CONCLUSION

Knowing that articulating paper may not be accurate,[8] photocclusion should be considered for diagnosis and treatment of occlusal disharmonies. Combined with articulating paper, it might indicate the precise area in which a deflective contact occurs. It might also be advisable to use the photocclusion method as a follow-up to occlusal adjustment in all patients.

We wish to thank Professor M. Arcan of Tel-Aviv University for his advice and Mr. Ed Warner, Director of Biomedical Communications, Faculty of Medicine, Technion-Israel Institute of Technology, for the illustration.

REFERENCES

1. Arcan, M., and Zandman, F.: Mécanique du contact et biréfringence mémorisée. C R Seances Acad Sci (Paris) Series B, January 14, 1980, p 290.
2. Arcan, M., and Zandman, F.: A method for in vivo quantitative occlusal strain and stress analysis. J Biomechanics **17**:67, 1984.
3. Durelli, A. J.: Applied Stress Analysis. Englewood Cliffs, N.J., 1967, Prentice-Hall, pp 38-51.
4. Gutman, D., Minkov, B., Kost, Y., and Ben-Aryeh, H.: La mesure quantitative de l'occlusion par photoplasticité. Actual Odontostomatol (Paris) **138**:273, 1982.
5. Goldman, H. M., and Cohen, D. W.: Occlusal adjustment by selective grinding. *In* Goldman, H. M., and Cohen, D. W., editors: Periodontal Therapy, ed 4. St. Louis, 1968, The C. V. Mosby Co., pp 568-628.
6. Hosman, H., and Naeije, M.: Reproducibility of the normalized electromyographic recordings of the masseter muscle by using the EMG recording during maximal clenching as a standard. Oral Rehabil **6**:49, 1979.
7. Solberg, W. K., and Clark, G. T.: Temporomandibular joint changes related to dental occlusion. *In* Solberg, W. K., and Clark, G. T., editors: Temporomandibular Joint Problems: Biologic Diagnosis and Treatment. Chicago, 1980, Quintessence Publ. Co., pp 129-138.
8. Dawson, P. E., and Arcan, M.: Attaining harmonic occlusion through visualized strain analysis. J PROSTHET DENT **46**:615, 1981.

Reprint requests to:
PROF. D. GUTMAN
DEPARTMENT OF ORAL AND MAXILLOFACIAL SURGERY
RAMBAM MEDICAL CENTER
HAIFA, ISRAEL

Influence of vertical dimension on masseter muscle electromyographic activity in patients with mandibular dysfunction

Arturo Manns, D.D.S.,* Rodolfo Miralles, D.D.S., and Francisco Cumsille, M.S.*****
University of Chile, Faculty of Medicine, Santiago, Chile

Several investigators have demonstrated a decrease in electromyographic (EMG) activity of the masseter and temporal muscles when the mandible is depressed beyond the postural position.[1-6] Others have observed that the vertical dimension of occlusion can be increased several millimeters with occlusal splints without evidence of EMG disturbances.[7-9]

We studied the relation between basal tonic EMG (BT-EMG) activity and variations of vertical dimension in patients with normal function of the masticatory system and in patients with mandibular dysfunction.[10,11] Through static and dynamic variations of the vertical dimension of occlusion, the exact site where minimum BT-EMG activity of the masseter muscle occurred was determined (mean 10 mm of interocclusal distance in normal function and 8.45 mm in myofascial pain-dysfunction syndrome). Rugh and Drago[12] also observed a specific vertical dimension of occlusion of least BT-EMG activity for the patients studied that ranged from 4.5 to 12.6 mm (mean, 8.6 mm).

The purpose of the present study was to analyze the influence of increments in the vertical dimension on BT-EMG activity of the masseter muscle by means of occlusal splints adjusted at different heights in patients with mandibular dysfunction.

MATERIAL AND METHODS

The study was carried out on 60 patients, 51 women and nine men, ranging from 13 to 52 years of age (mean age, 27.3 years). They were selected according to the following criteria[13-15]: spontaneous fascial pain in the preauricular area, severe painful tenderness to palpation of the elevator jaw muscles, mandibular deviation or

*Associate Professor and Chief, Oral Physiology Laboratory, Department of Physiology and Biophysics.
**Assistant Professor, Department of Physiology and Biophysics.
***Associate Professor, School of Public Health.

Fig. 1. Occlusal splints in patients of **A**, group No. 1; **B**, group No. 2; and **C**, group No. 3

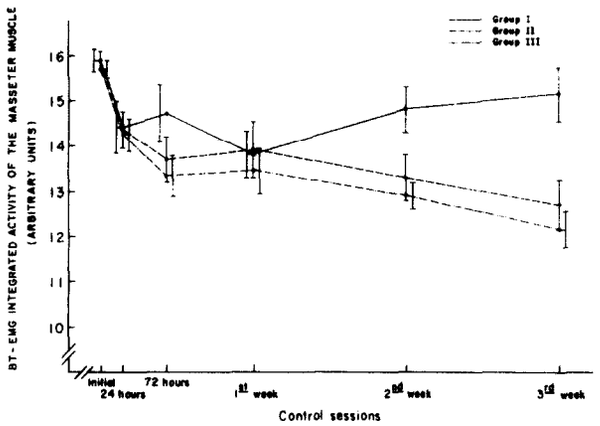

Fig. 2. BT-EMG activity of masseter muscle registered in postural mandibular position (series A) throughout control sessions and for each treatment group.

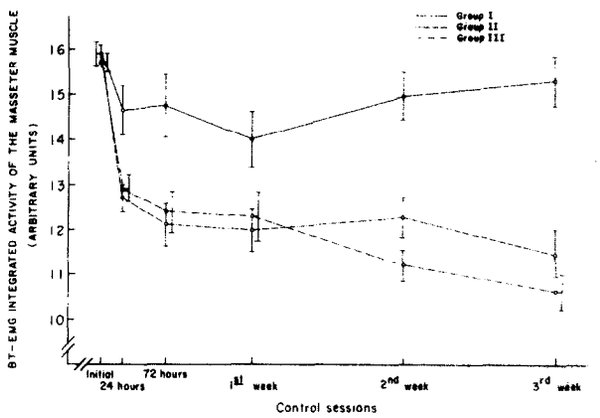

Fig. 3. BT-EMG activity of masseter muscle registered with splint (series B) worn throughout control sessions and for each treatment group.

restricted opening, clicking or popping sounds of the TMJ, and grinding or clenching of the teeth. Patients who had previously used an occlusal splint, showed radiographic changes in the TMJs, or used removable prostheses were not included.

A maxillary occlusal splint was used. It was made with heat-polymerized acrylic resin and had a flat occlusal surface with stable contact and freedom in centric occlusion, with uniform anterior and canine guidance. Disclusion of the posterior teeth was obtained in the different contact positions and functional jaw movements. The use of the splint was restricted to 3 hours diurnally and all night for 3 weeks to avoid extrusion of the posterior teeth.

The vertical dimension of minimum BT-EMG activity or "neuromuscular resting vertical dimension" was determined for each patient according to a technique in which we used a device specifically designed for that purpose.[10] EMG recordings were performed by placing bipolar surface electrodes (Grass 5e 5s, Grass Instrument Co., Quincy, Mass.) on the masseter muscle of the most affected side in the same place each session.[16] EMG activity was filtered (80 Hz to 100 kHz), amplified 1000 times, and then amplified again 10 to 50 times, integrated (time constant 1800 msec), and finally registered on a polygraph (Nihon Khoden RJG-4022, Nikon Kohden Kogyo Co. Ltd., Tokyo, Japan). The recordings of the masseter muscle were used because they showed a more circumscribed EMG activity decrease when compared with the temporal muscle.[10]

The patients were randomly divided into three groups according to the vertical dimension to which the occlusal

Table I. Analysis of variance for BT-EMG activity recorded in postural mandibular position (series A)

Source of variance	*df*	SS	MS	*f*
Between subjects	59	940.25		
Groups	2	86.31	43.16	2.88 ($0.05 < p < .10$)
Error	57	853.94	14.98	
Within subjects	300	947.61		
Time	5	240.75	48.15	21.79 ($p < .01$)
Time × groups	10	75.73	7.57	343 ($0.025 < p < .05$)
Error 2	285	631.13	2.21	
Total	359	1,887.86		

Table II. Analysis of variance for BT-EMG activity recorded with splint (series B)

Source of variance	*df*	SS	MS	*f* ($p < 0.001$)
Between subjects	59	1,297.59		
Groups	2	430.42	215.21	14.15
Error 1	57	867.17	15.21	
Within subjects	300	1,269.29		
Time	5	459.93	91.99	39.70
Time × Groups	10	148.88	14.89	6.43
Error 2	285	660.48	2.32	
Total	359	2,566.88		

splint was adjusted (Fig. 1). Group No. 1 included 20 patients with the splint adjusted to 1 mm from occlusal vertical dimension. There were two men and 18 women in the group, whose mean age was 26 years with a range of 13 to 52 years. Group No. 2 included 20 patients with splints adjusted to a vertical dimension that corresponded to half the difference between occlusal vertical dimension and the vertical dimension of least BT-EMG activity of the masseter muscle. There were four men and 16 women in group No. 2, whose mean age was 28 years with a range of 15 to 52 years. The mean vertical dimension was 4.25 mm. Group No. 3 included 20 patients with splints adjusted to a vertical dimension of least BT-EMG activity of the masseter muscle. There were three men and 17 women in group No. 3, whose mean age was 28 years with a range of 15 to 53 years. The mean vertical dimension was 8.25 mm.

BT-EMG activity of the masseter muscle was evaluated initially and during control sessions (24 hours, 72 hours, first week, second week, and third week) under two experimental conditions: A, recordings in the postural mandibular position; and B, recordings with the splint inserted and with slight tooth contact. Three recordings of BT-EMG activity were performed in each series for a total of 60 recordings each in series A and in series B, in each control session, and for group treatment.

ANALYSIS OF DATA

Recordings of BT-EMG activity obtained in each control session lasted approximately 20 seconds; therefore, they were divided into 3-second intervals. Values in the ordinate were obtained by manual measuring, and the mean amplitude was then calculated for each recorded curve. Subsequently, a mean value of the three curves in each series per control session and for each patient was used because standard deviation values were similar and negligible.

RESULTS

Fig. 2 shows BT-EMG activity of the masseter muscle registered in the postural mandibular position (series A) during control sessions and for each treatment group. The plotted curves were based on the mean value of masseter BT-EMG activity per control session and for the 20 patients of each group. In this figure it is possible to note a gradual and continuous decrease of EMG activity from first to last session for group Nos. 2 and 3 in comparison with group No. 1, which shows a fluctuating tendency.

Table I presents the analysis of variance (ANOVA) for series A. The overall group effect was not found to be significant ($f = 2.88$, $0.05 < p < .10$). However, at the end of the treatment there were significant differences between group Nos. 1 and 2 as well as between group Nos. 1 and 3 (Tukey test).

Fig. 3 shows the evolution of BT-EMG activity of the masseter muscle registered with the splint (series B) throughout control sessions and for each treatment group. The plotted curves were based on the mean value of masseter BT-EMG activity per control session and for the 20 patients of each group. The EMG activity

registered in the postural mandibular position was considered to be the initial value. In this figure a reduction of EMG activity when the splint was worn (from 24 hours to the third week of treatment) for group Nos. 2 and 3 can be observed compared with group No. 1. Note also the faster masseter muscle EMG reduction at 24 hours for group Nos. 2 and 3 and the gradual decrease to the last session (third week). Group No. 1 shows only a slight, fluctuating decrease throughout the control session.

Table II shows the ANOVA for series B. There was a significant overall group effect ($f = 14.15$, $p < .001$) and also group × time interaction ($f = 39.70$, $p < .001$). There were significant differences between group Nos. 1 and 2 as well as between group Nos. 1 and 3 (Tukey test).

DISCUSSION

Several hypotheses have been offered to explain the clinical efficacy of occlusal splints in the treatment of masticatory muscle hyperactivity. One hypothesis maintains that success is due to the muscular relaxation produced by a decrease of EMG activity of the jaw muscles.[17-20]

In this study the occlusal splint design was kept constant, with changes introduced exclusively in its vertical height. It is therefore tempting to conclude that the significant reduction of BT-EMG activity of the masseter muscle at the end of treatment was due to the vertical dimension increment factor. The vertical height of the splints of group Nos. 2 and 3, which were adjusted at or near the vertical dimension of least EMG activity, may be effective in short-term efforts to reduce masseteric muscle hyperactivity.

These results are similar to those obtained by Carlsson et al.[8] and Clark et al.[21] It should be mentioned that the Carlsson study used asymptomatic subjects. Our results are in disagreement with the "clinical criterion" that an increase in vertical dimension of occlusion beyond the postural one would trigger muscular hyperactivity.

BT-EMG activity reduction observed throughout control sessions with splints in place, which exceeded the interocclusal distance in comparison with those obtained initially in the postural mandibular position, can be explained as follows. To maintain the vertical jaw postural position, a certain amount of muscular tonic activity is necessary. This means a certain number of muscle fibers are active and finally a certain number of sarcomere cross-bridges are involved.

In group Nos. 2 and 3 patients, the vertical height of the splints lengthened the masseter muscle near its optimum physiologic elongation, where the highest number of sarcomere cross-bridges between thin and thick myofilaments of its muscle fibers are available.[6,22] Near the optimum muscular length, therefore, a lesser number of muscle fibers are necessary to provide a certain tonic muscular activity. In the muscular length corresponding to the postural mandibular position there are fewer cross-bridges, which means that to provide the same tonic muscular activity, more muscle fibers and therefore more motor units must be recruited, thereby determining highest EMG activity.

The gradual decrease of EMG activity observed in the postural mandibular position (series A) throughout the control sessions, especially that of group Nos. 2 and 3 compared with group No. 1, can be explained by the effect of EMG activity reduction induced by the vertical height factor of the splints already mentioned. On the other hand, the apparent muscular relaxation is also due to a lower integrated EMG activity of the masseter muscle developed during maximum clenching with a splint worn in group Nos. 2 and 3 as demonstrated in a previous study.[23]

SUMMARY

Occlusal splints were adjusted to different vertical heights and used to single out the influence of vertical dimension of occlusion in increments on BT-EMG activity of the masseter muscle in patients with mandibular dysfunction.

The vertical dimension of least EMG activity was determined for each of 60 patients, who were randomly divided into three groups according to the vertical dimension at which the occlusal splint was adjusted: group No. 1, 1 mm from occlusal vertical dimension; group No. 2, mean vertical dimension, 4.25 mm; group No. 3, mean vertical dimension, 8.25 mm. Results showed a significant reduction of masseter BT-EMG activity (series A and B) at the end of the 3-week treatment period for patients in group Nos. 2 and 3 in comparison with group No. 1. Furthermore, the short-term use of occlusal splints with a vertical height that exceeded the so-called physiologic interocclusal distance did not result in an increase in masseter BT-EMG activity.

This study suggests that an increase of vertical dimension of occlusion to or near the vertical dimension of least EMG activity by means of occlusal splints can be an effective way to obtain a reduction in masseteric muscle activity.

We would like to thank Dr. Fernando Lolas for reading and commenting on this article.

REFERENCES

1. Göepfert, H., and Göepfert, C.: Funktionelle Beziehungen zwischen Masseter und Temporal-muskulatur in der Darstellung ihrer Aktionsströme. Dtsch Zahnarztl Z 10:1530, 1955.
2. Garnick, J., and Ramfjord, S. P.: Rest position. An electromyo-

graphic and clinical investigation. J PROSTHET DENT **12**:895, 1962.
3. Storey, A. T.: Physiology of a changing vertical dimension. J PROSTHET DENT **12**:912, 1962.
4. Garret, F. A., Angelone, L., and Allen, W. L.: The effect of bite opening, bite pressure, and malocclusion on the electrical response of the masseter muscles. Am J Orthod **50**:435, 1964.
5. Manns, A., and Spreng, M.: EMG amplitude and frequency at different muscular elongations under constant masticatory force or EMG activity. Acta Physiol Lat Am **27**:259, 1977.
6. Manns, A., Miralles, R., and Palazzi, C.: EMG, bite force, and elongation of the masseter muscle under isometric voluntary contractions and variations of vertical dimension. J PROSTHET DENT **42**:674, 1979.
7. Kovaleski, W., and De Boever, J.: Influence of occlusal splints on jaw position and musculature in patients with temporomandibular joint dysfunction. J PROSTHET DENT **33**:321, 1975.
8. Carlsson, G., Ingervall, B., and Kocak, G.: Effect of increasing vertical dimension on the masticatory system in subjects with natural teeth. J PROSTHET DENT **4**:284, 1979.
9. Drago, C., Rugh, J., and Barghi, N.: Nightguard vertical thickness effects on nocturnal bruxism. J Dent Res **58**(Special Issue A):316, 1979 (Abstr No. 901).
10. Manns, A., Miralles, R., and Guerrero, F.: The changes in electrical activity of the postural muscles of the mandible upon varying the vertical dimension. J PROSTHET DENT **45**:438, 1981.
11. Manns, A., Miralles, R., Santander, H., and Valdivia, J.: Masseter electromyographic changes as a function of vertical dimension in patients with MPD syndrome. IRCS Med Sci **9**:354, 1981.
12. Rugh, J., and Drago, J.: Vertical dimension: A study of clinical rest position and jaw muscle activity. J PROSTHET DENT **45**:670, 1981.
13. Brooke, R. I., Stenn, P. G., and Motherskill, K. J.: The diagnosis and conservative treatment of myofascial pain-dysfunction syndrome. Oral Surg **44**:844, 1977.
14. Laskin, D.: Etiology of the pain-dysfunction syndrome. J Am Dent Assoc **79**:147, 1969.
15. Manns, A., Miralles, R., and Adrián, H.: The application of audiostimulation and EMG biofeedback to bruxism and myofascial pain-dysfunction syndrome. Oral Surg **52**:247, 1981.
16. Miralles, R., Manns, A., Pavic, J., and Palomino, H.: EMG, bite force and its relation to craniofascial characteristics. IRCS Med Sci **9**:836, 1981.
17. Christensen, L. V.: Effects of an occlusal splint on integrated electromyography of masseter muscle in experimental tooth clenching in man. J Oral Rehabil **7**:281, 1980.
18. Greene, C., and Laskin, D. M.: Splint therapy for the myofascial pain dysfunction (MPD) syndrome: A comparative study. J Am Dent Assoc **84**:624, 1972.
19. Kovaleski, W. C., and De Boever, J.: Influence of occlusal splint on jaw position and musculature in patients with temporomandibular joint dysfunction. J PROSTHET DENT **33**:321, 1975.
20. Newton, A. V.: Predisposing causes for temporomandibular joint dysfunction. J PROSTHET DENT **22**:647, 1969.
21. Clark, G., Beemsterboer, P., Solberg, W., and Rugh, J.: Nocturnal electromyographic evaluation of myofascial pain dysfunction in patients undergoing occlusal splint therapy. J Am Dent Assoc **29**:607, 1979.
22. Nordstrom, S. H., Bishop, M., and Yemm, R.: The effect of jaw opening on the sarcomere length of the masseter and temporal muscles of the rat. Arch Oral Biol **19**:151, 1974.
23. Manns, A., Miralles, R., Valdivia, J., and Santander, H.: Influence of occlusal splint adjusted to different vertical dimension on electromyographic activity, during maximum clenching in patients with MPD syndrome. IRCS Med Sci **9**:848, 1981.

Reprint requests to:
DR. ARTURO MANNS
UNIVERSITY OF CHILE
FACULTY OF MEDICINE
CASILLA 137-D
CORREO CENTRAL
SANTIAGO, CHILE

Reproduction of waxed functional occlusal patterns in fired ceramics

Juan Carlos Abarno, D.D.S., and Pablo Kreiner*
Salto and Montevideo, Uruguay

The typical ceramic materials used in dentistry cannot be cast. Therefore, it is difficult to successfully transfer the occlusal morphology from wax to porcelain. Procedures have been reported to create functional occlusion in ceramics.[1-5] Among them are the use of silicone indexes[6,7] and the "every other tooth" technique.[5,8] All these methods are expensive and time consuming. Most require several additional bakes to form the final anatomy. They must be performed by highly skilled ceramists with excellent knowledge of occlusion.

This article presents a simplified technique to reproduce a functional occlusion in ceramics as formed previously by the drop-wax technique. It can be used for single, multiple, or full arch restorations. It incorporates the standard steps for gnathologic reconstruction and makes it possible to reproduce individualized occlusal morphology in ceramic material.

All the steps in this method are controlled by four

Presented at the Second Congress of the World Confederation of Dental Technologists, Barcelona, Spain.
*Dental Laboratory Technician.