use procedure to avoid the generation of torsional strains on the oral hard structures. Evolution in the technical procedures to simplify functional management should be encouraged.

STATEMENT OF CONFLICTS OF INTEREST

The authors state no conflict of interest.

REFERENCES

1. Akgül AA, Toygar TU. Natural craniofacial changes in the third decade of life: a longitudinal study. *Am J Orthod Dentofacial Orthop* 2002;122:512-22.
2. Iblher N, Kloepper L, Penna V, Bartholomae JP, Stark GB. Changes in the aging upper Lip--a photomorphometric and MRI-based study (on a quest to find the right rejuvenation approach). *J Plast Reconstr Aesthet Surg* 2008;61:1170-6.
3. Rosati R, de Menezes M, Rossetti A, Ferrario VF, Sforza C. Three-dimensional analysis of dentolabial relationships: effect of age and sex in healthy dentition. *Int J Oral and Maxillofac Surg* 2012;41:1344-9.
4. Cecílio FA, Regalo SC, Palinkas M, Issa JP, Siéssere S, Hallak JE, Machado-de-Sousa JP, Semprini M. Ageing and surface EMG activity patterns of masticatory muscles. *J Oral Rehabil* 2010;37:248-55.
5. Palinkas M, Cecilio FA, Siéssere S, de F Borges T, de Carvalho CA, Semprini M, de Sousa LG, Regalo SC. Aging of masticatory efficiency in healthy subjects: electromyographic analysis-Part 2. *Acta Odontol Latinoam* 2013;26:161-6.
6. Dawson PE. Evaluation, Diagnosis and treatment of occlusal problems. 2nd ed. St.Louis: Mosby;1989.
7. Tanaya, Pankaj D, Piyush T, Shivam ST, Divyesh M. Multidisciplinary approach in full mouth rehabilitation. *J Res Med Dent Sci* 2020;8:57-62.
8. Li J, Chen Z, Dong B, Wang HL, Joda T, Yu H. Registering maxillomandibular relation to create a virtual patient integrated with a virtual articulator for complex implant rehabilitation: a clinical report. *J Prosthodont* 2020;29:553-57.
9. Farias-Neto A, Dias AHM, de Miranda BFS, de Oliveira AR. Face-bow transfer in prosthodontics: a systematic review of the literature. *J Oral Rehabil* 2013;40:686-92.
10. Ferrario VF, Sforza C. Biomechanical model of the human mandible: a hypothesis involving stabilizing activity of the superior belly of lateral pterygoid muscle. *J Prosthet Dent* 1992;68:829-35.
11. Ferrario VF, Sforza C. Biomechanical model of the human mandible in unilateral clench: distribution of temporomandibular joint reaction forces between working and balancing sides. *J Prosthet Dent* 1994;72:169-76.
12. Hellmann D, Giannakopoulos NN, Schmitter M, Lenz J, Schindler HJ. Anterior and posterior neck muscle activation during a variety of biting tasks. *Eur J Oral Sci* 2012;120:326-34.
13. Tecco S, Epifania, E, Festa F. An electromyographic evaluation of bilateral symmetry of masticatory, neck and trunk muscles activity in patients wearing a positioner. *J Oral Rehabil* 2008;35:433-9.
14. Ferrario VF, Sforza C, Dellavia C, Tartaglia GM. Evidence of an influence of asymmetrical occlusal interferences on the activity of the sternocleidomastoid muscle. *J Oral Rehabil* 2003;30:34-40.
15. Kiliaridis S. Masticatory muscle influence on craniofacial growth. *Acta Odontol Scand* 1995;53:196-202.
16. Koyano K, Tsukiyama Y, Kuwatsuru R. Rehabilitation of

occlusion - science or art? *J Oral Rehabil* 2012;39:513-21.

17. Dellavia C, Francetti L, Rosati R, Corbella S, Ferrario V F, Sforza C. Electromyographic assessment of jaw muscles in patients with all-on-four fixed implant-supported prostheses. *J Oral Rehabil* 2012;39:896-904.
18. Ferrario VF, Tartaglia GM, Galletta A, Grassi GP, Sforza C. The influence of occlusion on jaw and neck muscle activity: a surface EMG study in healthy young adults. *J Oral Rehabil* 2006;33:341-48.
19. Ferrario VF, Sforza C, Tartaglia GM, Dellavia C. Immediate effect of a stabilization splint on masticatory muscle activity in temporomandibular disorder patients. *J Oral Rehabil* 2002;29:810-5.
20. Rosati R, Semelewa E, Satygo E, Ivanova EP, Rosati F, Silin A, Ferrario VF. Standardized electromyographic indexes allow a reliable measurement of masticatory muscles function. *Stomatol Edu J* 2016;3:10-7.
21. Suvinen TI, Kemppainen P. Review of clinical EMG studies related to muscle and occlusal factors in healthy and TMD subjects *J Oral Rehabil* 2007;34:631-44.

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