Commentary

Commentary-practicing state of the art occlusion in the Digital Era of Dentistry

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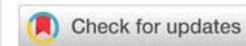***Corresponding author:** Kerstein RB, DMD, Former Assistant, Clinical Professor, Department of Restorative Dentistry, Tufts University School of Dentistry, Boston, 38 Copperwood Drive, Stoughton, MA, 02072, USA, E-mail: tmjdoc@ix.netcom.com

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New technological developments in modern dental medicine offer clinicians insight and treatment advances to many outdated, dogmatic concepts that have been widely believed for many years, despite there being a lack of scientific evidence to support them. This is especially true in the field of Dental Occlusion, whose scientific development has been hampered by the use of traditional, non-digital occlusal indicators that do not quantify occlusion, other than possibly describing "contact area". Yet, the literature continues to suggest that dentists can visually observe the size of holes in wax or silicone, the size and color depth of articulating paper marks, or judge shim stock hold between occluding teeth, as being reliable methods to describe occlusal force levels, when research shows these traditional "beliefs" are scientifically untrue [1-3]. And despite having no scientific validity, articulating paper mark size continues to be the "Standard of Care" to analyze occlusal contact forces. Presently, no published study shows articulating paper marks can measure occlusal force by how they appear (Figure 1) [1-3]. Moreover, it has been shown in 3 separate studies that clinicians choose forceful contacts poorly when Subjectively Interpreting articulating paper marks [4-6]. This leads to numerous occlusal adjustment errors that shorten restoration longevity, prolong patient acceptance of new restorations, cause Temporomandibular Disorder symptoms after orthodontics [7], promote fractures of implant components [8] and complicate the practice of occlusion for the clinician. A recent systematic review determined little evidence supports using traditional occlusal indicators because they measure nothing occlusal, and their use is highly subjective and inaccurate [9].

Presently, Dental Medicine is incorporating digital technologies into the Digital Workflow (intraoral scanning;

CAD/CAM milling, and restorative fabrication), which improves outcomes beyond what is possible with traditional, non-digital methods. An example is employing scanning, virtual articulation, and virtual mandibular motion compared to mounting stone casts with a facebow registration and plaster and manually moving the casts on an articulator that poorly approximates human motion. Scanning and virtual articulation eliminate the spatial errors inherent in the facebow method (impression distortion, stone, and mounting plaster setting contraction, wax imprint distortion, and mechanical articulator motion), while virtual articulation closely reproduces human mandibular motion patterns. Further, the addition of digital occlusal technology with the T-Scan 10 Novus Computerized Occlusal Analysis system (Tekscan Inc. S., Boston, MA USA)
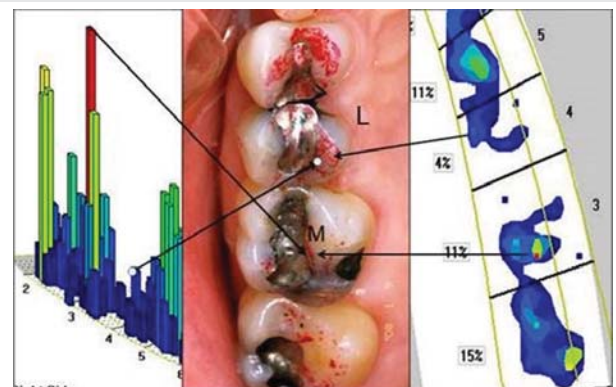

Figure 1: Contrary to popular (incorrect) belief, the highest force (M) is often *not* the largest paper mark, and the lowest force contact is often *not* the smallest paper mark (L). Reprinted from Kerstein, R.B., Radke, J. Clinician accuracy when subjectively interpreting articulating paper markings. *The Journal of Craniomandibular & Sleep Practice* 2013; 32 (1):13-23.

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to both diagnose and guide occlusal adjustments, has been shown for nearly 4 decades to improve occlusal outcomes over traditional non-digital occlusal indicators (Figure 2a) [10-19] This is because T-Scan 10 *objectively measures relative occlusal forces, contact timing, and overall occlusal force distribution non-subjectively, accurately, and repeatedly [*9], such that when compared to traditional occlusal indicators, that same systematic review determined that much scientific evidence supports the use of T-Scan [9,20-23].

So, how should State of the Art occlusion be practiced in the Digital Era of Dental Medicine? By employing 2 complimentary occlusal measurement technologies that quantify occlusal function. They are:

· The T-Scan 10 Novus Computerized Occlusal Analysis System (Figures 2a-c)

· Synchronized Surface Electromyography BioEMG III (sEMG; Bioresearch Associates, Milwaukee, WI, USA) (Figure 3).

The T-Scan 10, with its 5th generation High Definition (HD) recording sensor (Novus HD, Tekscan, Inc., S. Boston, MA, USA), can record 256 relative occlusal contact force levels
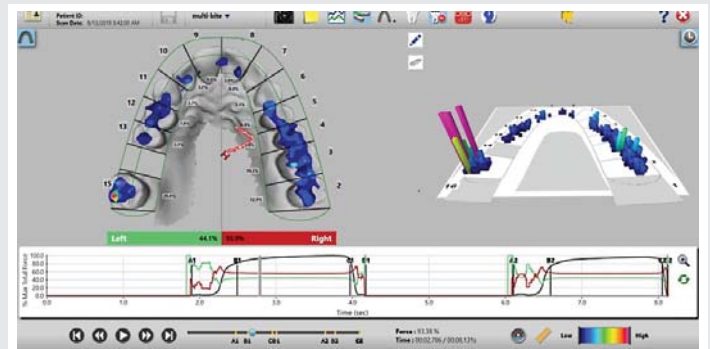

Figure 2a: The T-Scan 10 Novus System is comprised of a high-definition flexible printed electronic circuit sensor that relays occlusal contact force, pressure, and timing data through the Novus Handpiece to companion software. The T-Scan graphically displays a patient's occlusal function in a dynamic video format that plays frame-by-frame or continuously forwards or backward.

Figure 2b: The Novus HD Sensor being inserted intraorally to record the occlusion of an implant patient.

Figure 2c: T-Scan 10 force and timing data can be combined with a .stl file to accurately locate which cusps or fossae are under high occlusal contact force.

across elapsed time in 0.003 second-long increments. When a patient occludes upon the electronically-charged HD sensor (Figure 2b), opposing teeth make approximating contact and compress together the upper and lower sensor surfaces, which results in a change in the electronic resistance in each of the contacted 0.5 mm^2 force measurers (known as *sensels*). These resistance changes are measured by the T-Scan 10's hardware electronics as a change in Digital Output Voltage (DO) [24] Higher contact force produces large resistance changes and low contact force produces lesser resistance changes. The T-Scan 10 software uses a multi-colored 2 and 3-dimensional graphical desktop display (Figure 2c), to represent the variable changing occlusal forces that rise during complete intercuspation or engage frictionally during mandibular excursive movements [24] This non-subjective occlusal force distribution diagnosis can guide occlusal treatment to reach high-precision occlusal contact timing and force treatment end-points that cannot be achieved with the subjectively assessed, non-digital occlusal indicators [9,17], or with scanner occlusograms, which contain no true force measurements and solely project the geometry of occluding teeth [9,24].

Surface Electromyography (BioEMG III) can record varying muscle contraction levels of the superficial masseter, the anterior temporalis, the anterior digastric, and the sternocleidomastoid muscles, in both healthy and dysfunctional muscles. The T-Scan 10 and the/BioEMG III when paired together have synchronized data sets [19], representing a major advance in the study of occlusal function by simultaneously recording occlusal contacts and their corresponding muscle activity response (Figures 3a,b).

When prolonged posterior occlusal contacts are present in excursions, muscular hyperactivity is also present, causing muscular ischemia from lactic acid accumulation, and the clinical appearance of muscular symptoms [10-19]. The mechanism of muscular hyper contraction is a posterior pulp and PDL mechanoreceptor mediated process, resultant from prolonged excursive opposing posterior teeth occlusal surface engagements, that directly elevate masticatory muscle activity through the unique neuroanatomy of the molar and premolar pulp/PDL fibers, which synapse with the Trigeminal Motor Nucleus [25]. Every time opposing posterior teeth contact or flex under excursive loading, masticatory muscle activity is created directly from this neural mechanism (Figure 4).
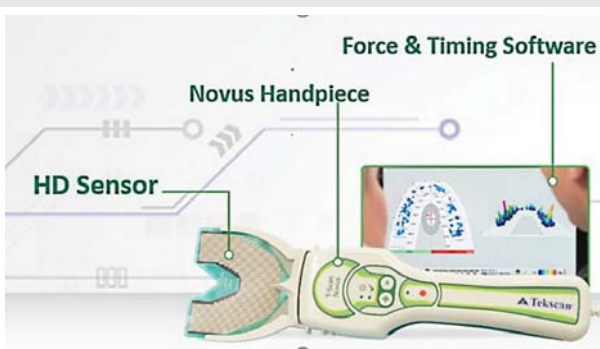
An example of using the T-Scan 10/BioEMG III to remove muscular hyperactivity by altering the time duration of excursive occlusal contacts (known as the *Disclusion Time* [20]) can be seen in Figures 5-7.

For many years, a female patient experienced chronic bilateral masseter tension, frequent temporal headaches, regular morning jaw soreness, daytime clenching, and nighttime bruxing, despite wearing an appliance for many years. She presented with slightly worn bilateral canine contacts (Figure 5a,b) that lacked guidance lift resulting in poor posterior disclusion.

Pretreatment articulating paper linear marks that depict the right excursion's long Disclusion Time and frictional excursive contacts (Figure 6a) is then treated with ICAGD, based on the pretreatment right excursive T-Scan data.

Reducing the Disclusion Time is accomplished by performing the Immediate Complete Anterior Guidance Development coronoplasty (ICAGD) [10], which is a measurement-driven, excursively focused computer-guided occlusal adjustment procedure that shortens prolonged excursive occlusal surface contact to a Disclusion Time to < 0.5 seconds per excursion [10,21,24,26-28] ICAGD is performed in the maximum
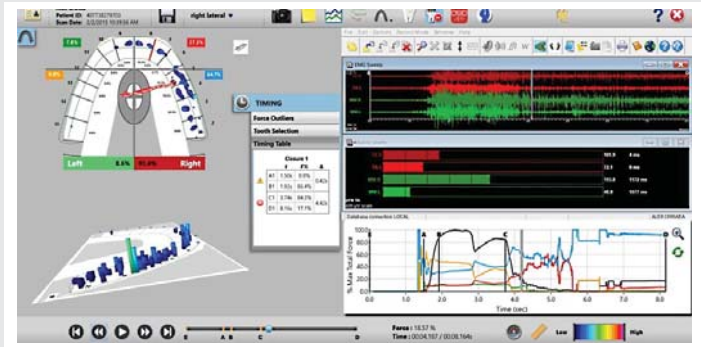

Figure 3a: T-Scan 10 data being recorded with simultaneous EMG data leads on the bilateral temporalis and masseter muscles.

Figure 3b: The T-Scan/BioEMG III desktop shows both recorded data sets of a right working excursive movement, which is hyperfunctioning the patient's right temporalis (EMG upper and middle right panes) because the patient maintains posterior contacts (visible in the T-Scan data left pane).

Figure 4: The T-Scan 10/BioEMG III data of the right working excursion with very prolonged right Disclusion Time = 4.42 seconds from a working side group function (T-Scan left pane). The EMG data illustrates severe excursive muscle hyperactivity (EMG upper right and middle panes) in 4 masticatory muscles (TA-R & L; MM-R & L). These 2 data sets illustrate the posterior contact in the right excursion is causing high muscle firing.

Figure 5a: MIP of Occluso-muscle Disorder patient with worn anterior guidance surfaces predisposing the patient to group function excursions.

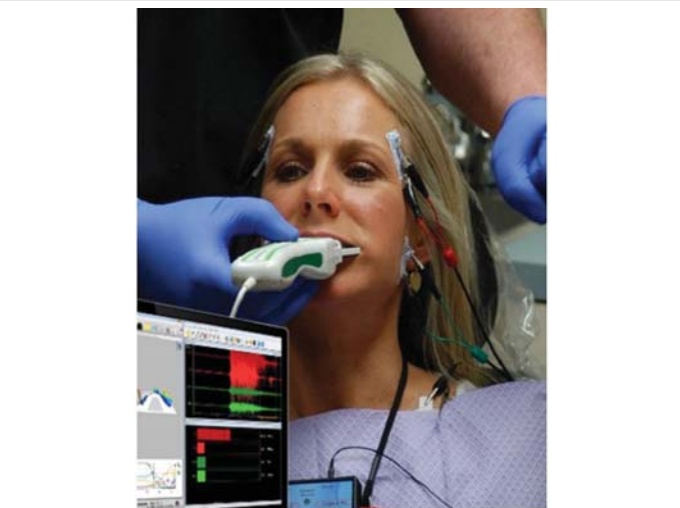**Figure 5b:** Early in the right excursion with working side group function displayed in Figure 4.

intercuspal position (MIP) [11] simplifying treatment as no Bimanual Manipulation to CR is employed, no jaw repositioning with splints/orthotics are needed, and no vertical dimension changes are utilized [10-19]. Shortening the Disclusion Time drastically reduces posterior teeth compression and flexure so their pulp and PDL fibers fire muscles for far less time than pre-ICAGD [10-19] Correctly performed ICAGD removes all linear contacts leaving only small points that reflect almost no "time travel" of opposing occlusal surfaces (Figure 6b). This process is repeated with the left excursion (not shown for brevity) until visual disclusion has been achieved bilaterally (Figure 6c).

Physiologic muscle activity level changes can be seen by comparing Figure 7 (the post ICAGD right excursion) to Figure 4. This muscular relaxation is why shortening the Disclusion Time with ICAGD is an effective Occluso-muscle Disorder treatment [10-19].

It is through the simultaneous measurement of the occlusion and muscles with the T-Scan 10/BioEMG III that computer-guided occlusal treatment can predictably improve Occluso-muscle Disorder symptoms [10-19] when compared to the poor therapeutic effectiveness of unmeasured and subjectively interpreted paper mark-only occlusal adjustments.

So, practicing Occlusion in the Digital Era of Dental Medicine should require the use of State of the Art occlusal measurement technologies.

Figure 6a: Pretreatment right excursive linear paper marks on the maxillary premolars and molar crowns that result from marking the excursions while maxillary and mandibular opposing occlusal surfaces engage frictionally.

Figure 6b: Post-ICAGD corrected articulating paper contact marks. There are very small point contacts present.

Figure 6c: Visible disclusion of the right excursion post ICAGD. New post-ICAGD T-Scan/BioEMG III recordings will verify the Disclusion Time has been properly shortened (Figure 7).

Figure 7: Post-ICAGD the Disclusion Time = 0.36 seconds indicating there is a very short duration of posterior excursive contact. The muscle activity levels in all 4 muscles are dramatically lessened compared to pretreatment in Figure 5 (to the right of Line C; upper right and middle panes).

Conflict of interest disclosure

The Author is a Clinical Consultant for Tekscan, Inc., but receives no compensation for sales of the product

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