

Refining occlusion with muscle balance to enhance long-term orthodontic stability

Derek Mahony

The primary objective of orthodontic treatment is the movement of teeth into a more ideal relationship, not only for aesthetic, but also for functional considerations. Another very important objective, often not given enough consideration, is the need to finish the case with the muscles of mastication in equilibrium. If muscle balance is not achieved, an endless procession of retainers is required for retention. In simple terms, if the occlusal forces in maximum intercuspation are unevenly distributed around the arch, tooth movement will most likely occur. Today, however, it is possible to simultaneously and precisely measure the relative force of each occlusal contact, the timing of the occlusal contacts and the specific muscle contraction levels. This technological breakthrough represents a paradigm shift in thinking and may improve orthodontic stability.

J Clin Pediatr Dent 29(2): 93-98, 2004

MUSCLE BALANCE AND OCCLUSION

Many well-respected orthodontists agree that there is more to occlusion than just “teeth.” Temporomandibular joint function and the maxillo-mandibular relation are as much a part of occlusion as are the teeth. Consequently, when a mal-function occurs within the TM joints or a maxillo-mandibular mal-relation exists, a compensatory response is elicited from the stomatognathic musculature. Most often that response can be measured through electromyography (EMG).

Over 50 years ago a dentist began to record muscle activity through surface electromyography in an effort to better understand the functions of the muscles of mastication.¹ In the intervening years since, surface EMG has revealed several key facts about the relationship between the muscles and occlusion. Today we can routinely record up to 8 channels of EMG data, in the clinic. This data interpretation can lead us to a better understanding of the specific condition of the patient.

Determining muscle balance in function is an easy task for EMG.⁶⁻¹³ Typically, the patient is asked to clench in maximum intercuspation and then swallow. The clench will appear balanced (Figure 3a.) or unbalanced (Figure 3b.). The swallow will either be with the teeth together (Figure 3c.) or with a tongue-thrust (Figure 3d.) Then, if an appliance is utilized, muscle activity can be recorded before, during and after adjustment of the appliance. This will immediately demonstrate the effectiveness of the appliance.¹⁴⁻²⁰



Figure 1. An 8 channel Electromyograph.

If we see that the muscles are balanced, we know we have a result that will remain stable. But, if the muscles are not in balance, we can not tell from the EMG recordings along exactly what to do about it. While much has been learned about muscle hyperactivity and the various conditions of imbalance that can exist within the masticatory musculature, EMG is not, nor will it likely ever be, adequate to the task of directing case treatment by itself. While surface EMG is a fast, easy and reliable way to record the relative contraction levels of the muscles at rest or in function, it has a low sensitivity to occlusal force locations and the timing of tooth contacts.

Dr. Derek Mahony, Specialist Orthodontist. 49 Botany Street, Randwick NSW 2031, Sydney, Australia.

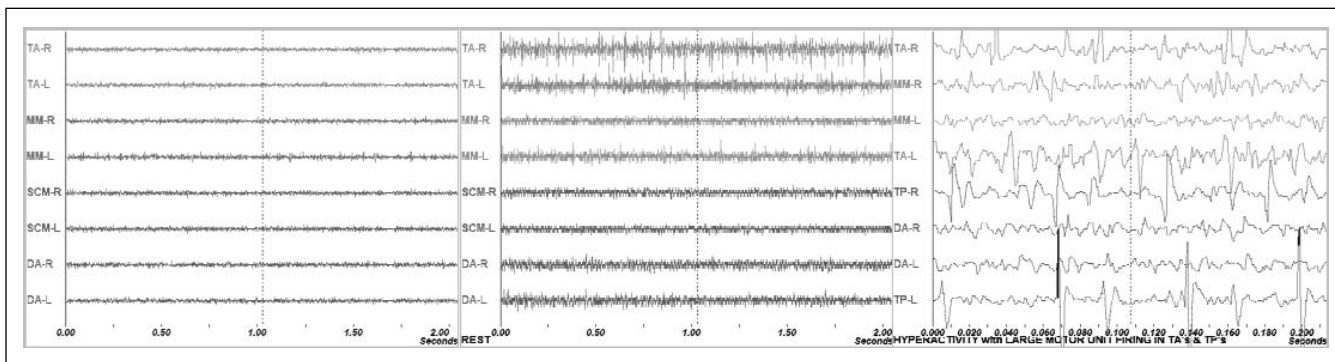


Figure 2. muscles that are; **a)** relaxed at rest (the normal condition) **b)** hyperactive at rest (indicating a maxillo-mandibular malrelation) or **3)** exhibiting a neurological abnormality (large motor-unit firing) are seen. While these factors routinely go unmeasured, their contribution to a precise diagnosis can be highly significant, even to the long-term outcome of a particular case.²⁻⁵

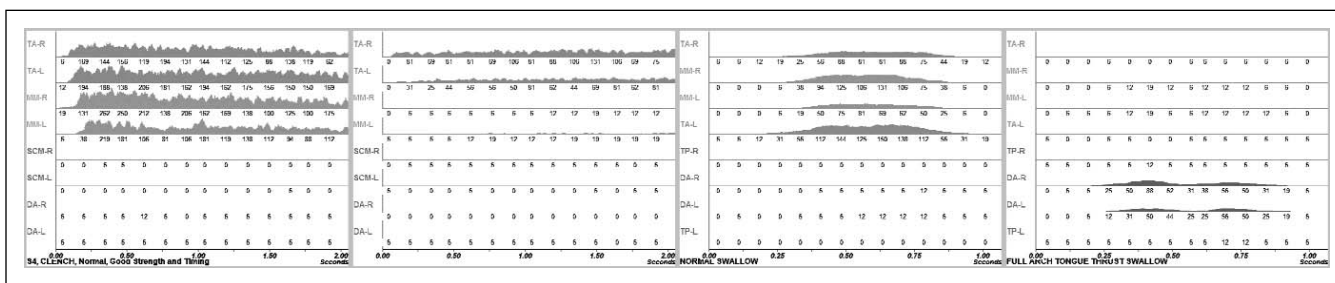


Figure 3. a) balanced clench b) unbalanced clench c) normal swallow d) aberrant swallow.

T-Scan II

The simplest solution to the problem of evaluating the timing and force of occlusal contacts is the T-Scan II.²¹⁻²³ It provides a very sensitive measure of contact force and a moving picture of the order in which the contacts occur.²⁴⁻³² It is the only technology available to the clinician that can show precisely the order in which contacts occur and simultaneously, the relative force of each distinct contact. The new high density sensors are flexible, more precise and very durable (usable for up to 30 registrations).

A bite-force recording is taken by having the patient bite down several times on the T-Scan wafer to condition it. This allows it to conform to the shape of the arch. Then a recording is taken with the patient closing from rest position into the intercuspal position, followed by a clench. Other recordings can also be taken in centric relation, lateral excursions and protrusion.

In the recording in Figure 5, the initial contact points occur only on the incisors. As the patient continues to close a contact appears on the right area of the second molar. Eventually a contact appears on the left second molar creating a tripod effect.

When the recording is replayed as a “force movie” a three dimensional graph is displayed showing the relative force at each point of contact. Again we see that the initial contacts are on the incisors, then the right posterior and finally the left second molars. What



Figure 4. The T-Scan II.

is also evident is that in full closure, the highest contact force is actually on the left second molar, (indicated by the tallest spike) despite the lateness of the contact. Further inspection clearly suggests that the reason the excessive force is being born by the left second molar is due to a lack of solid contacts on the left first molar and bicuspids. In spite of the large number of contact points around the arch, this is an occlusion badly in need of adjustment.

However, as we analyze the tracing above, as clear as the picture of occlusion of this case is, we realize that we do not and cannot from this information understand

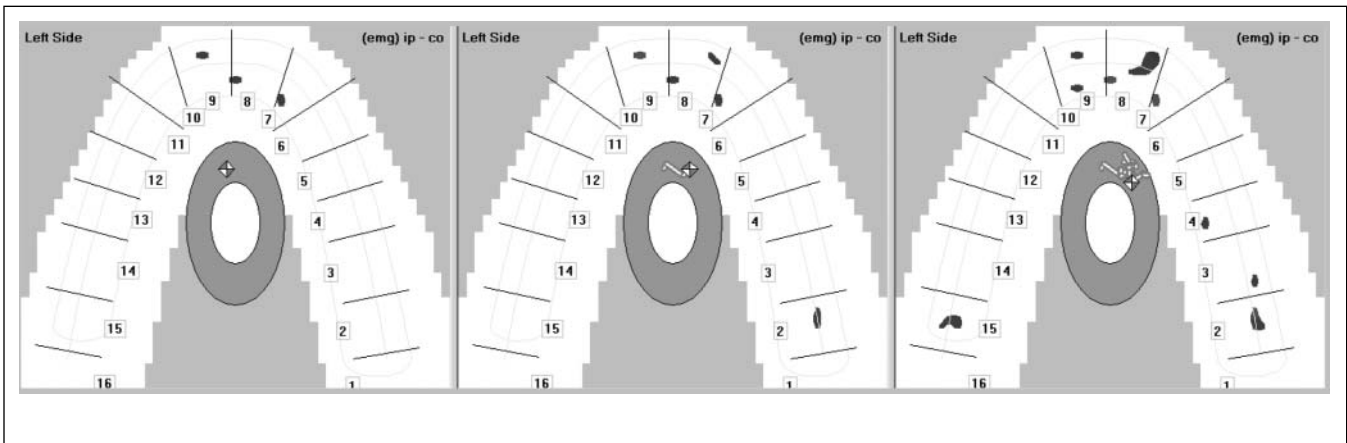


Figure 5. A Map of the Sequence from Initial Anterior Contact to Bilateral Contact: **a)** 1st contact **b)** 1st Posterior Contact **c)** 1st Left Posterior Contact.

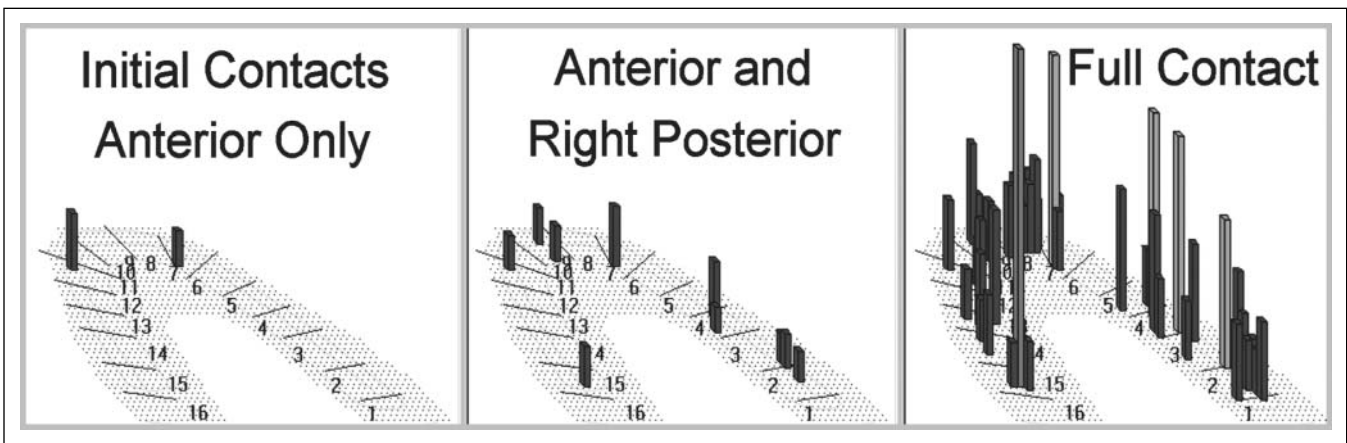


Figure 6. Force movie frames.

what the musculature is doing to accommodate. But there is a way to do both.

T-SCAN II – BioEMG II

Previous studies have attempted to correlate T-Scan data with EMG data.^{33,34} Recently the two companies who separately manufacture the T-Scan II and the BioEMG II have created a milestone by making the programs talk to each other.³⁵ This is not something that happens often in dentistry, but the synergy created now offers a unique opportunity for dentists to more clearly understand their patients’ occlusal conditions comprehensively. The reason that the programs needed to talk to each other was to synchronize their respective data streams. This is accomplished by having either program act as a “master”, while the other program acts as a slave to it. Thus, a dentist can ‘Run” the T-Scan program and the BioEMG II program will dutifully “follow” it. Or, the dentist can “Run” the BioEMG II program and the T-Scan II program will follow it. This is true in recording as well as in playback analysis.

Why the T-Scan wafer at 85 microns is not too thick.

According to the latest research on mandibular function (Gallo *et al.*) we now know that the sagittal path of closure is more complicated than a simple hinge movement. In fact, the “helical axis of rotation” moves from the vicinity of the angle of the mandible (early in opening) to about mid-ramus (late in opening) in close proximity to where the inferior alveolar nerve enters the mandibular foramen. For a voluntary closure between rest and occlusion (2-3 mm) the average amount of rotation has been measured at 0.7 degrees (Lewin A. and Moss C.). For an 85 micron change that’s about 0.02 degrees of rotation (about 1.5 minutes of arc). If the A/P distance between the incisors and the 2nd molars is 40 mm, 1.5 minutes of arc translates to an 18 micron difference in molar and bicuspids. In spite of the large number of contact points around the arch, this is an occlusion badly in need of adjustment. However, as we analyze the tracing above, as clear as the picture of occlusion of this case is, we realize that we do not and cannot from this information understand what the musculature is doing to accommodate. But there is a way to do both.

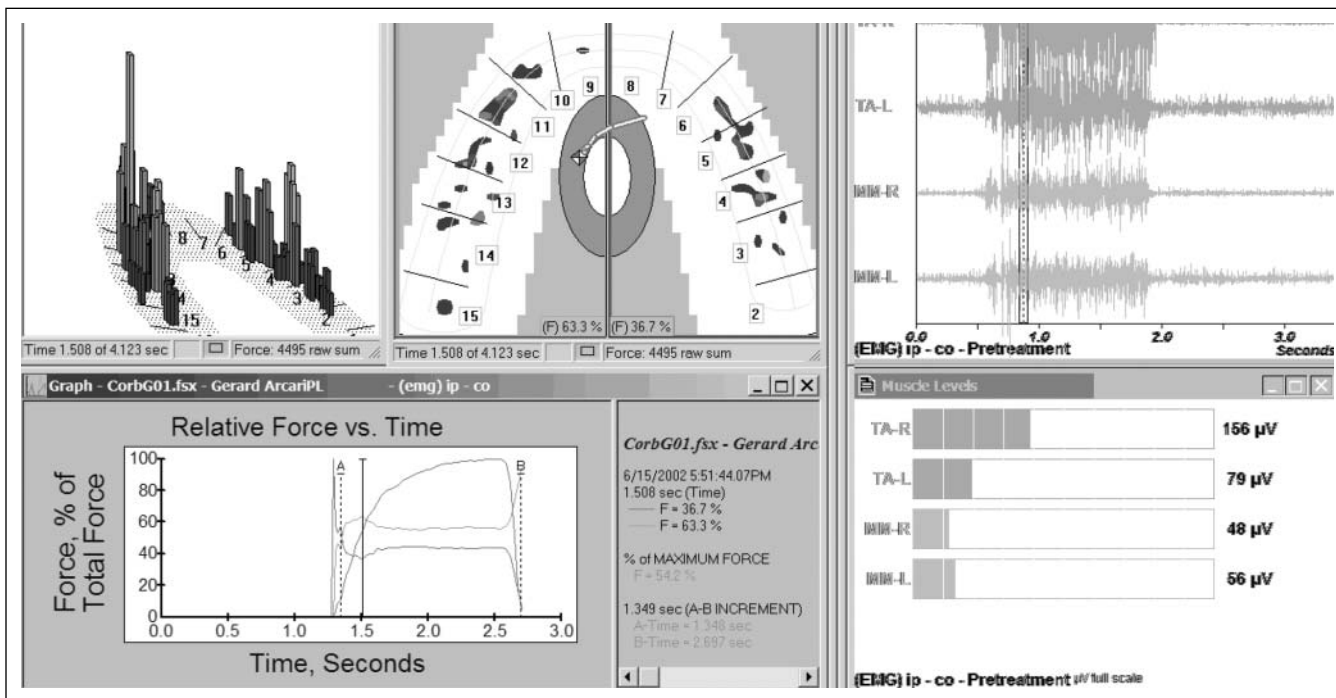


Figure 7. The simultaneous recording of occlusal force, timing and muscle activity. One high force point on the left bicuspid, right anterior temporalis hyperactivity.

A Force and Muscle Activity Balanced Occlusion

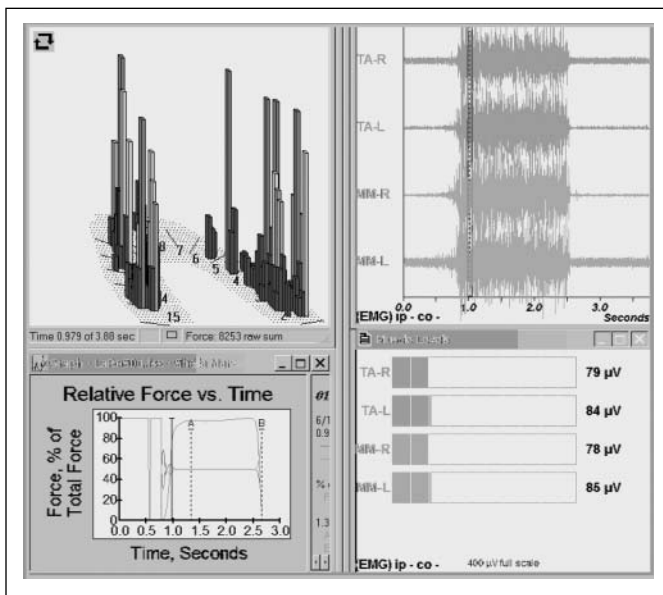


Figure 8. Both the forces and the activities of the muscles are balanced in this patient.

This is a very small difference in comparison to the size of an occlusal adjustment being made and well within the adaptive capacity of the system. Another benefit of placing the T-Scan wafer between the arches ... it that it reduces the acuity of proprioception, which reduces, but does not eliminate, the ability of the central nervous system to avoid any existing prematurities.

T-SCAN II - BioEMG II

Previous studies have attempted to correlate T-Scan data with EMG data.^{33,34} Recently the two companies who separately manufacture the T-Scan II and the BioEMG II have created a milestone by making their programs talk to each other.³⁵ This is not something that happens often in dentistry, but the synergy created now offers a unique opportunity for dentists to more clearly understand their patients' occlusal conditions comprehensively. The reason that the programs needed to talk to each other was to synchronize their respective data streams. This is accomplished by having either program act as a master while the other program acts as a slave to it. That is, a dentist can "Run" the T-Scan program and the BioEMG II program will dutifully "follow" it. Or, he/she can "Run" the BioEMG II program and the T-Scan II program will follow it. This is true in recording as well as in playback analysis. The simultaneous recording of occlusal force, timing and muscle activity (Figure 7). One high point on the left bicuspid, right anterior temporalis hyperactivity is noted.

Analyzing the combined traces

When we see that the highest force of contact is on the left can we assume that the greatest muscle activity will be the same? Not at all, Figure 7, shows an example of a patient with a higher force level on the left side (63% of total), focused in the bicuspid area. At the same time we clearly see that the right anterior temporalis is firing at nearly twice the level of the left one. It is also apparent that the combined activities of the

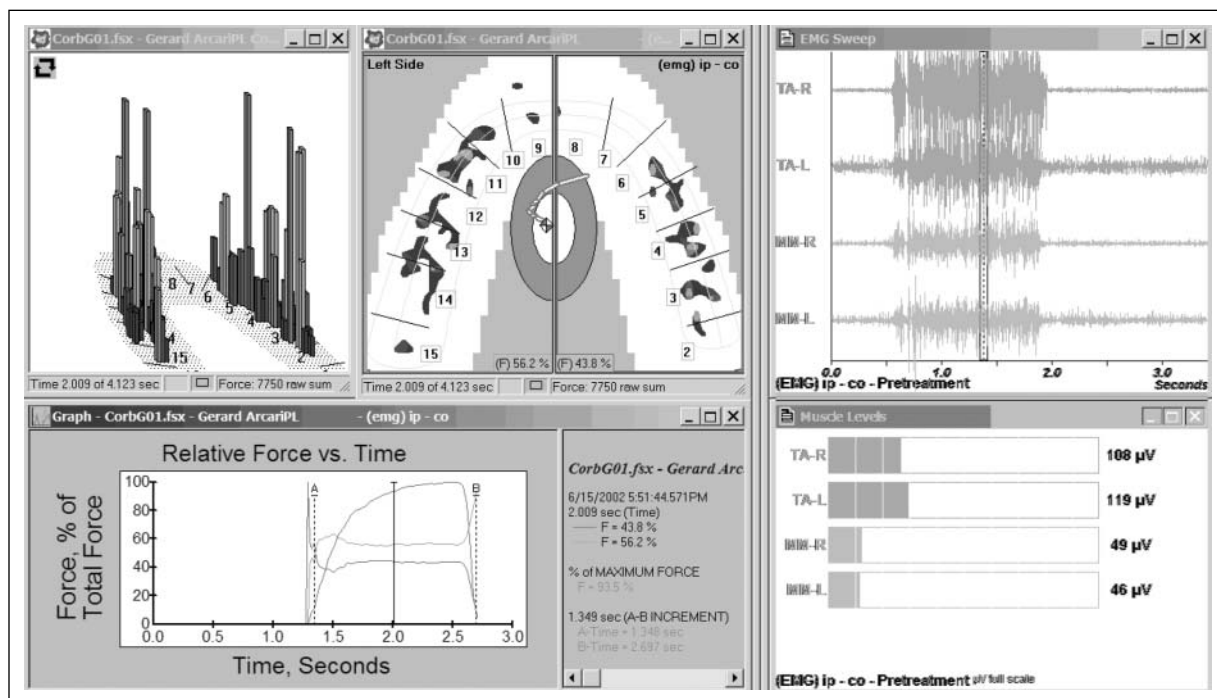


Figure 9. By the time the total force has reached 93.5% of maximum, the center of force has returned to the midline and the vertical muscle forces are even between left and right sides. However, it is clear that the temporalis muscles are “overloaded” compared to the masseters.

right masseter and temporalis are far greater than the same muscles on the left. How is this possible?

Not one of the muscles of mastication that elevates the mandible is positioned such that there is a straight vertical relationship between the origin and the insertion. Each elevator muscle has a horizontal component to its direction of applied force. Due to the ginglymo-arthroidal structure of the temporomandibular joints, the mandible is able to move freely forward and back, left and right. The same “elevator muscles” that apply vertical forces, can and do apply horizontal forces, to the mandible as needed for function. In Figure 7, we can see that while the left side muscles are applying more force in the vertical direction, the right side temporalis must be applying a significant amount of force in a non-vertical (horizontal) direction. However, with some extra effort, it is possible to achieve a muscle and force balanced occlusion. See Figure 8.

Balanced forces do not guarantee balanced muscles

Sometimes we can record a relatively even balance of forces between the right and left sides, but the patient is still not comfortable. Even with adequate stable contacts on both sides some patients still complain. The patient in Figure 9, had regular temporal headaches. The left-right force balance was rather good at 56% right to 44% left. It is evident that the initial contact is on the left side (see the center of force vector), that during the closure the force passes to the right side before reaching its balanced force

condition at maximum intercuspation. However, notice that the temporalis muscles are contracting at 2-1/2 times greater levels than the masseter muscles. A repositioning appliance was placed that balanced both the muscle and the forces so the headaches were relieved.

With the technology that is available today an ordinary practicing dentist has the ability to more thoroughly evaluate the masticatory system than ever before. It is now possible to routinely adjust an occlusion, not only to equalize the occlusal forces, but also to create an environment where the muscles can function in harmony with each other.

REFERENCES

1. Thompson JR. Concepts regarding the function of the stomatognathic system. *JADA* 48: 626-637, 1954.
2. Gervais RO, Fitzsimmons GW, Thomas NR. Masseter and temporalis electromyographic activity in asymptomatic, subclinical, and temporomandibular joint dysfunction patients. *Cranio* 7: 52-7, 1989.
3. Glaros AG, McGlynn FD, Kapel L. Sensitivity, specificity, and the predictive value of facial electromyographic data in diagnosing myofascial pain-dysfunction. *Cranio* 7: 189-93, 1989.
4. Glaros AG, Glass EG, Brockman D. Electromyographic data from TMD patients with myofascial pain and from matched control subjects: evidence for statistical, not clinical, significance. *J Orofac Pain* 11: 125-9, 1997.
5. Kamyszek G, Ketcham R, Garcia R Jr, Radke J. Electromyographic evidence of reduced muscle activity when ULF-TENS is applied to the Vth and VIIth cranial nerves. *Cranio* 19: 162-8, 2001.
6. Belser UC, Hannam AG. The influence of altered working-side occlusal guidance on masticatory muscles and related jaw movement. *J Prosthet Dent* 53: 406-13, 1985.

7. McCarroll RS, Naeije M, Hansson TL. Balance in masticatory muscle activity during natural chewing and submaximal clenching. *J Oral Rehabil* 16: 441-6, 1989.
8. Visser A, McCarroll RS, Oosting J, Naeije M. Masticatory electromyographic activity in healthy young adults and myogenous craniomandibular disorder patients. *J Oral Rehabil* 21: 67-76, 1994.
9. Christensen LV, Rassouli NM. Experimental occlusal interferences. Part I. A review. *J Oral Rehabil* 22: 515-20, 1995.
10. Christensen LV, Rassouli NM. Experimental occlusal interferences. Part II. Masseteric EMG responses to an intercuspal interference. *J Oral Rehabil* 22: 521-31, 1995.
11. Borromeo GL, Suvinen TI, Reade PC. A comparison of the effects of group function and canine guidance interocclusal device on masseter muscle electromyographic activity in normal subjects. *J Prosthet Dent* 74: 174-80, 1995.
12. Christensen LV, Mohamed SE. Bilateral masseteric contractile activity in unilateral gum chewing: differential calculus. *J Oral Rehabil* 23: 638-47, 1996.
13. Saifuddin M, Miyamoto K, Ueda HM, Shikata N, Tanne K. An electromyographic evaluation of the bilateral symmetry and nature of masticatory muscle activity in jaw deformity patients during normal daily activities. *J Oral Rehabil* 30: 578-86, 2003.
14. McCarroll RS, Naeije M, Kim YK, Hansson TL. Short-term effect of a stabilization splint on the asymmetry of submaximal masticatory muscle activity. *J Oral Rehabil* 16: 171-6, 1989.
15. Naeije M, Hansson TL. Short-term effect of the stabilization appliance on masticatory muscle activity in myogenous craniomandibular disorder patients. *J Craniomandib Disord* 5: 245-50, 1991.
16. Lobbezoo F, van der Glas HW, van Kampen FM, Bosman F. The effect of an occlusal stabilization splint and the mode of visual feedback on the activity balance between jaw-elevator muscles during isometric contraction. *J Dent Res* 72: 876-82, 1993, Erratum in: *J Dent Res* 72:1264, 1993.
17. Visser A, Naeije M, Hansson TL. The temporal/masseter contraction: an electromyographic and clinical evaluation of short-term stabilization splint therapy in myogenous CMD patients. *J Oral Rehabil* 22: 387-9, 1995.
18. al-Quran FA, Lyons MF. The immediate effect of hard and soft splints on the EMG activity of the masseter and temporalis muscles. *J Oral Rehabil* 26: 559-63, 1999.
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* 29: 810-5, 2002.
20. Roark AL, Glaros AG, O'Mahony AM. Effects of interocclusal appliances on EMG activity during parafunctional tooth contact. *J Oral Rehabil* 30: 573-7, 2003.
21. Maness WL, Podoloff R. Distribution of occlusal contacts in maximum intercuspation. *J Prosthet Dent* 62: 238-42, 1989.
22. Maness WL. Laboratory comparison of three occlusal registration methods for identification of induced interceptive contacts. *J Prosthet Dent* 65: 483-7, 1991.
23. Reza Moini M, Neff PA. Reproducibility of occlusal contacts utilizing a computerized instrument. *Quintessence Int* 22: 357-60, 1991.
24. Mizui M, Nabeshima F, Tosa J, Tanaka M, Kawazoe T. Quantitative analysis of occlusal balance in intercuspal position using the T-Scan system. *Int J Prosthodont* 7: 62-71, 1994.
25. Gonzalez Sequeros O, Garrido Garcia VC, Garcia Cartagena A. Study of occlusal contact variability within individuals in a position of maximum intercuspation using the T-SCAN system. *J Oral Rehabil* 24: 287-90, 1997.
26. Garcia Cartagena A, Gonzalez Sequeros O, Garrido Garcia VC. Analysis of two methods for occlusal contact registration with the T-Scan system. *J Oral Rehabil* 24: 426-32, 1997.
27. Suda S, Matsugishi K, Seki Y, Sakurai K, Suzuki T, Morita S, Hanada K, Hara K. A multiparametric analysis of occlusal and periodontal jaw reflex characteristics in young adults with normal occlusion. *J Oral Rehabil* 24: 610-3, 1997.
28. Garrido Garcia VC, Garcia Cartagena A, Gonzalez Sequeros O. Evaluation of occlusal contacts in maximum intercuspation using the T-Scan system. *J Oral Rehabil* 24: 899-903, 1997.
29. Kirveskari P. Assessment of occlusal stability by measuring contact time and centric slide. *J Oral Rehabil* 26: 763-6, 1999.
30. Kerstein RB. Improving the delivery of a fixed bridge. *Dent Today* 18: 82-4, 86-7, 1999.
31. Suda S, MacHida N, Momose M, Yamaki M, Seki Y, Yoshie H, Hanada K, Hara K. A multiparametric analysis of occlusal and periodontal jaw reflex characteristics in adult skeletal mandibular protrusion before and after orthognathic surgery. *J Oral Rehabil* 26: 686-90, 1999.
32. Saracoglu A, Ozpinar B. In vivo and in vitro evaluation of occlusal indicator sensitivity. *J Prosthet Dent*. 2002 Nov; 88(5):522-6. Comment in: *J Prosthet Dent* 90:310; author reply 310-1, 2003.
33. Kerstein RB, Wright NR. Electromyographic and computer analyses of patients suffering from chronic myofascial pain-dysfunction syndrome: before and after treatment with immediate complete anterior guidance development. *J Prosthet Dent* 66: 677-86, 1991, Comment in: *J Prosthet Dent* 70: 99-100, 1993
34. Hidaka O, Iwasaki M, Saito M, Morimoto T. Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. *J Dent Res* 78: 1336-44, 1999.
35. Kerstein RB. Combining technologies: A computerized occlusal system synchronized with a computerized electromyographic system. *Cranio* 22: 96-109, 2004.