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TMD: The Great Controversy

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Twenty-five hundred years ago, Hippocrates recorded in his sixth book of *Epidemics* his observation, which confirmed traditional thought of the time, that many people with severe headaches also had crooked teeth. Over the centuries, while the tooth-headache connection was accepted, there did not seem to be a consistently successful treatment. With the advent of pharmacological pain medications in the 20th century, head pain was treated by drugs, thus treating the symptoms and not the cause. Since the patient's primary goal is pain relief, drug therapy was deemed a success by the patient — at least for a while.

Most dental students are taught a centric relation (CR) philosophy regarding TMD. While there are more than 25 accepted definitions of CR, the most common one taught in dental schools in the U.S. is that the proper position of the condyles of the mandible is in the uppermost and most posterior position in the glenoid fossa. (Thus, it fits into place like a puzzle piece.) Based on this CR position, a TMD patient in pain has often had teeth reconstructed to maintain CR. Keeping in mind that many people have achieved pain relief and function from this CR position, you might ask, "Why?" In fact, there are probably successful cases with every other CR position and TMD philosophy. Otherwise, why would dentists keep treating patients by using those approaches? (Although, at a recent TMD debate, one presenter admitted that she had TMD and has not been successful in curing it with her own philosophy.)

TMD pain is transmitted to the brain by nerves. Among the many TMD philosophies I have studied or reviewed, pain by nerve transmission is accepted. The controversy arises over what causes the pain and what is to be done about it. Relieving TMD pain is only a short-term goal; treating the cause to keep it from recurring is the long-term goal. I have relieved many TMD patients of their pain within a few minutes simply by having them close lightly on a cotton roll with their anterior teeth — but that is not a long-term solution.

Video for this article is available in the e-pub version of the *Journal*, available at cda.org/apps.

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Temporomandibular Disorders: A Human Systems Approach

James Fricton, DDS, MS

ABSTRACT The face and associated cranial, oral and dental structures are among the most complicated areas of the body, contributing to an array of common orofacial disorders that include temporomandibular disorders (TMD), orofacial pain disorders and orofacial sleep disorders. This paper presents a broad, inclusive approach to diagnosis and management of TMD that reflects both conceptual models of human systems in understanding chronic illnesses as well as systematic reviews of treatment for successful management.

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The face and associated cranial, oral and dental structures are among the most complicated areas of the body, contributing to an array of orofacial disorders, including temporomandibular disorders (TMD), orofacial pain disorders, orofacial sleep disorders, oral lesions, dental disorders and oromotor disorders. Orofacial pain disorders are the most common of these problems and can cause symptoms of orofacial pain, jaw dysfunction and chronic head and neck pain, with a collective estimated prevalence of at least 20 percent of the general population (**TABLE 1**).[1-7] To complicate matters, oral and craniofacial structures have close associations with the functions of eating, communicating, seeing and hearing, and they form the basis for appearance, self-esteem and personal expression and, thus, can deeply affect an individual's psychological and functional status.[7] A national poll found that adults working full time miss work because of head and face pain more often than for any other site of pain.[5]

The high prevalence, personal impact and poor access to care for these problems have led to an expanded role for dentistry in providing solutions. However, because dentists focus most of their patient care on treatment of the dentition and related structures, it can be a challenge to understand the broader scope of diagnosis and management of these conditions. Treatment of TMD, like many pain conditions, is often singular and can vary according to the clinician's favorite theory of etiology. Clinicians tend to see what they treat and treat what they see. Clinicians who see a stress etiology treat

TABLE 1

Nearly 20 Percent of the General Population Has an Orofacial Disorder That Is Severe Enough to Have Special Diagnosis and Treatment Needs

Orofacial Disorders With Special Diagnostic and Treatment Needs	Prevalence
Temporomandibular disorders (myofascial pain, disk disorder, muscle spasm, contracture, osteoarthritis, arthralgia)	5–7 percent
Oral and craniofacial pain disorders (burning mouth, neuropathic, atypical pain, migraine and neurovascular pain, benign headache)	2–3 percent
Orofacial sleep disorders (sleep apnea, snoring)	3–4 percent
Orofacial neurosensory and chemosensory disorders (taste, paresthesias)	0.1 percent
Oromotor disorders (dystonias, dyskinesias, bruxism)	4 percent
Oral lesions (herpes, apthous, precancer, cancer)	3–5 percent
Oral mucosal disease (lichen planus, candida)	1–2 percent
Salivary disorders and xerostomia	2 percent
Oral systemic disorders (oral and systemic manifestations of autoimmune disease, cancer, AIDS, heart disease and oral disease)	2–3 percent

with stress management; surgeons who see a joint pathology treat with surgery; and dentists who see a dental etiology treat the teeth. As a result, treatment success is often compromised by limited approaches that address only part of the problem.

This paper summarizes a broader, more inclusive philosophy in diagnosing and managing TMD that reflects both new conceptual models in understanding chronic illnesses as well as systematic reviews of therapeutic strategies for successful management of TMD.

Human Systems Theory: A Comprehensive Model for Understanding Chronic Illness

Humans are complex, multidimensional and dynamic and live within an ever-changing physical and social environment. Yet our traditional biomedical model is based on a scientific paradigm that is unidimensional, reductionist and inflexible because it is based primarily on understanding the underlying pathophysiology. While distinct pathophysiological mechanisms occur in all chronic conditions, understanding the multitude of factors that play a role in the onset, perpetuation and progression of the illness is the key to successful management.[8] Thus, traditional scientific protocols often fall short in providing an adequate framework for explaining, predicting and influencing chronic illness and its outcomes. Scientific and clinical communities have been searching for a more flexible, holistic and integrated model that describes the changes in human biology that can occur in response to the circumstances in our lives which contribute to the balance between health and illness.

Human systems theory (HST) provides this framework.[8] As originally stated by Aristotle in 300 BC, "The whole is greater than the sum of its parts." HST stems from research in general systems theory and originated in ecology out of the need to explain the interrelatedness of organisms in ecosystems.[8-10] While conventional biological theories view the subject as a single entity, HST views a person as a whole with an interrelationship between the subparts of his or her life. These subparts are not static but rather are dynamic, evolving and interrelated processes. The practical application of HST to patient care requires that we understand basic HST principles as they apply to the development and alleviation of illness. These include:

- Seeing the whole patient through the eyes of the biopsychosocial medical model.[8-10]
- Understanding recursive feedback cycles using cybernetics.[11,12]
- Seeing the broad cumulative impact of small changes using chaos theory.[13-15]
- Understanding the power of positive action through positive psychology and behavioral medicine to enhance health as part of the treatment of illness.[16-19]

These concepts provide a new model for understanding TMD and its management that is well founded in theory and science. It is beyond the scope of this paper to present an in-depth discussion of each concept. However, for those interested in reading further, the concepts are presented in a more creative format than traditional academic texts — i.e., as a murder mystery novel — as well as part of a University of Minnesota massive open online course (MOOC) at coursera.org/course/chronicpain.[20]

The biopsychosocial medical model was first proposed by Engel in 1977 and suggested that to understand health and illness, one needed to look at the whole person and not simply at physical pathophysiology.[8-10] It recommended that we "see the big picture" of illness. Most studies of risk factors and protective factors suggest that each person has a unique set of interrelated factors that can either perpetuate or protect from an illness, including TMD. These contributing factors correspond to each realm of our lives, including the mind, body, emotions, spirituality, lifestyle, social relationships and the physical environment (**FIGURE 1**). By improving them, the strategies for management have greater success than the sum of any individual treatment directed at one realm.

Cybernetics, a concept defined in physics, was first applied to human systems by Bateson in 1978.[11,12] It suggests that "what goes around comes around" and each element of a system generates a change, which causes feedback to the entire system. Positive feedback triggers a

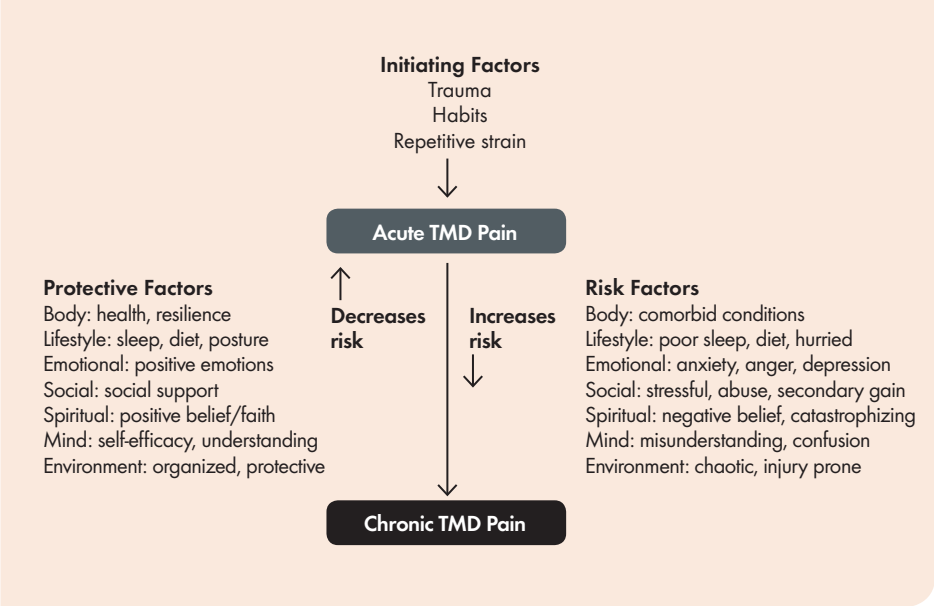

FIGURE 1. Multiple protective and risk factors play a role in the progression from acute to chronic TMD pain.

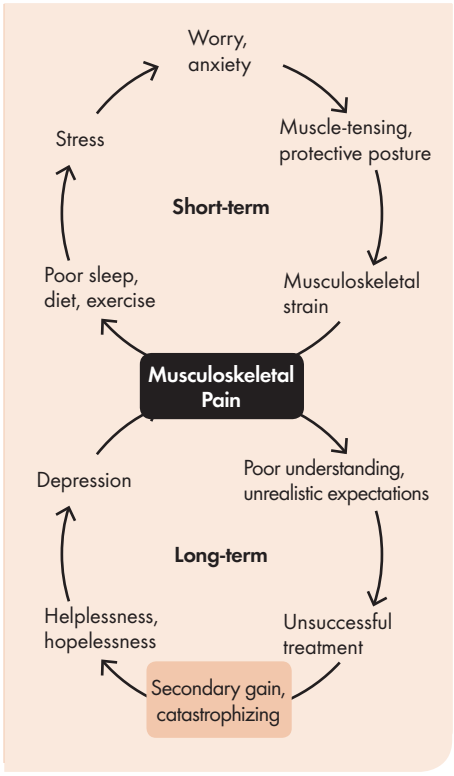

FIGURE 2. Positive and negative feedback cycles play an important role in sustaining a person's illness over time.

continuation of the cycle, while negative feedback leads to its discontinuation. This is often referred to as a self-reflexive or "circular causation" relationship. Positive and negative feedback cycles play an important role in sustaining a person's illness over time (**FIGURE 2**). Patients with an illness often fall into the recursive cycles that perpetuate the illness. Contributing factors to an illness, such as repetitive strain, depression or poor sleep, are elements that sustain the cycle.

Several types of change can influence these cycles (**FIGURE 3**). First-order change is based on "reinforcement" of existing elements that promote maintenance or escalation of the existing cycle and its related illness. A second-order change involves a "revelation" that makes a significant change from within the system through multimodal education, training and treatment that lead to a new state. This change may either be toward improved health or escalation of the illness, depending on the direction of change in the element. Finally, a third-order change is based on "enlightenment," which produces a change from outside to achieve a new level of existence distinctly different from the original structure. Second- or third-order changes are the basis for significant improvement of a condition to create a new paradigm for the health of the individual.

Small first-order compensatory changes made by a patient in response to TMD pain, such as reducing use of the jaw, taking an analgesic or other self care, can improve the illness if it is an acute self-limiting problem, at least in the short term. However, these compensatory changes may also allow a more complex illness to fall into a long-term chronic cycle (**FIGURE 2**). If a clinician can help a patient make higher order changes by understanding the multiple elements in the cycle and changing those keystone factors that perpetuate it, the illness may change more readily. Integrative care strategies that encourage second-order change within an existing cycle include splints, physical therapy and behavioral management of oral habits, sleep and muscle tension. This strategy works quite well for simple to moderate cases, but more complex patients may need a more robust intervention. In those cases, transformative care strategies encourage third-order changes that can lead to the most dramatic long-term results. Third-order change involves not only treatment of the TMD pain as noted, but also working with a team to identify all comorbid conditions and contributing factors and helping the patient make major changes to factors that may be perpetuating the long-term cycles. These changes could include managing a comorbid medical condition such as fibromyalgia, addressing stressful or abusive relationships and changing poor work situations. In this way, healthier, positive feedback cycles are set up that do not perpetuate the factors that drive the illness.

Chaos theory was first popularized by Lorenz (1963) in a paper on the theories of diverse weather patterns entitled "Does the Flap of a Butterfly's Wings in Brazil Set off a Tornado in Texas?" He presented evidence that small differences in initial conditions of a system might yield widely diverging outcomes within dynamic systems. Chaos theory suggests that "it's the little things that matter

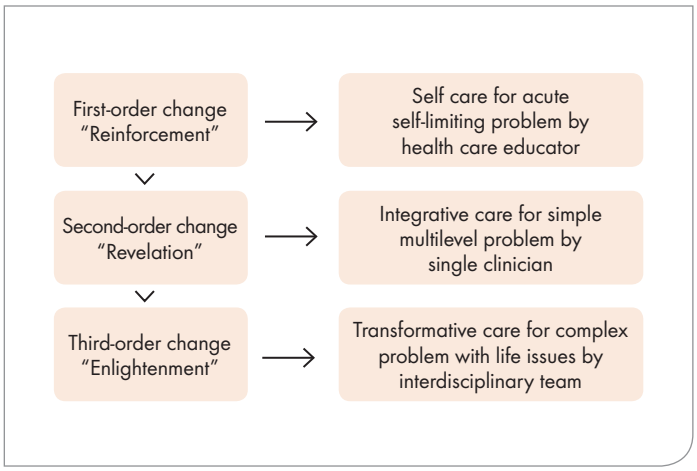

FIGURE 3. Three levels of change match the three levels of care for increasingly complex patients.

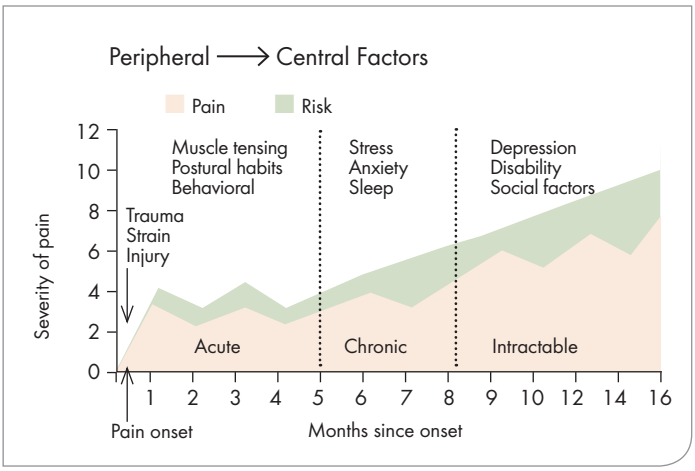

FIGURE 4. Multiple contributing factors can each play a small role at the early stages of a chronic illness, but when combined they will accelerate the condition dramatically.

the most." When applied to health and disease, it suggests that multiple risk factors can each play a small role at early stages of a chronic illness. However, when these factors are combined, they will accelerate the condition dramatically.

As **FIGURE 4** illustrates, an illness begins with initiating factors such as acute physical injury of the muscles and joints. In most cases, this pain is transient and resolves without complication or persistence. However, if a sufficient number of contributing factors are present, even though small, the balance can shift from healing of acute pain to delayed recovery and chronic pain (**FIGURE 2**).[44-50] Various underlying neural mechanisms, such as peripheral and central sensitization and wind-up, play a role in this process that is difficult to predict. Likewise, the presence of protective factors and early intervention in multiple factors will have the greatest impact in resolving the condition.

Behavioral medicine, then, suggests that specific behavioral interventions such as exercise and oral habit reversal can help restore health and wellness. It complements theories on positive psychology that focus on building health, strength and positive virtues as much as on correcting illness, problems and vices.[16,17] The Aristotelian idea that we are what we repeatedly do is supported by much research in achieving health and wellness.

These theories explain the diverse results of placebo-controlled clinical trials for TMD pain and other pain conditions which suggest that many different interventions, from splints and medications to physical and cognitive-behavioral therapies and even injections and surgery, can all be used to alleviate TMD pain.[21-39] The effect of each of these interventions beyond the placebo effect may be small, but they are all significant. Furthermore, by combining these concepts in a multimodal integrative model of care that is based on a human systems approach, the small effects of multiple interventions employed at the same time can result in the greatest positive outcomes. Thus, the evaluation and management approaches proposed in this paper follow these principles.

Principles of Evaluation

The principles of HST can be applied to the evaluation of patients with TMD by employing an inclusive problem list, determining the complexity of the case and following the decision tree for increasing the potential for successful management.

Determine the Problem List. HST expands the traditional "problem list" to include both the physical diagnoses and the contributing factors in each realm. The physical diagnosis is the physical problem that is responsible for the chief complaint and associated symptoms. The orofacial pain disorders noted in **TABLE 1** are included in this definition of the scope of dental practice because they have characteristics that involve the oral cavity, maxillofacial area and/or the adjacent and associated structures. Contributing factors include those that initiate, perpetuate or result from the disorder but in some way complicate the problem.

These risk and protective factors are diverse and involve the seven realms of our lives:[40-63] the physical (physiologic, genetic, molecular); lifestyle (repetitive strain, posture, lifestyle, eating, sleep); emotional (depression, fear, anxiety, anger); social (relationships, abuse, secondary gain); cognitive (attitudes, understanding, honesty); spiritual (faith, beliefs, purpose); and environmental (accidents, pollution, disorganization, hygiene).

Specific risk factors for chronic pain may include peripheral factors such as repetitive strain, oral and postural habits, central mediating factors such as anxiety and depression, and comorbid conditions such as fibromyalgia, somatization and catastrophizing. Protective factors

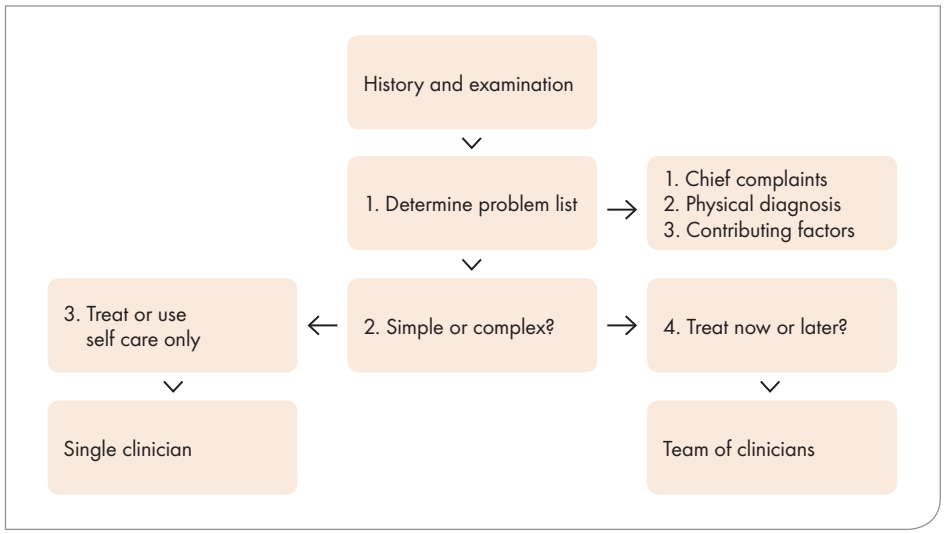

FIGURE 5. A decision tree for triaging patients and enhancing success.

reduce vulnerability to chronic pain. These factors, which include the level of coping, self-efficacy, patient beliefs (e.g., perceived control over pain, belief that pain is a sign of damage) and social support, can also affect outcomes.

Determining Complexity. The level of care for patients can also vary considerably depending on whether their condition is simple or complex. Patients with complex TMD often present with a frustrating medical and dental situation, which may include persistent aggravation of pain, multiple clinicians, long-term medications, repeated health care visits and an ongoing dependency on the health care system. Successful management of these patients is enhanced if the level of complexity is determined and matched to the complexity of the treatment strategy. Singular treatment strategies such as self care, physical therapy or splints can be quite successful with simple patients who have few contributing factors, but these treatments often fail in complex patients because of the chronic nature of the disease, central sensitization and long-standing maladaptive behaviors, attitudes and lifestyles.

Decision Tree for Triaging Patients. **FIGURE 5** outlines the decision tree for sequencing evaluation and management of simple and complex cases. Matching the complexity of a patient with the complexity of the management strategy is the key to success. Once you develop the complete problem list, including contributing factors, it can provide criteria to distinguish simple and complex patients. Complexity of the patient increases with factors such as:

- Presence of multiple comorbid conditions.
- Persistent pain lasting longer than six months.
- Significant emotional problems (depression, anxiety).
- Frequent use of health care services or medication.
- Daily oral parafunctional habits.
- Significant lifestyle disturbances.

In addition, some complex patients warrant deferral of treatment until more complex problems are addressed. The criteria for not treating until these problems are resolved include factors such as:

- Patient has primary chemical dependency.
- Patient has primary psychiatric disorder.
- Patient is involved in significant litigation.
- Patient is overwhelmed with other concerns.
- Patient is not motivated.

Once complexity is determined, the appropriate level of care that matches the complexity of the patient needs to be implemented (**FIGURE 3**). For example, a patient with acute self-limiting conditions can be managed with self-care strategy training from a health educator. TMD patients with multilevel problems require a second-order change that uses multimodal treatments as implemented by a single clinician. This integrative care strategy can include multiple treatments, such as splint, exercises, oral habit instruction, medication and palliative self care, to achieve second-order change with improvement over two to four months.

Use of a Health Care Team. Complex patients who have major life issues require a third-order change implemented by an interdisciplinary team to achieve success. This transformative care strategy involves the team of clinicians, such as a dentist, physician, health psychologist and physical therapist, working together with the patient to achieve success.[66-68] Different specialists can address different aspects of the problem in order to enhance the overall potential for success. Teams can be interdisciplinary (one setting) or multidisciplinary (multiple settings). A team approach helps in understanding and managing the whole patient, allows multiple aspects of the problem to be treated simultaneously, improves patient compliance and outcome, saves time and is more economical and more enjoyable because the team works together.

To address every aspect of the problem, treatments may include cognitive-behavioral therapy, counseling, mindfulness meditation, physical medicine treatments, medications, splints, exercises with physical therapy, occlusal therapy and surgery. A consistent philosophy and message to the patient is needed, including the importance

TABLE 2

Self Care for Temporomandibular Disorders

Apply moist heat or cold to tender muscle and joints.
Heat or ice applications used up to four times per day can relax the muscles and reduce pain. For heat, microwave a wet towel for approximately one minute or until towel is warm and wrap around a hot-water bottle or heated gel pack and apply for 15 to 20 minutes. For cold, use ice wrapped in a thin cloth on the area until you first feel some numbness. Use what feels best, but in general, heat is used for more chronic pain conditions and cold for acute conditions.

Eat a pain-free diet and chew your food on both sides.
Avoid hard foods such as French bread or bagels. Avoid chewy food such as steak or candy. Cut fruits and vegetables into small pieces. Chewing on both sides will reduce strain. If biting into food with your front teeth is painful, cut up your food and chew with your back teeth. Do not chew gum.

Avoid events or activities that trigger the pain.
Keep a pain diary to review daily activities that aggravate the pain and modify your behavior accordingly.

Keep your tongue up, teeth apart and jaw muscles relaxed.
Closely monitor your jaw position during the day (waking hours) so that you maintain your jaw in a relaxed, comfortable position. This often involves placing your tongue lightly on the palate behind your upper front teeth (find this position by saying "n"), allowing the teeth to be apart while relaxing the jaw.

Avoid muscle-tensing habits and activities that put strain on the jaw.
Remind yourself regularly to see if any of these oral habits are present with reminders such as stickers or timers. If noticed, these habits should be replaced with a positive habit such as the "n" tongue position.

- Clenching and grinding your teeth (bruxism).
- Touching or resting your teeth together.
- Biting cheeks, lips or tongue.
- Eating hard chewy foods and biting objects.
- Resting your jaw on your hand.
- Straining the jaw when playing a musical instrument.
- Pushing the tongue against the teeth.
- Opening your mouth too wide or too long when yawning, singing or during dental visits.
- Tensing your jaw or pushing your jaw forward or to the side.

Practice general relaxation and abdominal breathing.
This helps reduce your reactions to stressful life events and decrease tension in the jaw and oral habits such as clenching.

Get a good night's sleep.
Improve your sleep environment. Reduce light and noise and lie on a comfortable mattress. Reduce stimulating activities in the late evening, including computer work and exercise. Avoid sleeping on your stomach.

Avoid caffeine.
Caffeine can interfere with sleep and increase muscle tension. Caffeine or caffeine-like drugs are in coffee, tea, soda, power drinks and chocolate. Note that some decaffeinated coffee has up to half as much caffeine as regular coffee.

Use anti-inflammatory and pain-reducing medications.
Short-term use of over-the-counter ibuprofen, naproxen, acetaminophen or aspirin (without caffeine) can reduce joint and muscle pain. If available and compatible with your condition and lifestyle, consider using a combination of an analgesic and muscle relaxant in the evening.

of self care, self responsibility and education using concepts of HST. Success depends on communication, integration among clinicians and proper patient selection. With complex patients, improvement, but rarely resolution, is typically achieved in six months.

Interestingly, the economics of this model are quite favorable for each of the stakeholders, including the patient, the health care provider and the health plan. The patients receive more comprehensive effective care that is convenient if it is interdisciplinary in one setting. This not only has a higher potential to achieve success but also reduces the need for doctor shopping and single sequential trial-and-error treatments. Thus, the health plan's long-term costs are reduced compared with a patient whose treatment continues to fail and who bounces from one doctor and intervention to another. Finally, the clinicians within a team practice benefit economically because more of them are providing care and generating income to cover the overhead of the practice. It's a rare win-win-win scenario.

Principles of Management

Successful management of TMD is focused on treating the diagnosis and reducing the contributing factors in order to achieve the goals of:

- Reducing or eliminating pain.
- Restoring normal jaw function.
- Restoring normal lifestyle functioning.
- Reducing the need for future health care.

Once complexity is determined, the management options for TMD in general are consistent with treatment of musculoskeletal disorders in other parts of the body. The treatments involve interventions that have been documented with randomized controlled trials and are within the scope of dental practice to

deliver or recommend.[21-39] They include both reversible and irreversible treatments. Reversible treatments designed to encourage healing in the muscle and joints include self care, behavioral therapy, splints, medications and physical medicine. Irreversible treatments include joint surgery and permanent occlusal treatments. To determine whether the problem is self-limiting, self care should be initiated first. If the problem does not resolve within a few weeks and there is evidence of progression and/or persistence, treatment can proceed if pain and/or locking is severe enough to affect functioning or quality of life and the patient desires treatment. Each type of treatment is discussed briefly.

Reversible Treatments

Self Care. A key determinant of successful management of any musculoskeletal disorder involves educating the patient about the disorder and the necessity of compliance with the self-care aspects of management, including exercise, habit change and proper use of the jaw (**TABLE 2**).[30,31] Information about self care should be provided to all patients and in some cases is the only strategy needed.

Behavioral Therapy. Approaches to changing maladaptive habits and behaviors should be addressed and presented as an integral part of the overall treatment program for all patients with TMD and poor oral habits.[32,33] Behavior modification strategies are the most common techniques used to change habits. Although many simple habits will change when the patient is made aware of them, changing persistent habits requires a structured program facilitated by a clinician trained in behavioral strategies. Habit change using a habit reversal technique can be accomplished when the patient becomes more aware of the habit, learns how to correct it (i.e., what to do with the teeth and tongue) and knows why it is important to correct it.

When this knowledge is combined with a commitment to conscientious monitoring, most habits will change. Progress in changing habits should be addressed at all appointments. In some cases, patients may have significant psychosocial problems that accompany a TMD and may benefit from medication or counseling by a mental health professional. Prior to initiating treatment, a decision should be made as to whether the psychological distress is the primary problem. If this is the case, treatment of the psychological problem is best accomplished first and as an issue separate and apart from the TMD.

Information about self care should be provided to all patients and in some cases is the only strategy needed.

Intraoral Splints. Splint therapy can be effective alone or in combination with other treatments for each stage of temporomandibular joint (TMJ) internal derangements and myofascial pain.[22] Although there are many useful types of splints, four are commonly used for TMD: the full-arch stabilization splint, the anterior repositioning splint, the anterior bite plane and the posterior bilateral partial coverage splint. Complications that can occur with the use of any splint include caries, gingival inflammation, mouth odors, speech difficulties and/or psychological dependence on the splint. The most serious complication is major irreversible changes in the occlusal scheme (open bites) that occur because of long-term use of partial coverage splints such as the anterior bite plane and the posterior coverage splint. Splints should not be designed to move teeth orthodontically during treatment of a TMD.

Pharmacotherapy. The most commonly used medications for pain are classified as nonnarcotic analgesics (nonsteroidal anti-inflammatories), narcotic analgesics, muscle relaxants, tranquilizers (ataractics), sedatives and antidepressants.[37-39] Analgesics are used to allay pain, muscle relaxants for muscle tension and nocturnal activity, tranquilizers for anxiety, fear and enhancing sleep and antidepressants for pain, depression and enhancing sleep.

Opioid analgesics have their own problems because of the potential for abuse and should be used sparingly and only with patients who have intractable chronic pain, no psychiatric conditions and no history of chemical abuse. If prescribed, clinicians need to follow specific opioid prescribing standards such as use of pain contracts, urine toxicology testing, suspension of medications with violation and other guidelines found at fsmb.org/pdf/2004_grpol_Controlled_Substances.pdf.

Despite the advantages of medications for pain disorders, problems can occur because of their misuse. For this reason, an important goal of treatment for most patients is to eliminate the need for medications long term. With chronic pain patients, termination of current medications should take precedence over prescribing additional ones. Problems that can occur from use of medications include chemical dependency, behavioral reinforcement of continuing pain, inhibition of endogenous pain relief mechanisms, side effects and adverse effects from the use of polypharmaceuticals.

Physical Medicine. The use of physical medicine techniques follows the same orthopedic and physical therapy guidelines as the evaluation and treatment of any musculoskeletal condition.[23] Many exercises and modalities are available to help reduce pain and tenderness and increase range of motion. Exercises are recommended to stretch, strengthen and relax muscles, to increase joint range of motion, to enhance muscle strength or to develop normal arthrokinematics. They are prescribed in order to achieve specific goals and are changed or modified as the patient progresses. Once the patient has reached the goals of the treatment, a maintenance level of exercise is recommended to assure long-term resolution of the patient's problems. In some cases of structural joint problems, limited range of motion and inflammation, ultrasound, iontophoresis, phonophoresis, superficial heat, cryotherapy and massage have been found helpful. Electrotherapies such as electrogalvanic stimulation and transcutaneous electrical stimulation have also been shown to be useful. Muscle and joint injections may also be recommended. However, these modalities typically have short-term effects and need to be used with exercises to maintain the improvement. For this reason, they should be used only until there is no longer a change in objective signs and/or improvement in pain.

Irreversible Treatments

In most cases, TMD problems improve with self care in combination with reversible treatments that encourage the natural healing processes of the muscles and joints. Irreversible treatments involve risk and should be used only if specific criteria are met. This applies to both TMJ surgery and permanent dental stabilization.

Surgery. TMJ surgery has become an effective treatment for structural TMJ disorders.[34-36] However, the complexity of available techniques, the potential for complications, the frequency of behavioral and psychosocial contributing factors and the availability of nonsurgical approaches mandate that TMJ surgery be used only in selected cases that meet specific criteria. The decision to treat a patient surgically depends on the degree of pathology present within the joint, the success or failure of appropriate nonsurgical therapy and the extent of disability that the joint pathology creates. A discussion of individual techniques is beyond the scope of this paper and can be found in the current American Association of Oral and Maxillofacial Surgery (AAOMS) position paper on TMJ surgery. Surgical management may vary from the closed surgical procedure (arthroscopy) to an open surgical procedure (arthrotomy), depending on the degree of disk deformity and degenerative changes. Each of the following criteria, adapted from the AAOMS criteria, should be fulfilled before proceeding with TMJ surgery:

Irreversible treatments involve risk and should be used only if specific criteria are met.

- Documented TMJ internal derangement or other structural joint disorder with appropriate imaging.
- Evidence suggesting that symptoms and objective findings are a result of disk derangement or other structural joint disorder.
- Pain and/or dysfunction of such magnitude as to constitute a disability for the patient.
- Prior unsuccessful treatment with a nonsurgical approach that includes a stabilization splint, physical therapy and behavioral therapy.
- Prior management of bruxism, oral parafunctional habits and other medical or dental conditions or contributing factors that will affect surgical outcome.
- Patient consent after a discussion of potential complications, goals, success rate, timing, postoperative management and alternative approaches, including no treatment.

These conditions maximize the potential for a successful outcome but cannot guarantee it. Patients with factors such as fibromyalgia, depression or resistant nocturnal bruxism present with a complexity that has a poor prognosis. In addition, a full knowledge of complications and the reasons for surgical failure can help clinicians make this decision. Once this information is available, a realistic discussion of the prognosis, the patient's expectations and any complicating factors can help a patient make a correct decision about surgery. Postoperative physical and behavioral therapy should be integrated into the overall surgical management.

Permanent Dental Stabilization. Permanent dental treatment may be needed for some patients to provide stable occlusal support and function for the dental and temporomandibular structures.[40] These treatments include occlusal adjustment, restorative dentistry, fixed or removable prosthodontics and orthodontics with or without orthognathic surgery. If needed because of poor stability of the dentition, permanent treatment is recommended only after pain has been reduced and normal jaw function restored. The criteria for using secondary dental treatment to maintain comfort and function of the temporomandibular structures include:

- The function and stability of the occlusion does not provide adequate orthopedic support. This may be due to missing teeth, skeletal malocclusion or gross interferences in dental function.
- The lack of stable dental support is demonstrated to be directly related to aggravation or recurrence of the TMD after primary treatment of the disorder has been successfully completed.

Permanent dental treatment should proceed with the most conservative approach that will provide adequate function and stability of the occlusion. This ranges from occlusal adjustments to restorative dentistry to improve the dental occlusion and orthodontics to orthognathic surgery for changing the position of the teeth and skeletal relationships.

Conclusion

TMDs are common problems that can cause orofacial pain, jaw dysfunction and chronic head and neck pain, with a collective estimated prevalence of at least 20 percent of the general population (**TABLE 1**).[1-7] Because oral and craniofacial structures have close associations with functions of eating, communication, sight and hearing and form the basis for appearance, self-esteem and personal expression, they can deeply affect an individual's psychological, behavioral and functional status.[8] Thus, understanding TMD with a conceptual model that reflects a comprehensive and integrated problem list that is inclusive and flexible can better prepare clinicians to manage the full diversity of patients, from self limiting to simple to complex. A human systems approach and its related concepts can achieve this goal. ■

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Other Authors' Critiques of Dr. Fricton's Paper

Dr. Simmons

The reviewing author has the greatest respect for the authors of the other three manuscripts. They all provide care that helps patients with their pain, dysfunction and/or negative change in quality of life. The comments that are made are for the possible advancement of the knowledge and skills that further our commitment to better treat our patients.

Dr. Fricton's manuscript is an overview of current whole-body wellness theories and how they relate to the care of the temporomandibular disorder (TMD) patient. He covers the levels of care and the strategies for managing each patient type. He supports most peer-reviewed, evidence-based TMD care and, in appropriate cases, invasive and irreversible care.

TMDs are a group of disorders and not a specific diagnosis. Therefore, treatment should be directed at a specific diagnosis, such as capsulitis, disk displacement with reduction, masseter myalgia, temporal tendinitis, etc. Each diagnosis may have different management techniques.[1] It seems that the TMDs that are described in this manuscript are mainly intracapsular temporomandibular joint (TMJ) disorders.

Conventional wisdom usually directs against the use of the terms "any" and "all patients."

I would like to thank Dr. Fricton for participating in this journalistic endeavor. His patients appreciate his care in relieving their pain and dysfunction.

1. Simmons HC 3rd. A critical review of Greene's article "Managing the Care of Patients with Temporomandibular Disorders: a new Guideline for Care" and a revision of the AADR's 1996 policy statement on TMD, approved by the AADR Council in March 2010, published in the *JADA* September 2010. *Cranio* 2012;30(1):9-24.

Dr. Gelb

Dr. Fricton discusses an inclusive philosophy of TMD with human systems theory, a new concept for most dentists. Dr. Fricton states that humans are complex, multidisciplinary and dynamic and present with a multitude of factors regarding onset, perpetuation and progression of their illness. And yet most modern medicine is reductionist and static, looking only at a few factors according to a preconceived paradigm.

Dr. Fricton discusses a flexible, holistic, integrated model to explain the balance between health and illness using a biopsychosocial medical model, cybernetics and chaos theory.

This is a most thought-provoking paper and an excellent explanation of human systems theory for understanding TMD as a chronic illness.

Dr. Raman

Drs. Fricton, Gelb and Simmons' well-written papers contribute to the knowledge base for dentists.

Dr. Fricton's description of the theoretical basis of his humans systems theory (HST) treatment philosophy is reasonable. However, the crucial step is the actual application of this approach for a patient in clinical practice. That is where the proverbial rubber meets the road. He states that it starts with "seeing the whole patient through the eyes of the biopsychosocial medical model." Prominent proponents of this model such as Charles Greene, DDS, completely dismiss any occlusion-altering approach.[1] Occlusal changes affect the mandibular relationship to the maxilla. When there is a discrepancy in this relationship, correcting that would be "a change from outside to achieve a new level of existence," i.e., a third-order change. In his list of third-order changes, Dr. Fricton fails to include that which dentists are uniquely qualified to do: correct malalignment of mandible to cranial base. Physiologic neuromuscular dentistry (PNMD) does that exquisitely, guided by objective physiologic parameters.

Dr. Fricton's definition of complex patients fits almost every one of my patients. He states that resolution is rarely achieved with complex patients. The PNMD approach has been very successful in resolving medically diagnosed fibromyalgia, migraine and other clinical manifestations of TMD.

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Dr. Fricton's Response to Critiques

First, I want to thank the guest editor, Dr. Jenkins, for his innovative approach in this issue, and the three contributing authors, Drs. Gelb, Simmons and Raman for their thoughtful and engaging comments on their diverse approaches to managing TMD. It is only through this type of knowledge exchange and discussion that we will be able to improve the broad understanding and care of TMD patients. After reviewing the three authors' responses to each of the papers, some general as well as specific comments are warranted.

Evidence-based dentistry is the conscientious, explicit and judicious use of the best and most current evidence in making decisions about the care of each patient. As Turpin[1] stated, "The purpose of using the evidence-based approach is to close the gap between what is known and what is practiced, and to improve patient care based upon informed decision making." Systematic reviews of randomized clinical trials (RCTs) are considered the highest quality of scientific validation because they measure both the quality of RCTs and the power of combining outcomes from multiple studies (**FIGURE**).

With this in mind, systematic reviews of RCTs employing placebo-controlled clinical trials for TMD pain have demonstrated the efficacy of many different interventions, including intraoral splints, self care, exercise, medications, physical therapy, transcutaneous electroneural stimulation, cognitive-behavioral therapies, injections and TMJ surgery. Each addresses one or more of the many factors involved in the etiology of TMD, depending on the individual diagnoses and characteristics of the patient.

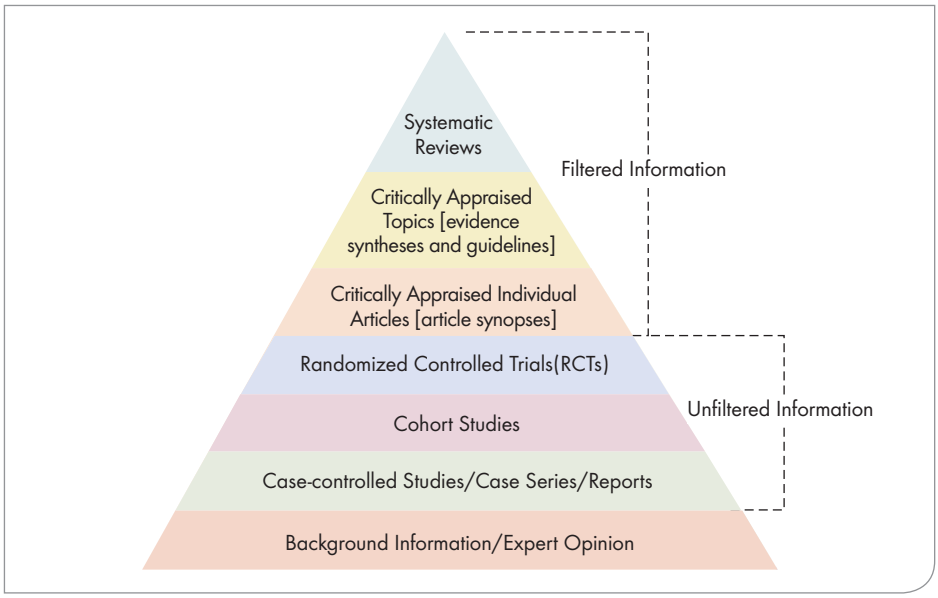

FIGURE. The hierarchy of scientific evidence.

Response to Dr. Gelb's critique

Dr. Gelb recognizes the importance of the concept that should be the basis for all TMD evaluation and treatment: TMD is a chronic illness with a multitude of contributing factors. His innovative paper shows how protection of the airway is one such factor that is paramount to survival and can play a role in the development and subsequent management of TMDs. Likewise, many other contributing factors complicate TMDs and are as important for survival. Examples include the patient with a closed TMJ lock as a result of an assault who now has post-traumatic stress disorder (PTSD), or the patient with masseter pain from being sexually abused who is now depressed and suicidal, or the patient with temple headaches from the anxiety of being a single working mother of two children, or the patient with jaw pain caused by severe nocturnal bruxism due to the side effects of antidepressant medication for ADHD. These types of patients exist in all TMD clinics and the many other contributing factors need to recognized and managed as with any chronic illness.

Response to Dr. Simmons' critique

Dr. Simmons astutely points out that there is no "one-size-fits-all" approach to TMD. Both the specific TMD diagnoses (muscle, joint or both) and the list of contributing factors (behavioral, cognitive, emotional, social, comorbid conditions, etc.) must be identified for each patient. Then the judicious use of these evidence-based interventions as part of an interdisciplinary and integrated approach to care for an individual patient will result in the greatest positive outcome.

Response to Dr. Raman's critique

Dr. Raman also wisely points out that the crucial step for any TMD philosophy is its actual application for patients in clinical practice. He states, "This is where the proverbial rubber meets the road," and provides an important rationale for an evidence-based approach. What works for the few patients who accept a specific treatment approach by a single dentist must also work for many patients who receive the same treatment by other dentists.

In this regard, systematic reviews of RCTs employing occlusal treatment as a primary treatment for TMD, including occlusal adjustment, restorative dentistry, orthodontics and orthognathic surgery, either have not had sufficient clinical trials or have not demonstrated consistent efficacy.[2-11] Although individual patients may improve after these interventions, the results of studies of larger populations are inconsistent. Because of these negative findings and the readily available TMD treatments that have scientific support for their efficacy and, with the exception of surgery, encourage natural healing and repair with fewer adverse events, occlusal treatments are currently not recommended as a primary treatment for TMD.

These recommendations do not mean that occlusion has no relevance to TMD or that dentists should ignore occlusion. For all dental patients, occlusion is critical in providing orthopedic support for stability, comfort and function of the teeth and is essential to eating, appearance, communication and personal expression. Furthermore, patients with TMD often need dental treatment as part of normal dental care. This is particularly true when malocclusion does not provide adequate orthopedic support because of missing teeth, dental or skeletal imbalances or gross interferences. Thus, providing sound evidence-based dental care to these patients is still of paramount importance. Safe dental treatment is also important because dental treatment can cause TMD injuries if the mouth is opened too wide or for too long a period.[12-14]

Conclusion

I believe that most clinicians who care for patients with TMD realize that there is both an art and a science to TMD treatment. The art is important when patient complexity requires recognition of the multitude of contributing factors and formulation of a personalized approach that also maximizes the outcomes of evidence-based treatments. Although we are dentists first and are well trained to treat the teeth and occlusion, we need to recognize that when managing a chronic illness, we must understand and manage the whole patient, even if it involves bringing in other clinicians with expertise we may not have.

Furthermore, there is still a place for empirical experience-based approaches to TMD, because we cannot always rely on science-based approaches that only estimate what strategies work best. But, as Isaac Asimov states, "There is a single light of science, and to brighten it anywhere is to brighten it everywhere." Let's continue to bring science to the treatment of TMD.

Note: For those interested in understanding the strategies and paradigms of a human systems approach to chronic pain, including TMD, the University of Minnesota in coordination with the International MYOPAIN Society (myopain.org) offers an online MOOC course on the topic at coursera.org/course/chronicpain. ■

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Temporomandibular Joint Orthopedics With Anterior Repositioning Appliance Therapy and Therapeutic Injections

H. Clifton Simmons III, DDS

ABSTRACT TMD orthopedics is the assessment, diagnosis and management of orthopedic disorders of the temporomandibular joint (TMJ). Anterior repositioning appliance (ARA) therapy for TMJ internal derangements is successful in long-term recapturing of disks in reducing and nonreducing joints at a rate of 64 percent and in regenerating degenerated condyles in some cases. ARA therapy for TMJ internal derangements is subjectively successful in relieving symptoms in reducing and nonreducing disk displacement TMJs in this study at an average rate of 94.5 percent.

AUTHOR

H. Clifton Simmons III, DDS, received his dental degree from the University of Tennessee College of Dentistry in 1977. He is currently an assistant clinical professor in the Oral and Maxillofacial Surgery Department at Vanderbilt University School of Medicine, an assistant professor at the University of Tennessee College of Dentistry and has a private practice. Dr. Simmons is a diplomate of the American Board of Craniofacial Pain and the American Board of Orofacial Pain. He is a fellow of the American College of Dentists, the International College of Dentists, the American Academy of Craniofacial Pain, the American Academy of Orofacial Pain, the Academy of General Dentistry, the Tennessee Dental Association and the Academy of Dentistry International. Dr. Simmons is president of the American Board of Craniofacial Pain, president of the Tennessee Dental Association and editor of the *Journal of the Tennessee Dental Association*.

Conflict of Interest Disclosure: None reported.

The American Association of Dental Research (AADR) defines temporomandibular disorders (TMDs) as a group of musculoskeletal and neuromuscular conditions that involve the temporomandibular joint (TMJ), the masticatory muscles and all associated tissues.[1]

Definition of TMD Orthopedics

TMD orthopedics is the assessment, diagnosis and management of orthopedic disorders of the TMJ with the goal of returning the joint and associated structures to the highest level of function and least pain achievable, with physiologic normal as the goal.

Informed Consent

Informed consent is paramount for the TMD orthopedic dentist. Some dentists have less than optimum formal education in the assessment, diagnosis and treatment of TM disorders[2] but we are legally liable in most states for diagnosing and treating these disorders.[3] This makes for an environment where the dentist providing TMD orthopedic care must make sure that his or her patients have a clear concept of the treatment that is proposed for them and the research supporting that care.

Patients have the right to decide between conservative and invasive care in treating disorders of the body.[4-6] Dental patients may decide whether they want

to have a tooth extracted or to have endodontic care. Cancer patients decide whether they want care or not. Proper informed consent requires that patients are informed of treatment methods that are available for their disorder.[4] There is adequate peer-reviewed, evidence-based literature to support orthopedic anterior repositioning appliance (ARA) care for some TMD patients.[7-12] If informed consent does not include informing an appropriate group of patients about TMD orthopedic ARA care, then proper informed consent has not been attained.

The author spends three hours conducting a history, examination and consultation with each new TMD orthopedic ARA care patient to ensure that there is clear informed consent before anything more than emergency care is provided. TMD orthopedic ARA therapy is complex care, and dentists should seek education and clinical training before attempting to provide these services to patients.[13] Successful ARA therapy depends on the knowledge and skills of the clinician and it has limitations.[14]

The author has developed a three-page consent form for initial active TMD orthopedic ARA care and, when needed, an additional three-page consent form for more durable, long-term occlusal care and retention.

Human Orthopedic Fundamentals

The American Academy of Orthopaedic Surgeons' definition states that this specialty's scope of practice includes the diagnosis, care and treatment of musculoskeletal disorders, including the body's bones, joints, ligaments, muscles and tendons.[15] The AADR defines TMDs as those that "encompass a group of musculoskeletal and neuromuscular conditions that involve the temporomandibular joints (TMJs), the masticatory muscles and all associated tissues." Weldon E. Bell, DDS,[16] said, "A good understanding of the basic principles of orthopedics should be fundamental to everyday dental practice. It is prerequisite to the rational management of temporomandibular disorders." Most TMDs are an orthopedic disorder, with magnetic resonance imaging (MRI) showing anatomic abnormality in the TMJ in greater than 80 percent of TMD patients.[9,17] In one recent study, 88 percent of 58 consecutive TMD patients seen in a referral-based practice had abnormal MRIs when read by an oral and maxillofacial radiologist.[9] Many TMDs are the result of injury to ligaments, muscles, tendons, nerves, vascular or joint structures.[18-21]

> "A good understanding of the basic principles of orthopedics should be fundamental to everyday dental practice."

Wiesel and Delahay's textbook, *Essentials of Orthopedic Surgery*, states that ligamentous injuries occur as a result of acute macrotrauma and represent a macrotrauma process. In contrast, injuries to tendons can be both acute and chronic processes. Chronic tendon overload represents the classic microtraumatic injury in sports medicine. These injuries occur at the sites of high exposure to repetitive tensile overload.[22] Macrotrauma is defined as either an impact blow or hyperextension of a joint system.[21] The conclusion can be drawn that a macrotrauma event is required to tear the ligaments that hold the TMJ disk in place and therefore displace the disk from a normal physiologic position to an abnormal pathologic position. Displacement of TMJ disks is the causation of TMJ internal derangements.[7] This would exclude normal function and occlusal dental conditions from causation of internal derangements of the TMJ. It would also exclude parafunction of the mandible as causation of TMJ disk displacement, as this is not defined as a macrotrauma event. There are six ligaments (Okeson includes the joint capsule in ligaments) in or associated with each human TMJ.[7]

MRI results were obtained on 30 infants and young children from age 2 months to 5 years. None of the 60 joints that were examined had a displaced TMJ disk.[23] Therefore, humans are not usually born with a TMJ internal derangement.

Isberg et al. described an arthrokinetic reflex in the muscles of mastication associated with disk displacements. "Continuous muscle activity was provoked by disk displacements and ceased when the disk position was normalized on mouth opening, only to occur again every time the disk became displaced on mouth closure." These findings were in line with those previously published on limb joints, which indicated that joint derangements are a cause of muscle hyperactivity.[10,21] Farrar reported that the evidence was "conclusive and irrefutable" that TMJ displaced disks produced the symptoms of myofascial pain dysfunction.[24] There is literature to support that recapturing a TMJ disk can relieve symptoms of the arthrokinetic reflex.[25] Relieving abnormal muscle activity can relieve pain of muscle origin.

Cyriax, in his *Textbook of Orthopaedic Medicine*,[11] states that muscle spasm should not be treated as a primary disorder when there is a concomitant joint disorder. He maintains, "If arthritis or a degree of internal derangement can be

abated, the protection given to the joint by the muscles becomes unnecessary." Cyriax also states, "No structure of the body is so quickly altered by influences outside itself as muscle. Once a muscle has wasted considerably, even though no disease of the muscle itself has ever occurred, it may never regain full bulk." A TMJ with a disk displacement (internal derangement) may cause abnormal muscle activity (contraction) around the joint. The abnormal muscle activity may then cause the patient to experience muscle pain through trigger points, headache, neck ache, autonomic phenomena such as dizziness and disequilibrium, fatigue in craniofacial muscles and mandibular dysfunction. The question for the TMD orthopedic dentist is, "Why is that muscle in a state of continuous activity, contraction, splinting or spasm?"

Knowledge of the anatomy and a systematic approach are the fundamentals of palpation.[26] A widely accepted method to determine muscle tenderness and pain is by digital palpation. A healthy muscle does not elicit sensations of tenderness or pain when palpated.[7,27] While tenderness of a particular structure may be present in the majority of individuals, tenderness should not be present in a healthy, optimally functioning structure. Consequently, while tenderness may be "the norm" for that individual, it is not truly normal and indicates a subclinical dysfunction. So the conclusion can be drawn that palpated normal structures should not elicit pain.

For proper orthopedic evaluation, joint motion must be assessed and measured.[26] The consensus among a large group of TMD authorities is that mandibular normal opening range is 40-50 millimeters, and the normal left and right lateral movements are 8-12 millimeters.[28]

TMD care was covered in orthopedic medicine and surgery textbooks until the 1980s,[11,29] when physicians and surgeons turned this area of care over to the dental profession. As testimony to this, *Campbell's Operative Orthopaedics*, fourth volume, 11th edition (4,899 pages) and Wiesel and Delahay's textbook, *Essentials of Orthopedic Surgery*[22] (615 pages) do not have the words "temporomandibular" or "TMJ" in either of their indexes. It is now the responsibility of the dental profession to provide orthopedic care for the only joints that the medical community does not treat. Many TMDs are orthopedic disorders and orthopedic care for some TMDs is appropriate.[16]

> It is now the responsibility of the dental profession to provide orthopedic care for the only joints that the medical community does not treat.

The TMD Orthopedic Dentist

An orthopedic TMD dentist is a dentist who may:

- Treat TMDs by utilizing orthopedic appliances to reposition the mandible to diminish the load on the TMJ.[7,30,31]
- Reposition the mandible to attempt to recapture displaced TMJ disks that are reducing.[7-9]
- Reposition the mandible to place the condyle in a more physiologic position to diminish an arthrokinetic reflex (protective muscle splinting).[10,11,21]
- Manipulate the mandible to reduce TMJ disks that may have been reducing and now are acutely nonreducing.[7,12,13]
- Manipulate the mandible to mobilize the TMJ condyle and/or disk.[7,32,33]
- Use injection techniques to diagnose and treat TMDs.[7,12,34-37]
- Use physical medicine to treat TMDs,[7,12,38] and, when indicated, provide long-term reversible and irreversible occlusal care for orthopedic TMDs.[3,7,39,40]

TMD orthopedic dentists may treat sleep apnea[13,41] and dental malocclusions,[39,42] but these disorders are not classified as TMDs. TMD orthopedic ARA care that is peer reviewed and evidence based is clearly available for some TMDs.[25,43-48] The American Dental Association (ADA) publication *Dental Practice Parameters for Temporomandibular (Craniomandibular) Disorders*[3] supports most of the procedures described in the above definition of an orthopedic TMD dentist. The ADA Council on Dental Care Programs[40] also supports most of these procedures. Dentofacial orthopedics is a part of mainstream orthodontic care utilizing functional appliances and Herbst appliances.[39]

Value of Normal Disk Position

Hall[49] stated that data now support the assumption that a normal TMJ disk position assists in alleviating pain, prevents the gross degenerative changes of osteoarthritis and promotes growth of the mandible. Based on these data, he believes there is a strong argument for including disk recapture as an important goal of any treatment for the painful joint with a displaced disk that reduces.

Nickerson,[50] using Boering's 30-year study of the natural course of TMJ degeneration,[51] showed that reestablishing normal disk position protects the joint from degenerative joint disease and osseous breakdown leading to occlusal collapse and facial distortion. Nickerson[50] stated that under certain conditions there is a relationship between TMJ disk displacement and masticatory

FIGURE 1. Normal TMJ anatomy (adapted from Lundh and Westesson).

FIGURE 2. Abnormal TMJ anatomy – TMJ disc displacement with reduction (adapted from Lundh and Westesson).

FIGURE 3. Awake mandibular orthopedic repositioning appliance.

musculoskeletal pain. He suggested that there is positive value to having the disk in a load-bearing position, and that the primary focus in treating patients with disk displacement with reduction should be an attempt to recapture the disk.

Schellhas et al.[20] used MRI to show the negative effects of disk displacement of the TMJ in children. They found that children with retrognathia and mandibular asymmetries usually have advanced degrees of TMJ derangements with characteristic shifts toward the most deranged joint. They proposed that in the growing facial skeleton, internal derangement of the TMJ either diminishes or stops condylar growth, resulting in facial distortion.

Lundh and Westesson[52] discovered that recapturing a displaced disk effectively eliminated pain and dysfunction in patients in whom a normal relationship between the disk and the condyle can be established. In their study, ARA therapy was deemed superior to either flat plane appliance therapy or to no treatment.

There is adequate literature to support the value of having the TMJ disk in a normal anatomical and load-bearing position, and there are definite negative consequences to having a displaced TMJ disk.

A study by Simmons and Gibbs[9] included 53 joints with disk reduction and 45 joints with disks recaptured with ARA, yielding a 3-D recapture rate of 85 percent. Recapture or improvement in disk position was achieved in 91 percent of reducing, 28 percent of nonreducing and 63 percent of all joints with internal derangements. No disk status was worsened.

TMD Orthopedic ARA Therapy Care

Treatment of most human disorders usually has as the goal a return to a more normal physiologic state. TMD orthopedic ARA therapy's goal is to return the mandibular condyle and the contents of the TMJ to the most normal physiologic orthopedic condition attainable. Imaging is necessary for proper bite positioning[53-55] and has shown recapture with MRI in 85-96 percent of patients with disk displacements with reduction.[8,9] Lundh and Westesson showed normal anatomy of the TMJ in their TMJ dissection videos (**FIGURE 1**) as the reference for normal, and others have validated this.[56-58] **FIGURE 2** shows abnormal TMJ anatomy demonstrated as disk displacement with reduction. Some patients with disk displacement with reduction start as shown in **FIGURE 1**, with teeth in maximum intercuspation, and through macrotrauma become as shown in **FIGURE 2**, with teeth in maximum intercuspation. Occlusal changes are possible from displacement of the TMJ disk.[7,13,49,50]

When the patient is awake, the reflex to swallow (deglutition) occurs once per minute[59,60] and causes the maxillary teeth to index into a mandibular orthopedic appliance (**FIGURE 3**) that is constructed to cause the mandibular condyle to return to a more physiologic position in the glenoid fossae. Over a period of one to two months, the patient adapts to the new swallowing occlusal index in the orthopedic appliance. Patient symptoms are usually relieved in three to six months by the normalization of the contents of the TMJ,[25,61] which reduces the protective muscle splinting (arthrokinetic reflex)[10] that may have caused the pain the patient was experiencing. Research has shown that the muscles associated with the TMJ sense where the condyle is positioned more than they sense where the disk is positioned.[25,62]

Lundh and Westesson[62] felt that replacement of the disk onto the condyle may not be absolutely necessary and that a protrusive change in condylar position may be sufficient to give relief of symptoms in some cases. During sleep patients swallow only three times per hour[63] so they need an appliance similar to that popularized by Farrar[43] (**FIGURE 4**) that does not rely on swallowing to compensate for the injured ligaments of

FIGURE 4. Farrar asleep maxillary orthopedic repositioning appliance.

FIGURE 5. Simmons asleep appliance.

the TMJ. This is accomplished by wearing an asleep appliance that holds the condyle in the same position as the awake appliance without relying on the swallow reflex.[12,57,64,65]

The author used the Farrar appliance for asleep wear with all research papers, but now uses the appliance shown in **FIGURE 5** because of improved retention of orthodontic corrections. The patient is required to wear an appliance 24 hours per day, except for oral hygiene care.[12,57,64,66] After accomplishing maximum medical improvement, the patient is asked to continue wearing the appliances for an additional three months to prove that his or her condition is stable.[40] End of active care records are then taken for the patient. For long-term retention of physiologic condylar position, the less durable acrylic awake appliance is either replaced with a more durable mandibular overlay partial denture (chosen 5 percent of the time by the author's patients), or patients have the option of orthodontic care to close their posterior open bite and finalize their teeth to the new mandibular position (chosen 93 percent of the time by the author's patients) or crowns and/or bridges, which are utilized only if the patient needed full-coverage dental restorations pretreatment (chosen 2 percent of the time by the author's patients). ARA therapy is not focused on the dental occlusion other than as a method of retaining the mandibular condyle in a more normal physiologic position to compensate for the inability of torn ligaments to hold the contents of the joint in a physiologic position. The asleep appliance is continued for the remainder of the patient's life as a retainer of teeth position and to keep the mandibular condyle in the more normal position in the glenoid fossae during the low swallowing environment of sleep[63] because injury to the ligaments are permanent and cannot provide this function.[22]

Only patients who have some degree of pain, dysfunction and/or negative change in quality of life (PDQ, a term trademarked by the author) warrant TMD orthopedic ARA care.[58,67,68] If a patient who does not have PDQ elects to have orthopedic ARA care for a TMD a clear informed consent relevant to this issue is strongly recommended.

Superiority of ARA Therapy to Flat Plane Appliance Therapy

Lundh et al.[61] evaluated 70 patients with TMJ internal derangements. They divided treatment of the patients into anterior repositioning appliance therapy, flat plane appliance therapy and a control group with no appliances. Both appliance groups had reduced joint tenderness, but the ARA group demonstrated a significantly greater improvement with respect to internal derangements and symptoms.

Anderson et al.[69] divided 20 patients with internal derangements into two groups and treated one group with maxillary flat plane appliances and the other with ARA. After 90 days, the ARA group experienced a significant reduction in dysfunction and symptoms. The flat plane appliance group experienced no change in dysfunction and two patients progressed to closed lock (disk displacement without reduction).

In 2002, Brown and Gaudet[70] published a long-term, multisite study of 2,104 treated, 250 untreated and 44 long-term treated TMD patients. A valid and uniform assessment of treatment outcomes across a large number of practices was assured by utilizing the TMJ Scale (Pain Resource Center, Durham, N.C.). This paper showed that untreated TMD patients do not improve spontaneously over time and that patients treated with a variety of active modalities achieve clinically and statistically significant levels of improvement. The use of ARA therapy produced superior results compared to flat plane appliance therapy.

Symptom Relief From ARA Therapy

Simmons and Gibbs[25] found that at maximum medical improvement (MMI), symptom improvement from ARA therapy was 81-87 percent in patients with both disks either in normal position or recaptured position and 76 percent in patients with at least one disk that did not recapture. Occipital headache, which was the most common complaint, occurred in 94 percent of the patients. Headaches after MMI were unchanged in 1 percent of the patients, better in 33 percent and eliminated in 66 percent.

TABLE 1

Symptom Frequency Versus Disk Status in 48 Patients*

Disk status at MMI	Patients (no.)	Pretreatment frequency		Weighted frequency at MMI[a]		Improvement (percent)	
		Mean	95% CI	Mean	95% CI	Mean	95% CI
All	48	54	50-58	11	8-14	80	75-85
N-N	7	48	34-62	7	2-12	87	79-95
N-WR	5	47	31-63	10	4-16	81	68-94
WR-WR	11	58	49-67	9	4-14	85	76-94
WR-WOR	9	55	43-63	13	6-20	76	63-89
WOR-WOR	16	54	47-61	14	8-20	76	68-84
$\chi 2$		13.6		31.2		12.2	
Df		4		4		4	
P		<0.01		<0.001		<0.02	

[a] Weights for symptom frequencies at MMI: absent 0, improved 0.5, unchanged 1, worse 2.

MMI = maximum medical improvement, N = normal TMJ disk status, WR = with recapture of the TMJ disk and WOR = without recapture of the TMJ disk. Seven patients with normal disk status on MRI had TMJ clicking and symptoms.

* Adapted from Simmons HC, Gibbs SJ. Anterior Repositioning Appliance Therapy for TMJ Disorders: Specific Symptoms Relieved and Relationship to Disk Status on MRI. *Cranio* April 2005; 23:89-99.

TABLE 1 shows pretreatment and posttreatment symptom levels for each disk status posttreatment and a statistical analysis. All classifications of disk displacement had significant positive results with ARA therapy.[25]

TMD Orthopedic Assessment, Diagnosis and Management Appointment Sequence

1. History, examination and consultation appointment.
2. Diagnostic appointment.
3. Appliance delivery appointment.
4. Range of motion, anatomic site palpation, follow-up evaluation of presenting symptoms at three- to six-week intervals for six to nine months.
5. End of reversible care appointment.

Posterior Open Bite

TMD orthopedic ARA therapy creates a posterior open bite as the condyles are moved forward in the fossae to recapture disks or to move the condyles to a more physiologic position in the fossae when the disk(s) cannot be recaptured.[71,72] A posterior open bite is an expected and acceptable result of ARA therapy and is compensated for by continued wearing of the active treatment intraoral appliance or a more durable overlay partial denture, or it is corrected by crowns and/or bridges or orthodontic care.[40,73] Patients must be informed of the possible creation of a posterior open bite before initiation of ARA therapy.

Therapeutic Injections for TMDs

Orthopedic care of the TMJ may utilize various injection techniques.[12,13,37] Waldman[34] stated that injection of the TMJ is indicated as an important component in the management of TMJ dysfunction, the palliation of pain secondary to internal derangement of the joint and in the treatment of pain secondary to arthritis of the joint. Injection of local anesthetic is used to diminish trigger points in muscle bellies and tendons.[35,74] Bell[37] stated that the use of local anesthetic in the treatment of orofacial pains is very effective. To be successfully treated, some pain syndromes require the use of local anesthetic injections. Proliferative therapy injections are used to strengthen and thicken injured tendons, ligaments and joint capsules.[75-78] Proliferative therapy injections were not used in any research paper referenced in this article, but are now an integral part of the author's care of TMD patients.

Untreated Cohort of TMD Patients Versus Patients Treated With ARA and Injection Techniques

On June 7, 2007, letters were sent to 420 patients who had decided not to have treatment and who had completed a TMJ Scale test from 10 years to one year prior. The letter asked the patients to complete a new TMJ Scale if they had not had treatment for their TMD. Forty-five test replies were received. **TABLE 2** shows the cohort of 45 untreated TMD patients compared with 100 consecutive patients treated in the author's office using ARA therapy and therapeutic injections. This untreated cohort versus treated patients shows a control and has a statistical significance of <0.001.

Long-term, 10-year Follow-up on ARA Patients

Of the 48 patients who finished active orthopedic ARA care in a study by Simmons and Gibbs,[25] 39 patients were provided more durable, long-term occlusal care. Beginning on April 8, 2006, MRIs were obtained on these patients to determine long-term status of their TMJ disks. The author's durable occlusal care options for long-term retention of condylar position were described earlier. These patients finished more durable occlusal care from six to 12 years before this data was recorded, with an average of 10 years.

Of the 39 patients who finished more durable occlusal care, 20 agreed to long-term follow-up MRIs. Of the 40 joints in this long-term study, 25 had disks that reduced on mouth opening before treatment. Of these, at appliance delivery there were 20 joints for which disks were

TABLE 2

Untreated Cohort of TMD Patients Versus Patients Treated With ARA and Therapeutic Injections

TMJ scale domains	45 untreated patients	100 treated patients
	Percent improvement	Percent improvement
Pain report (PR)	30.3	68.2
Pain palpation (PP)	8.8	76.4
Perceived malocclusion (MO)	14.7	37.2
Joint dysfunction (JD)	14.2	76.2
Range of motion limitation (RL)	19.0	56.9
Non-TM disorder (NT)	5.1	55.1
Psychological factors (PF)	13.1	43.7
Stress (ST)	8.8	37.5
Chronicity (CN)	18.2	23.5
Global score (GS)	24.3	64.1

This yields a statistical significance of <0.001.

recaptured with ARAs. That yields a 3-D initial disk recapture rate of 80 percent (20/25) in this patient population.[9]

All MRIs were read by a board-certified oral and maxillofacial radiologist (S. Julian Gibbs, DDS, PhD). Twelve joints retained the recapture of disk at long-term MRI evaluation, for a 60 percent (12/20) retention of initial TMJ disk recapture in this patient population and a long-term recapture rate of 48 percent (12 recaptured disks long term/25 joints with reducing disks before treatment). Some of these patients had experienced significant trauma to the mandible since finishing care.

At long-term follow-up, six joints had new recapture of the disks that were not recaptured initially. Three of the six were displacement with reduction and three were displacement without reduction before treatment. Three disks that recaptured long term from the reducing group that did not recapture initially, added to the 12 disks that initially recaptured, equals 15 disks that recaptured long term. This raises the long-term recapture rate of this patient population to 60 percent (15/25) of disks recaptured from the reducing group. Twelve joints out of 40 had disk displacement without reduction (closed-lock) at pretreatment initial MRI. Three disks recaptured from the nonreducing group to a normal position by ARA therapy and long-term retention. This yields a 25 percent (3/12) recapture of disks that were disk displacement without reduction prior to treatment. When the three new recaptures from the displacement without reduction group are added to the final count of recaptures, the total is 18 disks recaptured long term (12 retained from initial recapture, three new recaptures from reducing group and three new recaptures from nonreducing group) of the 28 joints (25 reducing and three nonreducing), for a recapture rate of 64 percent (18/28).

Four patients had the six surprise disk recaptures. All of these patients were compliant and reported that they wore their maxillary ARA almost every time they slept following completion of more durable occlusal care.

Subjective percent improvement statements were signed by each of the 20 patients who had a long-term MRI. The average subjective symptom relief in this group was 94.5 percent of presenting symptoms relieved. Eight of the patients reported that 100 percent of their presenting symptoms were gone at an average of 10 years' follow-up.

Regeneration of Mandibular Condyles From ARA Therapy and Long-term Retention

Several of the long-term follow-up patients showed regeneration of the mandibular condyles as a result of their ARA therapy, durable occlusal care and long-term retention. **FIGURES 6A–B** and **7A–B** show one of these regeneration cases.

Retention of Orthodontic Care and Condylar Position

Joondoph[79] devoted a complete chapter in a textbook to his findings that postorthodontic treatment results after ARA therapy completely relapsed over time (four years). In a recent study by Lenz and Harris,[80] orthodontic relapse was 50 percent of dental correction and 115 percent of skeletal correction at 10 years posttreatment in a group of dental students who were treated by their hometown orthodontists. Lenz and Harris state that there is little to suggest long-term stability of an orthodontic result. Aggressive lifetime retention appears to be the only predictable method of permanently retaining orthodontic corrections.[73] The author's cases in this report were all aggressively retained by a maxillary anterior retaining appliance to be worn during sleep for the rest of the patient's life. Proper aggressive lifetime retention solves ARA case relapse.

Conclusions

In Katzberg and Westesson's opinion,[58] protrusive appliance therapy, followed by permanent alteration of the dental occlusion to match the therapeutic position, is an effective method of diminishing symptoms related to disk displacement with reduction. Okeson[7] states that when occlusal therapy is indicated to resolve the symptoms of a TMD, the specific treatment goals are

FIGURE 6A. MRI – right TMJ, 1/28/95, 42 years 3 months old.

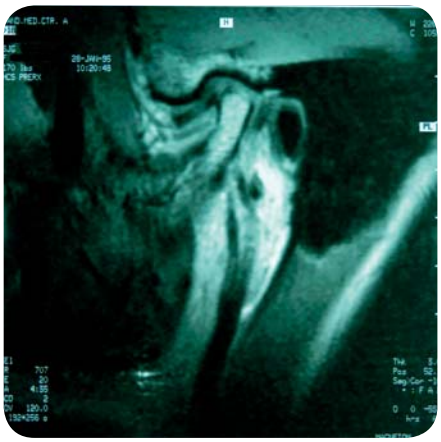

FIGURE 6B. MRI – left TMJ, 1/28/95, 42 years 3 months old.

FIGURE 7A. MRI – right TMJ, 4/29/06, 53 years 6 months old.

FIGURE 7B. MRI – left TMJ, 4/29/06, 53 years 6 months old.

determined by an occlusal appliance that has successfully diminished the symptoms. If an intraoral appliance has diminished the signs and symptoms, a similar occlusal condition may be introduced by irreversible occlusal therapy.

Simmons and Gibbs[25] concluded a 1997 paper by stating that if the largest category in a consecutive complex chronic TMJ pain population is disk displacement with reduction, and 85 percent of these will recapture when the condyle is placed in the Gelb 4/7 position (physiologic normal), and symptomatic relief following ARA therapy has been shown by both subjective and objective criteria in patients with other categories of disk disorder, then ARA should be the appliance of choice for this patient population.

Orthopedic care is appropriate for some TMDs. ARA therapy for TMJ internal derangements was successful in long-term recapturing disks in reducing and nonreducing joints in this patient population at a rate of 64 percent. ARA therapy for TMJ internal derangements was subjectively successful in relieving symptoms long term in reducing and nonreducing joints in this patient population at an average rate of 94.5 percent. Based on the evidence presented in this study, the orthopedic TMD dentist utilizing ARA therapy may now regenerate TMJ condyles in some patients. ■

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Other Authors' Critiques of Dr. Simmons' Paper

Dr. Fricton

The papers by Drs. Gelb, Simmons and Raman highlight diverse approaches to understanding the etiology of temporomandibular disorders (TMD). Each author astutely recognizes that TMD is a complex chronic condition that is multifactorial in etiology. For this reason, TMD is included as one of the major conditions in the advanced area of dentistry known as orofacial pain. The field of orofacial pain has evolved over the past 20 years and now has more than 12 advanced specialty training programs in universities across the country, recognition by the Commission on Dental Accreditation, internationally recognized board certifications and a wealth of National Institute of Health-sponsored research programs. However, because of the high prevalence of TMD and its integral relationship to teeth and jaw function, each of these authors recognizes that it is of paramount importance that all dentists be able to recognize the broad aspects of this condition.

Orthopedic "Disk Recapture" Strategy. Dr. Simmons restores the health of the temporomandibular joint and masticatory system in patients who have clicking and pain from TMJ disk derangements by achieving a physiologic normal disk-condylar position that minimizes microtraumatic injury to the joint, joint inflammation and secondary myofascial pain. Anterior repositioning appliance therapy (ARA) using cephalometrically corrected tomograms is one method of orthopedically repositioning the condyle to achieve functional harmony. The paper reviews the clinical trials to support the efficacy of ARA. To Dr. Simmons' credit, the adverse events related to this approach are discussed. They include open bites and the subsequent need for permanent occlusal reconstruction, overlay partials or orthodontics. The paper also reviews the use of joint and muscle injections to supplement ARA therapy and resolve any residual pain.

Conclusion

Sir William Osler, the father of modern medicine, suggested a principle that has important implications for clinicians who treat TMD: "It is much more important to know what sort of person has a disease than what sort of disease a person has." Despite different etiologies, each of the authors principally relies on a consistent general treatment approach – that of primarily correcting the mandibular jaw position through splints. It is true that systematic reviews of randomized controlled trials (RCTs) demonstrate the efficacy of splint therapy beyond placebo and thus can be a part of TMD treatment plans.[1-3] However, the scientific literature also suggests that there is much more to treating the patient with TMD than use of splints. The diverse results of placebo-controlled clinical trials for TMD suggest that there are many interventions, from self care, exercise and medications to physical and cognitive-behavioral therapies. Injections and surgery can each be used to improve TMD pain in different cases, depending on the characteristics of the patient.[1-20] We know there is no "one-size-fits-all" approach to TMD. Thus, the judicious use of each of these evidence-based interventions, including splints, as part of a personalized approach to care for an individual patient will result in the most positive outcomes.

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Dr. Gelb

The TMJ is a synovial joint, with a disk and two compartments working in a class-three lever system that follows orthopedic principles.

Dr. Simmons makes us aware of how little time is spent in the undergraduate dental curriculum on TMD diagnostic competency, yet the dentist is legally liable in most states to diagnose and treat these disorders.

Isberg described the arthrokinetic reflex, which was also seen by Cyriax, a physician, and by Gelb and Farrar and other orthopedically minded dentists to explain continuous muscle activity, contraction, splinting and spasm. This counters a purely neuromuscular approach in favor of orthopedic anterior repositioning therapy.

Informed consent is a very important part of anterior repositioning appliance (ARA) therapy, as the teeth are secondary and bites are often altered.

In ARA therapy and Airway Centric (AC) philosophy, posterior open bites are frequently observed, as the TMJ and airway are optimized.

Dr. Simmons' orthopedic approach using ARA therapy to recapture disks has been well documented. Although disk recapture is preferable, joint decompression with pseudo-disk formation is also successful in reducing symptoms.

Dr. Simmons states that his cases usually require case finishing: Two percent crown and bridge, 5 percent permanent appliance and 93 percent orthodontics

In children, I agree that almost 100 percent of cases would be finished. orthodontically to a Gelb 4/7 position and open airway with nonextraction expansion functional and fixed orthodontics (Mew, Hang, Singh, Mahoney, Miraglia, Rondeau).

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OTHER AUTHORS' CRITIQUES, CONTINUED FROM 546

With adults, we attempt to wean our patients off daytime appliance therapy using cognitive behavioral therapy, starting with lips together, teeth apart, tongue to the spot, sternum up, core engaged, with the feeling of a string lifting the head.

In my practice, 5 percent require some dentistry such as anterior guidance or crown and bridge. Another 10 percent are sent for orthodontic evaluation.

Approximately 85 percent are finished with only a nighttime appliance such as a Farrar or AC oral appliance.

Given the epigenetic and iatrogenic changes to our faces and occlusions, a posterior open bite should not be viewed as abnormal. It is preferred to a compressed TMJ and closed airway position.

Dentistry has been retruding the jaw, compressing the joint and closing the airway for 85 years. The time has come for change and for the orthopedic principles of anterior repositioning therapy as explained by Dr. Simmons.

Dr. Raman

Dr. Simmons' paper describes his treatment approach of anteriorly repositioning the condyle to recapture the disk. The PNMD approach does include this concept to achieve optimal results, as a dislocated articular disk is not congruent with calm muscles. While it is agreed that a displaced disk elicits muscle hyperactivity, a displaced disk is not a prerequisite for muscle hypertonicity.[1] A poor mandibular alignment that necessitates increased activity of the temporalis muscle(s) also leads to myofascial pain dysfunction (MPD). So MPD syndrome could precede disk displacement.

Dr. Simmons dismisses any other causation besides macrotrauma for disk displacement. All joints are protected by ligaments at the limits of their range of motion. Normally, the muscles stabilize the joints. If a joint chronically functions at the limits, it is "leaning on the ligament." Such chronic overloading of ligaments has been shown to damage them[2] and to lead to dislocation of articular cartilage.[3]

Further, he suggests that there is some positive value to having the disk in a load-bearing position, and that the primary focus in treating patients with disk displacement with reduction should be an attempt to correct this condition. Normal function of crushing food – the activity of maximal load on the TMJs – occurs with teeth apart. However, if the teeth are together and maximal load is applied, the TMJ experiences load with the disk in the ideal position. Of course, this describes clenching, which is parafunction. Post-condylectomy patients who have been treated with PNMD concepts are functioning well – able to chew food and remain pain-free – even in the absence of an intact condyle-disk-fossa assembly.

Dr. Simmons also states that anterior repositioning appliance (ARA) therapy for TMJ internal derangements is subjectively successful in relieving symptoms long-term in reducing and nonreducing joints at an average rate of 94.5 percent. While subjective improvement is what matters to patients, is it possible to treat a case to subclinical asymptomatic status that would be more vulnerable for relapse or dysfunction? Why not use objective data such as EMG to augment subjective reports to guide treatment?

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Dr. Simmons' Response to Critiques

Response to Dr. Fricton's critique

Dr. Fricton states that a posterior open bite is an adverse event related to anterior repositioning appliance (ARA) therapy. In most cases, a posterior open bite is a predictable and expected part of ARA therapy. The patient must be informed before treatment[1] of this mid-treatment event so that he or she expects possible further treatment to correct the usual dental occlusal disharmony created by ARA therapy.[2,3] Other areas of dentistry have similar treatment outcomes. When a molar endodontic procedure is completed, the tooth typically needs a crown.

Response to Dr. Gelb's critique

Dr. Gelb recommends weaning most TMJ internal derangement patients off their awake ARA therapy appliance and allowing them to return to their pretreatment dental occlusion. This practice is utilized by a large number of dentists who provide ARA therapy and is recommended by some guideline texts.[4] The dental occlusion usually changes secondary to TMJ disk displacement when a thicker disk is exchanged for a thinner posterior attachment tissue. Therefore, the spacer between the condyles and fossae usually changes with chronic TMJ disk displacement and the forces of the masticatory elevator muscles. Teeth position adapts to changes in the TMJ condyle position and also to changes to the teeth throughout life.[5] Most TMJ disorder patients are chronic pain patients,[6] and therefore, the dental occlusion has usually had time to adapt to the pathological position of the condyles in the fossae.[7] This is the reason for the need for occlusal therapy after reversible ARA therapy. When people have posterior teeth, they have a reflex desire to occlude their maxillary and mandibular posterior teeth to swallow approximately 1,500 times per day and to masticate food.[8,9] If patients are allowed to return to their pretreatment dental occlusion, they may return to some degree of their pretreatment signs and symptoms because ligaments that once held the TMJ components in a physiologic position do not heal to pretrauma condition.

Response to Dr. Raman's critique

Dr. Raman questioned the concept that macrotrauma is the etiology of TMJ disk displacement disorders. There are several references in the peer-reviewed literature that lead one to believe that trauma is the major cause of TMJ intracapsular disorders.[10-13] Wiesel and Delahay's textbook, *Essentials of Orthopedic Surgery*,[14] which was quoted in the manuscript, is used by medical schools to teach third- and fourth-year medical students the basics of orthopedic surgery. Dr. Wiesel is the professor and chair of the Department of Orthopedic Surgery at Georgetown University Medical Center. Dr. Delahay is professor and vice-chair of the same department. The textbook is in its third edition, so any errors would have been corrected by the third edition. Ten other orthopedic surgeons contributed to this textbook, which states that "ligamentous injuries occur as a result of acute macrotrauma and represent a macrotrauma process." TMJ disks are held in place by ligaments.[4,15]

The references that Dr. Raman cites relating to joint overload as a cause for articular cartilage displacements are both related to lower limb weight-bearing joints.[16,17] The human TMJ disk is fibrous connective tissue and is not cartilaginous.[4,15,18] Human maxillary and mandibular teeth contact each other for only 20 minutes out of 24 hours in a normal person.[8,9] If chronic overloading of the TMJ ligaments could lead to disk displacement, then chin straps on football and other helmets should be reconsidered as to whether they are safe. If pressure on the TMJ ligaments can lead to osteoarthritis of the TMJ, then forces that are used for orthodontic care of Angle's Class III patients should be reconsidered.

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CDA JOURNAL, VOL 42, N°8

Airway Centric TMJ Philosophy

Michael L. Gelb, DDS, MS

ABSTRACT The airway governs our ability to breathe and to achieve a restful, oxygenated, restorative night's sleep, as well as to perform optimally during the day. Any temporomandibular joint or occlusal philosophy must address airway patency while managing pain and dysfunction, identifying contributing factors and alleviating perpetuating factors. The teeth are the last piece of the Airway Centric paradigm. The airway is the first, then joint and muscle and, lastly, the occlusion.

AUTHOR

Michael Gelb, DDS, MS, is an innovator in sleep apnea, painful TMJ disorders and other head and neck pain disorders. Dr. Gelb has studied breathing-related sleep disorders (BRSD), specializing in how they relate to fatigue, focus and pain, and their potential adverse effects. He received his dental degree from Columbia University School of Dental and Oral Surgery and a master's degree from the State University of New York at Buffalo School of Dental Medicine. He is the former director of the TMJ and Orofacial Pain Program and a clinical professor in the Department of Oral Medicine and Pathology at New York University College of Dentistry.

Conflict of Interest Disclosure: Michael Gelb, DDS, MS, is the co-inventor of the Airway Centric medical device and is the chairman and CEO of Gelb Technologies LLC. Historical portions of this content are from previously published material.

The airway guides the development of the nasomaxillary complex, mandible, temporomandibular joint (TMJ) and, ultimately, the occlusion of the teeth.[1-5] Occlusion is driven by the airway, and malocclusion and facial morphology are compensation for a narrowed airway. Airway Centric (AC) TMJ philosophy explains this important paradigm shift based on new research, with an emphasis on prevention of sleep disordered breathing (SBD), temporomandibular disorders and neurobehavioral disorders[5,6] (**FIGURES 1** and **2**).

The airway governs our ability to breathe and achieve a restful, oxygenated, restorative night's sleep, as well as to perform optimally during the day. Epigenetics[7] and phylogenetics[8] have made humans susceptible to airway collapse because of a variety of factors, including a descending epiglottis,[9] a floating hyoid, high narrow palate,[10] retruded constricted maxilla[4] and maxillomandibular retrognathia as well as enlarged tonsils, adenoids and tongue. In addition, current orthodontic technique[11] and nightguard fabrication may compress condyles and narrow pharyngeal airspace.[12] Environmental factors, such as feeding patterns, dietary characteristics, trauma, pacifier use, digit sucking, mouth breathing and swallowing habits, are also associated with malocclusion.[13] Airway narrowing and SDB lead to alterations in the nasomaxillary complex and mandible as well as to further malocclusion.[14]

The dentist plays a key role in airway health, as 90 percent of obstruction occurs behind the maxilla and mandible in the region of the soft palate, tongue and lateral fat pads.[15] The ear, nose and throat specialist (ENT) and orthodontist are also essential to establishing nasal and pharyngeal airway patency.

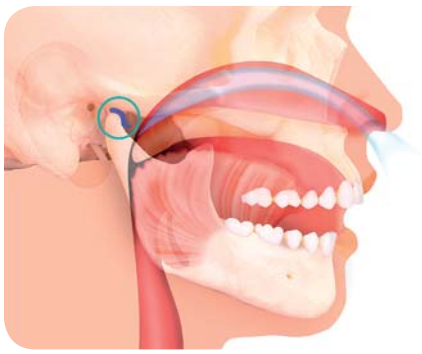

FIGURE 1. Closed airway.

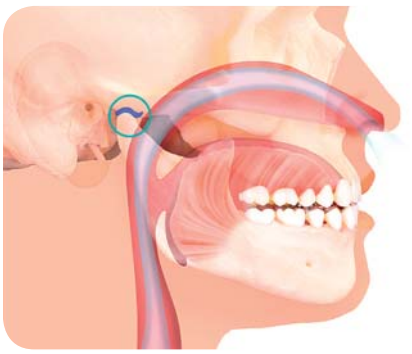

FIGURE 2. Airway Centric philosophy.

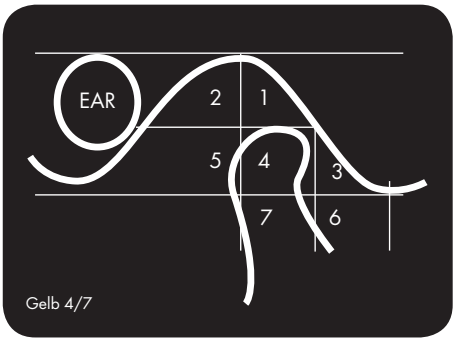

FIGURE 3. Gelb 4/7 position.

Any TMJ or occlusal philosophy must also include a nighttime component to address parafunction or bruxism because of the shearing forces to the joint[12] and increased tension of the cervical and masticatory muscles. Sleep bruxism is classified as a parasomnia or stereotyped movement disorder[16] with obstructive sleep apnea as a leading risk factor. Other etiologic factors are autonomic sympathetic cardiac activation, sleep arousal, neurochemicals, comorbidities (SDB) and psychosocial factors.

SDB, defined as mouth breathing, snoring, upper airway resistance syndrome (UARS), hypopnea and apnea, leads to sleep fragmentation and decreased stage-three restorative sleep. Decreased stage-three, or delta slow wave, sleep has been linked to fibromyalgia[17] and increased chronic pain.

Any TMJ or occlusal philosophy must address airway patency while managing pain and dysfunction, identifying contributing factors[18,19] and alleviating perpetuating factors. The teeth are the last piece of the AC paradigm. The airway is the first, followed by joint and muscle and, lastly, the occlusion and anatomy of the teeth. Prevention of temporomandibular disorders (TMD), malocclusion and neurobehavioral and neurocognitive issues[6] is the goal of AC TMJ philosophy and requires early identification and early intervention, although intervention can occur at any age.

History of Centric Relation Dentistry

My introduction to centric relation and the TMJ dates back to 1965 when I viewed the images my father, Harold Gelb, DDS, used for his lectures. It is now 49 years later, and the Gelb 4/7 position (**FIGURE 3**) has serendipitously evolved into the AC philosophy and the Gelb 4/7 Bite, Balance, Breathing method.

A little more history: In 1930 the fathers of gnathology, Harvey Stallard, PhB, PhD, DDS, Charles Stuart, DDS, and Beverly B. McCollum, DDS, followed Bonwill's mechanical occlusion theory[20] and translated the movement of the jaw to an articulator. The gnathologists developed a jaw position called centric relation (CR), which is the most retruded superior position of the joint (**FIGURE 4**). Some dentists referred to this jaw position as rearmost, uppermost or terminal hinge. The focus at that time was on the teeth and the occlusion and the way the teeth fit together and contacted in right and left lateral excursions. Other articulators were developed to support occlusal philosophies over the next 80 years, and include the Artex, Sam, Panadent, Whip Mix and Denar.

These gnathologists were revered and were inducted into the USC Dental Hall of Fame. Around the same time, Charles H. Tweed, DDS, had just graduated from Angle's School of Orthodontics and rejected nonextraction theory as producing faces that were too protrusive.[21] He began extracting permanent bicuspids to "flatten" profiles and supposedly give more stable results (**FIGURE 5**). Ron Roth, DDS, and Robert Williams, MS,[22] applied the CR concept to orthodontics in ensuing years. Over the next 40 years, the gnathologists and Tweed orthodontists contributed to a more retruded jaw position with fewer teeth (**FIGURE 5**). This jaw position was taught and utilized in American dentistry from 1930-1995 and is still taught in some parts of the country.

To dentists such as Bill Farrar, DDS, Barney Jankelson, DDS, and Harold Gelb, this made no sense. The condyle wars in the 1970s pitted gnathologists such as L.D. Pankey, DDS, Peter E. Dawson, DDS, and the Society of Occlusal Studies against Gelb, Farrar, Jankelson and John Witzig, DDS. Witzig taught the European school of functional orthodontics popularized by Laszlo Schwartz, DDS, and Christine Frankel, DDS, which used the Gelb 4/7 position in nonextraction expansive orthodontics. Witzig was the expert witness in a landmark legal case involving a four-bicuspid extraction patient who required TMJ surgery following extraction orthodontics. The patient received more than $1 million, a substantial settlement at the time.

In the 1980s Dawson, along with the authors of the glossary of prosthodontic terms,[23] realized that the gnathologists had no biologic or physiologic evidence for a retruded centric position. They followed Gelb, but with a more conservative anterior-superior position (**FIGURE 6**).

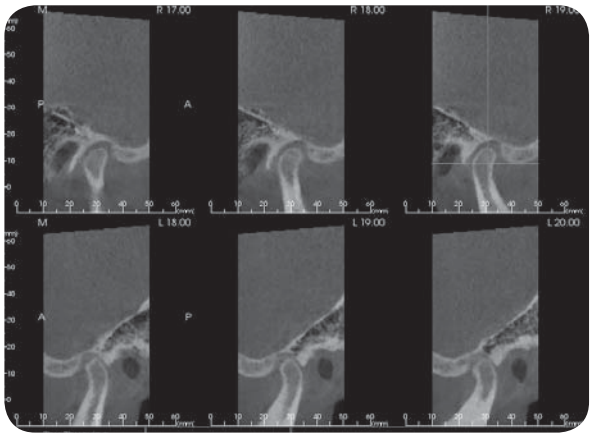

FIGURE 4. Old centric relation – retruded jaw position, 1930-1995.

Celenza[24] coined the term "long centric" after patients returned with their habitual comfort bites forward of the artificially retruded CR. Most prosthodontists and orthodontists still follow the "old" centric relation (**FIGURE 4**).

Psychophysiologically oriented Dr. Schwartz[25] popularized the myofascial approach to TMJ treatment at Columbia University in the 1950s, and Daniel Laskin, DDS, and Charles Greene, DDS, then advanced their theory of myofascial pain dysfunction at the University of Illinois in 1969.[26]

Working with arthrography in the 1980s, Farrar and W.L. McCarty, DDS,[27] in Montgomery, Ala., began to understand the workings of the TMJ disk. Further TMJ magnetic resonance imaging (MRI) research by Per-Lennart Westesson, DDS, and R.W. Katzberg, DDS,[28] elucidated normal and pathologic movements of the condyle disk fossa assembly. Farrar believed that TMJ internal derangement produced myofascial pain.

Controversy continued as neuromuscular dentists concentrated on muscles while surgeons and other TMJ dentists focused on internal derangements of the TMJ. Teflon proplast TMJ implants were a disaster, but there was moderate success with TMJ arthroscopy and arthrocentesis.

The triad approach of muscle-joint-teeth, which considered myofascial pain and trigger points as well as TMJ internal derangements, became popular in the 1990s and was taught by Henri Gremillion, DDS, and Noshir Mehta, DDS, among others.[29] It emphasized diagnosing joint and muscle pathology before looking at the occlusion.

Biopsychosocial research and theory published in the 1990s used research diagnostic criteria (RDC) from University of Washington faculty members Samuel Dworkin, DDS, PhD, Linda LeResche, ScD, and Edmond Truelove, DDS, MSD. The neuroscience group of the American Association for Dental Research (AADR) and the International Association for Dental Research (IADR) supported this philosophy and proposed reversible nonocclusal therapy, viewing oral appliances as unnecessary and mercenary. Unfortunately, most biopsychosocial researchers were not clinicians familiar with objective measurements found in polysomnograms (PSG) during sleep or with clinical pain management other than cognitive behavioral therapy.

AC TMJ Anterior Repositioning Therapy

Dr. Harold Gelb first described his mandibular orthopedic repositioning appliance in 1959[30] by placing the condyle in the Gelb 4/7 position within the glenoid fossa, slightly forward of concentric and against the eminence. This orthopedic technique was intended to three-dimensionally reposition the mandible in harmony with the neck, back and feet. Relatively decompressing the auriculotemporal nerve and TMJ could improve clicking, locking and shearing forces.[12]

According to *Craniofacial Pain: A Handbook for Assessment, Diagnosis and Management* from the Academy of Craniofacial Pain,[31] "There is now a consensus opinion that the Gelb 4/7 position correlates with the physiologic normal position for the TMJ condyle in the fossa."[31] Farrar and McCarty advocated a position similar to that of Gelb and Ireland.[27]

Positioning the mandible anteriorly using orthopedic repositioning has been shown to be efficacious for treating anteriorly displaced disks and to be superior to stabilization appliances or neuromuscular splints for relieving pain and dysfunction.[27,32-37]

Before AC TMJ philosophy (**FIGURE 2**) was developed, the Gelb concept of three-dimensionally repositioning the mandible to reestablish a normal disk condyle position, while establishing normal resting lengths of the masticatory muscles, was the most effective method of treating internal derangements of the TMJ and the accompanying pain and dysfunction of the masticatory and cervical muscles.[38,39]

Recapturing of the disk with anterior repositioning occurred in 52 percent to 70 percent of patients in two early studies[40,41] and 86 percent in a more recent publication.[42] H. Clifton Simmons, DDS, and S.J. Gibbs, DDS, showed recapture in 25/26 joints, or 96 percent, using MRI before and after appliance therapy.[35] Bite position for recapture was established using the Gelb 4/7 position, which represents a consensus of normal position of the condyles in the glenoid fossa.

While Harold Gelb continued to use the Gelb appliance, in 1989 the author, as director of the TMJ and Orofacial Pain Program at New York University, began using the NYU appliance, a modified

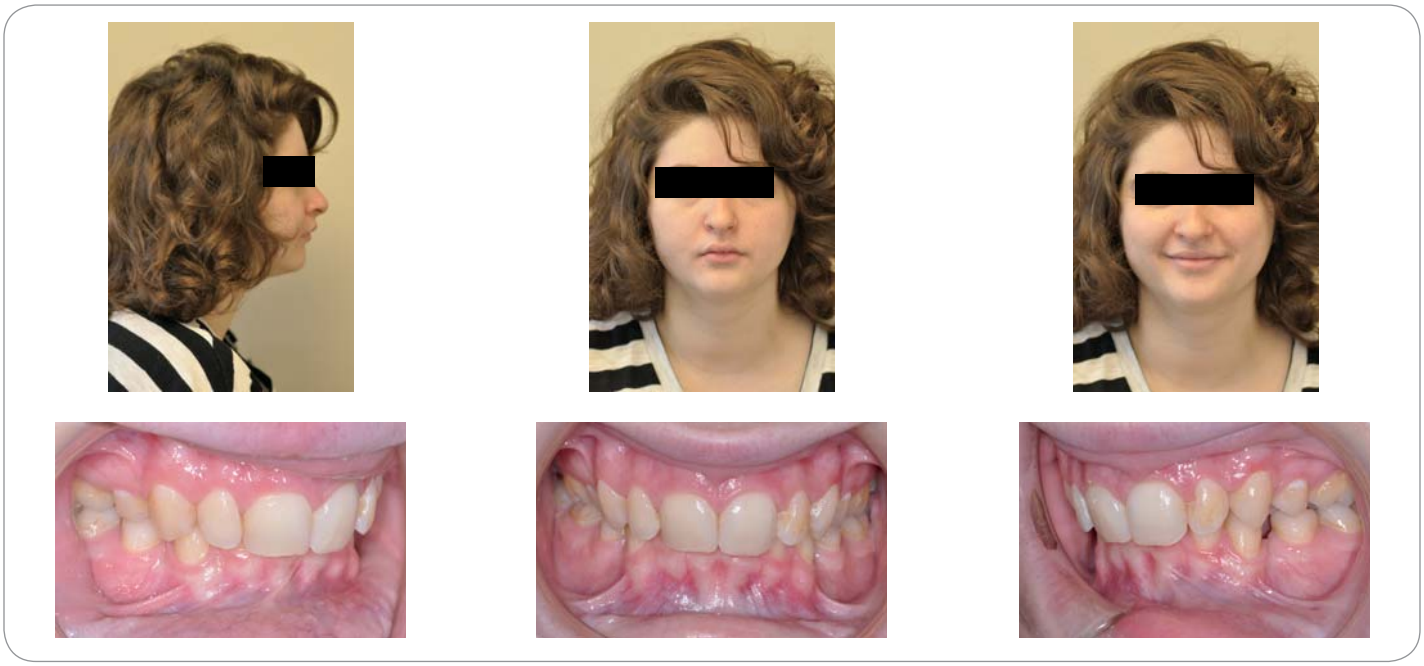

FIGURE 5. Four bicuspid case.

mandibular orthopedic repositioning appliance (MORA) (**FIGURE 7**). The NYU appliance covered the cuspids, which prevented intrusion and allowed for cuspid guidance, and placed acrylic around the linguals of the lower anteriors for stability. Both appliances worked best with occlusal indexing, which defined the new occlusion and gave increased proprioception while swallowing. Gelb and Gelb recommended a Farrar antiretrusion appliance at night for those patients with clicking or intermittent locking.[43]

Farrar[27] utilized a position very similar to the Gelb 4/7 in accordance with arthrography to reposition the jaw and maintain that position at night with the Farrar antiretrusion appliance.[27] Not only did Farrar prevent jaw clicking and locking during sleep, he, along with Gelb, serendipitously fabricated the first oral sleep appliances.

When the mandible retrudes to a retrognathic, or slack-jawed, position during supine sleep, the tongue and soft palate also retrude and collapse the airway. Nightguards traditionally fabricated in a terminal hinge-retruded position would also retrude the tongue and palate and lead to a collapsed airway. Gelb and Farrar were the first to go against the grain and maintain a forward position for an open airway during the day and at night.

Most of the TMJ/TMD research of the last 30 years has been measuring the wrong variables. With the advent of PSGs we can easily measure electrical activity of the heart with an electrocardiogram (EKG), electrical activity along the scalp with electroencephalography (EEG), electrical activity produced by muscles with electromyography (EMG), heart rate variability (HRV), CO_2 and O_2 saturation, as well as apnea, hypopnea, upper airway respiratory symptoms, arousals of the brain and body position with sound and video.

I propose that these objective physiologic measurements have already shown the efficacy of mandibular positioning appliances over the last 20 years, with multiple position papers published by physicians, sleep specialists and researchers.[44]

Sleep deprivation and SDB have profound effects on stage-three restorative sleep, which is necessary for repair and regeneration of musculoskeletal tissue, as well as on rapid eye movement (REM) sleep that is needed for well-being and memory consolidation. SDB also profoundly affects tissue inflammation, hypoxia and reperfusion, oxidative stress and endothelial dysfunction, all of which impact the TMJ, muscles of mastication and general well-being of the patient.

AC philosophy takes dentistry into the field of medicine and empowers the dentist or physician to treat apnea, hypopnea, upper airway resistance syndrome and snoring and, in doing so, to improve overall health and wellness.

AC TMJ is a new philosophy in dentistry. The airway now trumps everything else in dentistry or medicine. Along with sleep and breathing, the airway is hierarchically the most important function for humans. Ideal health, wellness and brain development depend on an open pharyngeal airway, nasal breathing and restorative sleep. This requires a partnership between the ENT, pulmonologist, lactation consultant, myofunctional therapist,

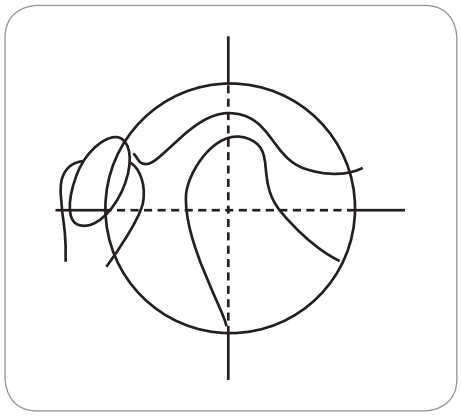

FIGURE 6. New centric relation anterior-superior prosthodontic.

obstetrician/gynecologist, osteopath, chiropractor and physical therapist.

The AC Bite, Balance, Breathing system recognizes these components and builds on the Gelb 4/7 position to establish an AC treatment philosophy so that dentists can recognize, diagnose and treat airway, breathing and sleep disorders to increase oxygenation and improve sleep architecture.

The AC team is an interdisciplinary collaboration of practitioners who integrate the airway, TMJ, masticatory and cervical muscles and teeth with growth and development as well as brain development,[6] cardiovascular health, and treatment of diabetes, obesity and other chronic disease.

The airway includes the nasal airway, tonsils, adenoids, tongue, soft palate, uvula and lingual tonsil down to the epiglottis. Airway resistance and blockage have been associated with oxidative stress, systemic inflammation, intermittent hypoxia and endothelial dysfunction.

Phylogeny, Ontogeny and Animal Models of the Airway

Todd Morgan, DMD, and John Remmers, MD,[8] shed light on the origins of air breathing from the lungfish to modern amphibia up to mammals, where we see the appearance of a diaphragm. The single oropharynx of the amphibian is transformed into three cavities: the nasal cavity, the oral cavity and the

FIGURE 7. NYU appliance.

pharynx in reptiles and mammals. The soft palate becomes more developed in mammals as it separates the nasal cavity from the oral cavity and pharynx. The epiglottis appears with the evolution of the mammalian pharynx.[10] The hyoid and larynx migrate downward and the airway above the epiglottis becomes angulated during mammalian evolution. With suckling or breast-feeding in humans, the epiglottis mechanically locks in with the soft palate to allow simultaneous sucking, swallowing and nasal breathing. The overlap of the soft palate and epiglottis is unique to all suckling mammals, except humans, where the epiglottis descends between six months and 1 year of age.

Morgan and Remmers[8] ask the question, "Walking, talking and breathing: what is the problem?" Our evolutionary pressures to be bipedal and speak influenced the development of the pharynx. Our success as Homo sapiens depended on our intellectual advancement; with the development of the brain came our ability to walk and stand upright and our speech and articulation.[45] These three factors had major effects on our pharynx and ability to breathe while asleep. With the possible exception of the English bulldog, obstructive sleep apnea (OSA) is a uniquely human disease.

The length and flexibility of the pharynx required for human speech is what leaves it vulnerable to collapse while we are asleep. The vast neural network and mechanoreceptors, which protect the airway during wakefulness, seen as increased activity of the genioglossus muscle, is lost during SDB. Morgan[8] speculates, "Three features of the pharynx allowed walking and talking but severely limited the ability to breathe during sleep. These are:

1. Severely angulated airflow path because of upright posture.
2. Lack of epiglottal lock because of epiglottis descent and laryngeal length.
3. Free-floating hyoid and loss of hyoidal strutting. In all other mammalian species, the hyoid is firmly attached to the laryngeal skeleton. The descent of the hyoid from the mandibular plane predisposes for OSA."

One of the most important changes in human primates is the shortening of the horizontal oral length and the relative lengthening of the vertical pharyngeal height. This change has a major impact on the AC TMJ and occlusal philosophy, as the maxilla has moved retrusively through evolution and epigenetic factors.[46-48]

Changes in the Maxilla – the Key

As humans evolved to an upright posture, the larynx descended,[49] the forebrain grew and the facial framework retreated as the nasal airway became diminished in size and function. This is one reason humans do not have the olfactory ability of other mammals. As the cranial base angle flexed, the maxilla was compressed and the paranasal sinus size was reduced, creating millions of sinus sufferers, as well as other facial changes.

The flattened maxilla and longer face are a relatively recent human phenomenon, which differentiates us from primates. The decrease in nose volume associated with cranial base flexing may have increased high upper airway resistance and potential for collapse

further down in the oropharynx. Humans were no longer obligate nose breathers, and with increased demands, mouth breathing was born. This trend of mouth breathing, downward migration of the tongue base and descent of the hyoid is associated with changes in mandibular posture to retrognathic. The increase in mouth breathing is also associated with less time spent with the tongue to the palate, narrowing of the maxilla and increased facial height.[50] The downward and backward rotation of the maxilla and mandible is a powerful predictor of SDB[51] as well as TMJ and malocclusion. A variety of researchers, clinicians and anthropologists has identified an underdeveloped maxilla as the root cause of malocclusion and naso-oropharyngeal constriction. Identification of mouth breathing is therefore recommended as early as the first year of life.[52]

The animal model of OSA is the English bulldog that suffers from brachiocephalic syndrome. Since the 1950s the bulldog has been bred with a thicker neck and pushed-in snout. This brachiocephalic "retropositioning" results in a retruded maxilla and mandible similar to the description of human evolution above. This bony malformation reduces oral volume and pharyngeal space. The bulldog often exhibits pseudo class-three occlusion, crowded teeth, pinched nostrils and a large tongue that protrudes from the mouth. Most bulldogs expire from heart disease or cancer secondary to the effects of brachiocephalic airway narrowing and subsequent systemic inflammation, oxidative stress and hypoxia.[53]

Egil Harvold, DDS,[54] converted rhesus monkeys to mouth breathers by obstructing nasal breathing and observed increased face height, posterior rotation of the mandible and malocclusion. In growing animals in which the nasal airway is gradually occluded there is an adverse effect on the size of the nasomaxillary complex, mandible and pharyngeal air space.[10] The same changes are seen in children who display habitual mouth breathing and who are at risk of SDB. Harvold[54] stated, "Elimination of nasal airway interferences followed by changes from oral to nasal respiration may result in improvement of certain aspects of facial and dental deviations."

A key aspect of the AC TMJ occlusal philosophy is, therefore, establishment of nasal breathing with ideal development of the maxilla.

> The downward and backward rotation of the maxilla and mandible is a powerful predictor of SDB as well as TMJ and malocclusion.

AC in Children

Pediatric sleep disorders result in disrupted, inefficient and inadequate sleep and may affect brain development and cause neuronal damage.[1,6] Even habitual snoring is an indicator of a number of health problems in children, including poor physical growth, emotional and behavioral problems, neurocognitive impairment and decreased academic performance.[55]

It is accepted that an apnea–hypopnea index (AHI) greater than 1 is abnormal in a child. Nasal airway obstruction is particularly significant in infants and young children who are obligate nose breathers. Many premature infants are born with high narrow palates and are mouth breathers from birth.[10] These children also display orofacial hypotonia and secondary changes in maxillomandibular growth. Other children develop difficulty with nasal breathing when tonsils and adenoids develop between ages 2 and 8, which leads to chronic mouth breathing and SDB. Parents may report noisy breathing in infants rather than frank snoring.[52] Bonuck found habitual snoring in 9.6 percent to 21.2 percent of children six months to 6.75 years of age. At age 6, 27 percent were habitual mouth breathers. Snoring increased significantly between 1.5 and 2.5 years in a study of 11,000 children older than 6 years. SDB causes abnormal oxygen and CO_2 levels, interferes with restorative sleep and disrupts cellular and chemical homeostasis. The fragmentation of stage-three restorative slow-wave brain activity by disruptive sleep or hypoxia can result in issues with decision-making, ambition and emotional regulation.[56]

The AC TMJ philosophy starts prenatally with the mother's nutrition and airway. Our goal is for a full-term pregnancy with ideal development of the palate and maxilla. At birth, we advocate for at least two months of breast-feeding,[57] and preferably six months or a year if practical. This confers a reduction in SDB. A poor suck may result from hypotonia from birth and result in SDB.

Frenum attachments may need to be surgically released if they interfere with tongue movement or breast-feeding. Nasal breathing is of paramount importance for growth and development. If a child has nasal obstruction due to allergy, it must be addressed as early as possible.

Many premature infants are born with high narrow maxillas, which predispose them to mouth breathing, the first sign of an airway disorder. With mouth breathing, the tongue cannot assume proper rest posture against the premaxilla, resulting in

narrow, constricted, high-vaulted palates and poor maxillary growth. It can also result in a poorly developed nasal airway, increased facial height, a retrognathic mandible, shorter maxilla and mandible, larger tongue, longer and thicker soft palate and an inferiorly placed hyoid bone.

Tonsils and adenoids tend to hypertrophy between ages 2 and 8; however, before that, by six, 18 and 30 months of age, snoring and sleep apnea are already present, which predict neurobehavioral disorders at age 4 and 7. Children in one study who were symptomatic in infancy were 20 to 60 percent more apt to exhibit neurobehavioral disorders by age 4, and 40 to 100 percent more likely by age 7. Symptoms included hyperactivity, misconduct and peer difficulties. These attention and executive function deficits persisted into adulthood.[58]

Early SDB may lead to permanent prefrontal cortex change, causing attention and executive function problems even if the SDB improves. In other words, SDB's effects may be irreversible.[6]

Our knowledge of brain changes encourages intervention as early as the first year of age. The trend today is adenotonsillectomy (AT), palatal expansion and myofunctional therapy as early as age 3.5. AT resolved only 51 percent of OSA in nonobese prepubertal children.[1] Children who snore in early childhood tend to have lower academic performance independent of AT later in development.[10] History of either SDB or behavioral sleep problems in the first five years led to increased likelihood of special educational need at age 8 in one study.[59]

The maxilla can be developed very early in childhood and has a huge impact on improving nasal breathing and SDB. In adults with narrow palates, adequate nasal breathing is often impossible even with nasal surgery.

Narrow maxillas also predispose to TMJ disorders, growth abnormalities and SDB. Sixty percent of facial growth is attained by age 6 and 90 percent by age 11 or 12; therefore, early intervention is particularly warranted in children with SDB. Occupational therapy and myofunctional therapy with special orofacial exercises during feeding and chewing in the first two years of life may lead to improvement in facial anatomy, repositioning of the tongue and development of a normal nasomaxillary complex and mandible.[10]

The maxilla can be developed very early in childhood and has a huge impact on improving nasal breathing and SDB.

It is encouraging to realize that early interdisciplinary intervention may prevent SDB and subsequent pathologic sequelae.

Development of the Maxilla

Epigenetic factors are thought to have dramatically changed the development of the jaws.[5,7] Robert Corrucini, PhD, has also attributed crowded teeth and small, narrow jaws to the soft consistency of the diet. Kevin Boyd, DDS, a pediatric dentist, points to the dietary changes following the industrial revolution and lack of breast-feeding as a cause for the shrinkage of the maxilla.[7]

Seminal work by Weston Price, DDS, has demonstrated that malocclusion occurred in primitive tribes within two generations of the introduction of an industrialized diet.[60]

Most jaws today do not have room for all 32 teeth, as evidenced by the number of children and young adults who require wisdom teeth extractions. Comparing the wide U-shaped skulls from the Smithsonian and the Museum of Natural History with today's skulls indicates that the maxilla has significantly retruded.

Epigenetic factors include environmental pollutants, obesogens, sugar in our diet and pesticides. These factors are also thought to have caused the sudden dramatic increase in attention deficit hyperactive disorder (ADHD), obesity, diabetes, heart disease and a spectrum of other disorders.

Abnormal nasomaxillary growth is thought to be responsible for SDB and TMD. AC philosophy addresses the following vital pathologic processes:

- Oxidative stress — results in free radical production.
- Systemic inflammation — associated with the release of inflammatory cytokines, tumor necrosis factor alpha (TNF-alpha), interleukin 6 (IL6).
- Intermittent hypoxia — oxygen desaturation is followed by reperfusion, often hundreds of times per night.
- Endothelial dysfunction — reflects the health of the blood vessel wall and the ability to vasodilate. It is the risk factor of risk factors for cardiovascular disease.
- Autonomic deregulation — thought to be a major contributing factor in the development of cancer and cardiovascular disease.

Lack of quality sleep increases pain and lowers immune function while increasing TNF-alpha, IL6 and interleukin 8 (IL8).[61]

Most chronic diseases are greatly influenced by the airway and breathing. Opening the airway with the AC TMJ philosophy allows normalization of endothelial dysfunction and reduces oxidative stress, systemic inflammation and intermittent hypoxia. This is often

the missing link for the treatment of fatigue, obesity, ADHD, diabetes and cardiovascular disease.

AC treatment will help determine the final TMJ, muscle and occlusal position. The TMJ will be decompressed and the pharyngeal airway will be open.

Nighttime Philosophy

Therapeutic jaw position at night is dictated by the airway first and TMJ second. Because bruxism is associated with brain arousal and is thought to be related to SDB, a sleep study is required for any patient with excessive daytime sleepiness (EDS), snoring, witnessed apnea, high blood pressure (HBP) or narrowed airway. Home sleep studies or PSG are both adequate, depending on comorbidities and the information required.

A positive sleep study will usually necessitate an oral appliance to maintain an open airway, sometimes combined with continuous positive airway pressure (CPAP), nasal surgery and positional therapy. Treatment duration could be three to six months followed by a sleep study to ensure efficacy.

Bite changes can be expected, particularly for patients with class-two division-two malocclusions or retruded maxillas. At a three-week follow-up visit, the dentist monitors the list of chief complaints related to pain and dysfunction. Criteria for success require alleviation of pain and dysfunction complaints as well as of EDS, noisy breathing and OSA.

Daytime Philosophy

Oral appliances are often used during the day as well to address daytime complaints, which require habit control and TMJ or muscle rehabilitation, particularly for patients who need cognitive behavioral therapy. Many patients who present with SDB also have headache and dysfunction related to growth and development, parafunction or past trauma. In patients who present with TMD, pain or dysfunction, the appropriate appliance design is chosen in combination with physical therapy, medication, Botox injections, craniosacral therapy, chiropractic or osteopathic manipulation. Lower appliances are preferred during the day to help articulation. The NYU and lower stabilization appliances are recommended for six to 12 weeks of daytime wear and then as needed during physically and emotionally stressed periods. These might include exercising, playing competitive sports, studying for and taking tests, and putting in intense days at work.

> Our philosophy is to decompress the jaw joints bilaterally by anterior repositioning of the mandible.

Vertical Dimension

Most patients have lost vertical dimension or have compressed temporomandibular joints. In long-face patients, we want to decompress the joint without opening vertical more than necessary. In anterior open bites, we always establish anterior guidance by providing anterior contact.

In dental school, we were taught that one could not open the vertical dimension of occlusion. We now know that the body will reestablish freeway space, and often the vertical needs to be added to at night to maintain an open airway.

Anterior Posterior

Epigenetics has predisposed to predominantly retrognathic bites with forward head posture. As we reposition the mandible forward, we work with physical therapists who use the Alexander Technique, Feldenkrais Method, Pilates and Gyrotonics to strengthen the core and achieve ideal posture, like that of a dancer or actor.

As we bring the jaw forward, the head goes back over the shoulders. Our philosophy is to decompress the jaw joints bilaterally by anterior repositioning of the mandible. Criteria for repositioning include recapturing the disk when possible, alleviating joint noise when possible, achieving ideal facial esthetics, maintaining minimal bite opening during the day and maintaining natural anterior guidance when possible.

I tell my patients that I am putting their chins back to the middle of their faces. When phonetics and ramus height discrepancy support moving the mandible back to the center while alleviating joint compression and reducing joint noise, it is done. The mandible often migrates to the short ramus side, which is the high eye side.

Beauty

Nonsurgical facelifts were talked about in the ’80s and ’90s. Today we are able to restore full lips and reduce nasolabial folds, but more important, increase the oxygenation of the skin and open the eyes. There is a glow and sense of life that was missing. Part of the transformation is the reduction in pain and stress on the body. More important perhaps is the healing effect of restorative sleep, decreased inflammation, hypoxia and oxidative stress.

In approximately 10 percent of adult cases and 100 percent of children’s cases, orthodontics, such as palatal

expansion, is required. Smile lifts, as popularized by Larry Rosenthal, DDS, from NYU and Aesthetic Advantage, are often needed because of the preponderance of narrow maxillas. Dr. Rosenthal and I have restored several cases after TMJ and AC stabilization.

Occlusal Philosophy

Many patients have anterior open bites secondary to condylar degeneration or perimenopausal changes in the joint. In those cases, we always establish anterior guidance, typically bringing the mandible forward to decompress the joint and open the airway. Whenever possible, the appliance establishes canine guidance. I use a modified Gelb appliance for daytime, covering the cuspids and placing acrylic behind the lower anterior teeth to prevent shifting.

Gnathologic principles can be used if the jaw is in the right position.

Slight posterior open bites are acceptable and often preferred. We want the majority of force in the premolars and anterior teeth. A slight posterior open bite discourages parafunction.

In 10 percent of cases, some form of dentistry is required following my treatment plan, which often involves physical therapy, trigger point injections and Botox injections.

Criteria for Success

Airway

- Open day and night.
- Improved SDB or AHI; respiratory disturbance index (RDI) decreased by at least 50 percent.
- Improved EDS.
- Nasal breathing.

Posture (standing, seated and supine)

- String pulling up the back of the head with slight flexion.
- Normal spinal curvature achieved with Alexander Technique, Feldenkrais Method, Pilates, yoga.
- Lips together, teeth apart.
- Chest up.
- Belly in, engage abdominals.

TMJ

- Absence of clicking, popping, locking.
- Decompressed in the range concentric to Gelb 4/7.
- Full range of motion or a measured opening of 36-54 mm.

Face

- Shape — favors horizontal growth.
- Lips — full and symmetrical.
- Skin tone — glowing.
- Eyes — open and alive, not showing too much sclera.
- Profile — good vertical and strong lower jaw.

Teeth

- Smile lift or palatal expansion to fill buccal corridors.
- Support airway and TMJ.
- Cuspid rise.
- Anterior coupling.
- OK to have lighter contact posteriorly or slight posterior open bite.

Conclusion

A small upper airway and stunted nasomaxillary complex predispose humans to SDB.[8] Early intervention is essential to prevent and correct anatomic abnormalities, which will also prevent SDB and resultant emotional and behavioral problems, neurocognitive impairment, decreased academic performance and poor physical growth. SDB has also been associated with hypoxia, oxidative stress, disrupted sleep and endothelial dysfunction,[62] all precursors to obesity, cardiovascular disease and diabetes.

Upper airway resistance and SDB are also linked to a retruded short maxilla and retrognathic mandible, which predispose to TMD headache and cervical postural change.

The Airway Centric TMJ and occlusal philosophy will result in a condylar position between concentric and Gelb 4/7 during the day and Gelb 4/7 to the middle of the eminence at night.

Robert M. Ricketts, DDS, stated, "Respiration and mastication are biologically inseparable. It would appear that normal nasal breathing is conducive to normal growth of the maxilla and normal development of the occlusion of the teeth."[63] The influence of gnathology and orthodontics in the '30s and '40s led to the concept of treating just the teeth instead of the face or the patient as a whole.

Ricketts also wrote, "We talk about the oral cavity as if it is independent of the development of the first branchial arch and independent from respiration. Biologically, the functions of mastication and respiration have been connected with the same set of muscles and the same set of nerve paths. We can't separate them."[63]

Final occlusal restorations cannot be completed until SDB is successfully managed over a six-month to one-year period. There will be occlusal changes based upon the initial position of the nasomaxillary complex, mandible, pharyngeal air space, hyoid bone and craniofacial morphology.

The dentist should recognize and address TMJ and airway disorders prior to restorative dentistry, as TMJ and airway treatment may result in occlusal changes. ■

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Other Authors' Critiques of Dr. Gelb's Paper

Dr. Fricton

Dr. Gelb's Airway Centric TMJ Strategy is based on innovative research suggesting that the maintenance of an open airway is a critical factor in patients who have TMD. With a narrowed airway, changes in occlusion and facial morphology compensate for the need to maintain an open airway.

Management of patients with TMD thus needs to consider the airway, sleep-disordered breathing and related neurobehavioral disorders. The paper presents broader innovative outcome criteria to consider in managing TMD that include not only the teeth, occlusion and TMJ but also the airway, posture of the tongue, head and neck and facial esthetic features.

Editor's note: See Dr. Fricton's general comments and conclusion on page 545.

Dr. Simmons

Dr. Gelb's manuscript is an excellent review of the relationship between TMDs and sleep-disorder breathing (SDB). His thought process involves evaluating patients who needs TMD care for SDB. This is an appropriate process.

The term temporomandibular disorders should be used only as a general statement to describe all disorders that can afflict the temporomandibular complex. TMDs include all TMJ internal derangement disorders, arthritic disorders and fractures and all associated structure muscle disorders, nerve disorders, vascular disorders, neoplasms and genetic disorders. Specific disorders of the TMD complex should be referenced when treatment methods are described.[1]

Intracapsular TMDs are usually not preventable because most are a result of TMJ articular disk displacement secondary to ligament injury. The orthopedic medicine community clearly believes that acute macrotrauma is the cause of most ligament injuries.[2] Acute macrotrauma may not be preventable.

Dental occlusion is driven by many factors, among which are genetics, the tongue, the cheek muscles, dental diseases and the airway.

TMJ/TMD research measures appropriate variables,[3] such as range of motion, pain upon anatomic site palpation, etc., but it is also appropriate to measure SDB variables in this patient population.

Slight posterior open bites are an acceptable result of reversible anterior repositioning appliance care but should be closed by either a long-term appliance, orthodontics or other restorative method.[3,4] The reviewing author does not believe that most dentists would prefer a posterior open bite occlusion or that this status of occlusion discourages parafunction.

Not all TMD patients need airway care. A significant number of TMJ internal derangement patients have airway issues and need care for this disorder. The treatment concepts presented in this manuscript are valid.

I would like to thank Dr. Gelb for participating in this journalistic endeavor. His patients appreciate his care in relieving their pain and dysfunction and their airway needs.

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CONTINUES IN SIDEBAR ON 561

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OTHER AUTHORS' CRITIQUES, CONTINUED FROM 560

Dr. Raman

Drs. Fricton, Gelb and Simmons' well-written papers contribute to the knowledge base for dentists.

Dr. Gelb nicely summarizes the history of TMD treatment approaches. His Airway Centric approach is very congruent with the PNMD approach. TMD treatment guided by objective physiologic measurements such as real-time electromyography (EMG) and computerized mandibular scanning (CMS) is the foundation of PNMD. While useful, polysomnography (PSG) doesn't give real-time data for clinical dentists as do EMG and CMS.

Dr. Gelb states that anterior repositioning appliances are superior to neuromuscular (NM) splints. NM orthotics are constructed to a mandibular position where all masticatory and cervical muscles are unstrained. Craniocervical physical therapy to address cervical restrictions and recapture of any displaced disks is done before taking PNMD bite relation. This position is determined by the real-time physiologic parameters of EMG. The resulting changes to the condylar position vary on an individual case as recorded by CT scans. Often it is down and forward in the fossa. It can also be more downward on one joint. So his claim that an arbitrary anterior positioning of the mandible is more efficacious than a physiologic NM orthotic appliance is illogical. The referenced studies seem to compare flat plane appliances.

Dr. Gelb describes moving the mandible back to the center using phonetics and ramus height. Is this any less subjective than "romancing the mandible"? While acknowledging the utility of clinical judgment and subjective factors such as phonetics, EMG of muscles of mandibular and cervical posture gives real-time objective data on the physiology rather than using anatomical landmarks.

I respect the contributions of Dr. Harold Gelb. Dr. Michael Gelb states that the Gelb 4/7 position correlates with the physiologic normal position for the TMJ condyle in the fossa and that the Airway Centric philosophy will result in a condylar position between concentric and Gelb 4/7 during the day and Gelb 4/7 to the middle of the eminence at night. Focusing on the relative position of the condylar head in the fossa to an idealized position within the fossa misses on two counts:

- Morphological changes of the condyles – bending, breaking, flattening and other compensatory changes make the position of such a condyle different from an undamaged condyle within the same fossa.[1]
- Anatomical appearance shows the current condition of the structures that have resulted in response to the forces over time. It is akin to looking at the rearview mirror. Physiologic parameters – such as electrocardiogram (EKG), apnea–hypopnea index (AHI) and EMG give current data on the function of the organism. Function changes the form just as oral breathing changes maxillary shape.

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Dr. Gelb's Response to Critiques

Response to Dr. Fricton's critique

Dr. Fricton introduces the dental community to a human systems approach for chronic pain and temporomandibular disorders. I would like to thank Dr. Fricton for a novel and thought-provoking manuscript.

Response to Dr. Simmons' critique

I would like to thank Dr. Simmons for an excellent manuscript. In those TMJ patients who do not have resistive breathing or sleep disordered breathing, I would follow Dr. Simmons' TMJ philosophy.

We both treat to the Gelb 4/7 position and finish our cases orthodontically and restoratively. I may wean a larger percentage of patients off daytime appliance wear except for stressful periods such as midterms and finals and be content with a posterior open bite as long as chewing is not an issue.

Response to Dr. Raman's critique

I agree that Airway Centric (AC) TMJ philosophy is often congruent with a neuromuscular (NM) approach, as both open the airway and relatively decompress the joint.

Following six months to one year of AC appliance therapy, the mandible will usually reach a stable and repeatable down and forward position during the day with the appliance out. This position is taken only after a polysomnogram or home sleep test has confirmed successful treatment of sleep disordered breathing.

The NM approach does not ensure successful TMJ or airway management. It measures electromyography (EMG) and computer mandibular scanning. Some AC dentists measure real-time heart rate variability (HRV) to fine-tune appliance and jaw position.

AC moves beyond Gelb 4/7 condyle repositioning therapy by placing an open airway hierarchically at the top of the pyramid.

Final treatment position should optimize HRV, EMG and resonant frequency breathing. Final treatment position maximizes oxygen saturation, stage three and REM sleep and manages the apnea–hypopnea index (AHI), respiratory disturbance index (RDI) and sleep fragmentation and arousals.

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Physiologic Neuromuscular Dental Paradigm for the Diagnosis and Treatment of Temporomandibular Disorders

Prabu Raman, DDS, MICCMO, LVIM, FPFA, FACD

ABSTRACT Shifting from traditional anatomical/mechanistic models, the physiologic neuromuscular dentistry (PNMD) paradigm acknowledges the primacy of physiology in shaping and controlling anatomy in a functioning human body. Occlusal disharmony from mandibular discrepancy to cranium leads to temporomandibular disorders (TMD), which is a disease of musculoskeletal imbalance in the postural chain exceeding the individual's physiologic adaptive capacity. To diagnose optimal craniomandibular alignment, PNMD is guided by real-time objective physiologic data such as electromyography (EMG).

AUTHOR

Prabu Raman, DDS, MICCMO, LVIM, FPFA, FACD, has practiced dentistry in Kansas City, Mo., since 1983, with an emphasis on neuromuscular dentistry/temporomandibular dysfunction, esthetic dentistry-complex restorative dentistry, neuromuscular functional orthodontics and sleep breathing disorders/oral appliance therapy. He is a fellow of the American College of Dentists and a fellow of the Pierre Fauchard Academy. Dr. Raman is a past president of the International Association of Comprehensive Aesthetics, a past president of the Greater Kansas City Dental Society and serves as an HOD delegate, member of the Council on Dental Education and Licensure of the American Dental Association and as a trustee of the Missouri Dental Association. He earned his dental degree from the University of Missouri, Kansas City, School of Dentistry.

Conflict of Interest Disclosure: None reported.

The diagnosis and treatment of temporomandibular disorders (TMD) is the most confusing subject in dentistry. Many factors contribute to this confusion; chief among them is a simplistic view of this disease that relates it only to temporomandibular joints (TMJs) or attributes it to a single etiology. Another factor is the lack of TMD training in predoctoral dental education.

TMD encompasses a group of musculoskeletal and neuromuscular conditions that involve the masticatory system, the dentition (occlusion), the TMJs and all associated tissues. Quantum improvements occur in any arena with a change in the basic paradigm.[1] The physiologic neuromuscular dentistry (PNMD) paradigm offers such a significant improvement in how the dental profession views and treats TMD. It acknowledges the primacy of physiology in shaping and controlling anatomy in a functioning human body. A guiding principle of PNMD is, "If it has been measured, it is a fact. If it has not been measured, it is an opinion." As such, physiologic data such as electromyography (EMG) of the jaw and neck muscles drive diagnostic and clinical decisions.

Video for this article is available in the e-pub version of the *Journal*, available at cda.org/apps.

The concepts and practice of neuromuscular dentistry go back to the 1950s and have since been improved considerably. These concepts are based on principles of physiology that earned Nobel prizes for their discoverers — Hill (glycolysis), Sherrington (reciprocal inhibition), Krebs (adenosine triphosphate [ATP] production), Eccles, Hodgkin and Huxley (action potential, myoneural junction, sliding muscle filaments) and Katz (muscle frequency and fatigue). Yet, many in our dental profession are still unfamiliar with PNMD concepts.

A dentist's duty is to relieve pain or adverse symptoms from which a patient seeks relief. Our patients are best served when TMD is viewed more comprehensively as a disease of musculoskeletal imbalance in the postural chain exceeding the individual's physiologic adaptive capacity.[2] This paradigm is more useful in the diagnosis and definitive treatment. Cranio-cervico mandibular disorder (CCMD) would be a more accurate description of this disorder, but due to the historic use of the term, "TMD" is used in this paper.

Symptoms of TMD are so varied that it has been called the "great impostor." They include orofacial symptoms such as TMJ pain, articular disk displacement without reduction (closed lock), articular disk displacement with reduction (clicking) with or without pain, limited mandibular range of motion, facial pain, referred dental pain, excessive tooth structure loss, unexplained tooth mobility, unexplained bone loss and more. TMD symptoms also include headache, migraine,[3] earache,[4,5] ear congestion,[6] autophony, tinnitus,[7] vertigo,[8] cervical pain,[9] limited cervical range of motion, forward neck posture,[10,11] obstructive sleep disordered breathing,[12] fibromyalgia, swallowing disorders,[13] arm pain, paresthesia of fingertips,[13] back pain[13] and more. Other disorders

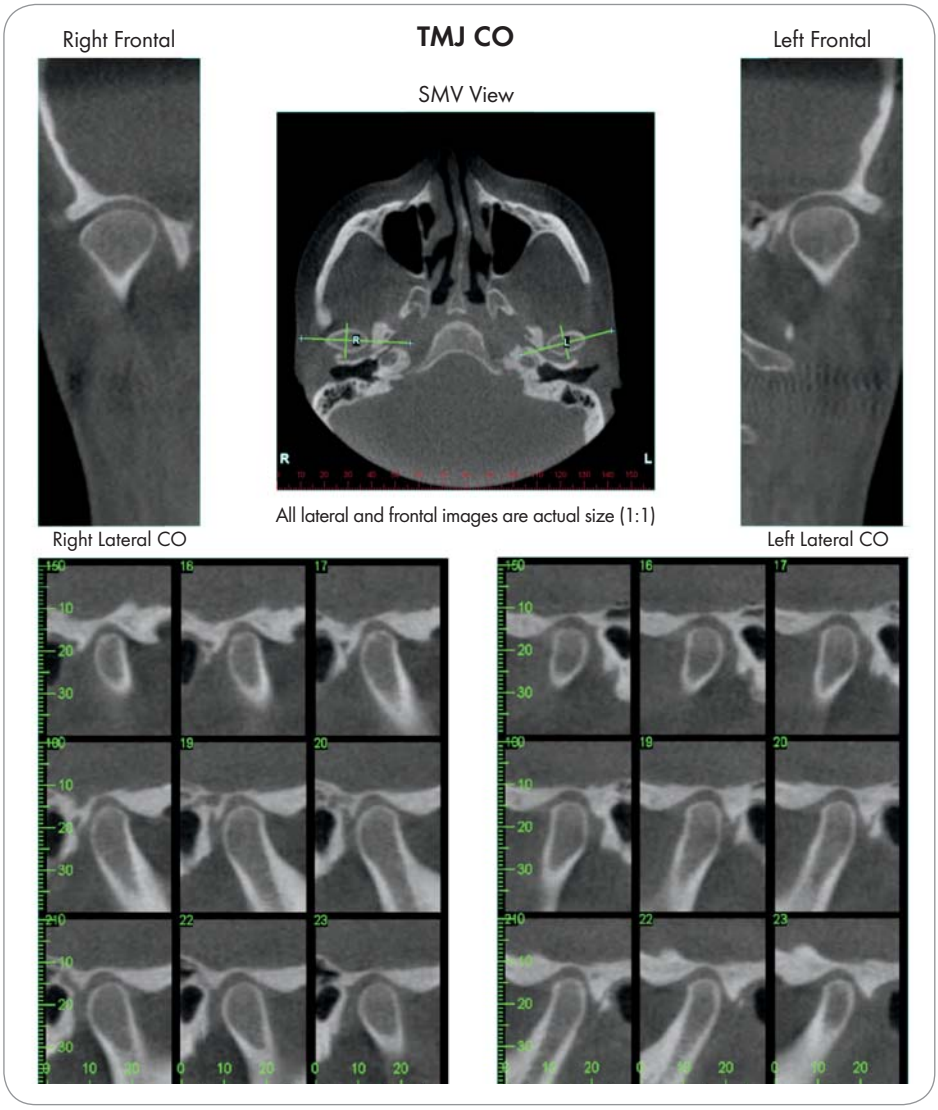

FIGURE 1. Pretreatment CT scan with teeth in occlusion – TMJ views coronal, axial and sagittal cuts.

of the body can cause some of the same symptoms, so a differential diagnosis must include TMD as a possible etiology, and other pathologies must be ruled out through appropriate tests or referrals.

The role of occlusion in the etiology of TMD has been widely documented in the dental literature.[14] Occlusal disharmony can result in hyperactivity and a disturbed pattern of muscle contractions leading to muscular pain and joint overload.[15] Palpation alone is a gross indicator at best and is subject to highly variable results among clinicians and to variability in the patient's tolerance. Therefore, palpation alone is inadequate to provide the best possible clinical evaluation of the masticatory muscles.[16] Would we use subjective pain reported by a patient as the only criterion to evaluate the health of periodontium or of a carious lesion? A scientific and objective assessment of the masticatory muscles as part of the clinical examination is essential. Numerous studies have shown that the TMD patient population has elevated resting EMG activity and weak or asymmetrical functional EMG activity.[17-19] TMD patients frequently exhibit altered muscle activation patterns.

FIGURE 2. Pretreatment CT scan with teeth in occlusion — panoramic view.

The role of dentition is unique in the postural chain. No other joint has the end point that is as changeable as the dentition is to the TM joints. While much emphasis is placed on the actual interdigitation of teeth (occlusion), the effort needed by the mandibular posturing muscles to bring the teeth into occlusion is not usually measured. No matter how poorly aligned the teeth might be, the masticatory muscles will bring the teeth into occlusion so that we may chew, eat, swallow and survive. For example, if a poorly aligned door runs into the doorframe, it can still be forced to shut; but over time, this would lead to deterioration of the hinges. While no one will consider only the shut position of such a door and pronounce it as perfectly fitting, looking at the final occlusion alone ignores the muscular effort required to bring the mandible into that position. In this analogy, would the deterioration of the hinges be the only condition to qualify it as a problem? This is akin to those who would *not* consider a patient to have TMD if there are no overt signs of TMJ internal derangement or other joint symptoms. This analogy does not at all convey the complexity of the stomatognathic system.

Mandibular position and occlusion have a profound effect on postural stability.[20,21] Swallowing occurs hundreds of times a day.[22] When teeth contact, as in swallowing and chewing, mechanoreceptors in the periodontal ligaments are stimulated. These serve as an important peripheral afferent of proprioception for the central nervous system.[23] Forty percent of the postural data that the brain receives is from the position of the mandible in space.[24] Mandibular posture and cervical posture are functionally connected;[25,26] as such, mandibular posture affects upper cervical posture.[27,28] The alignment of these craniocervical vertebrae also affects the lumen of the spinal canal at this critical level, as well as the flow characteristics through the vertebral arteries. It even impacts the tension on the recently discovered myodural junction between dura mater and the rectus capitus posterior minor muscle,[29] which could explain cervicogenic headaches. TMJs are functionally related to the atlanto-occipital joints,[30] which in turn have a profound impact on the central nervous system.[31] Cervical posture affects the lumbar and overall posture.[32] Based on these facts, it is clear that the impact of dental occlusion on the function of the human body is quite profound.

TMD sufferers do not want to be medicated for the rest of their lives to only dull their symptoms through a medical pain management paradigm. Many consider these medications to be ineffective or the side effects unacceptable. Most find their condition progressing from mild to worse and sometimes to disabling. While they experience unrelenting pain or discomfort, many patients do not show radiological evidence of breakdown in their TMJ for years or show external signs such as hemorrhage or edema. This is a helpless position to be in, to feel the pain but see no end in sight. However, EMG studies are valuable in objectively revealing the dysfunctional physiology of the masticatory muscles.

To illustrate this point, the author presents the case history of Dana P. After all, intellectual discussions of philosophical differences do not interest dentists in clinical practice as much as the application of such a philosophy in helping an actual patient. Dana, a 49-year-old female small business owner who was in good health except for a 15-year history of weekly migraines, presented for a TMD evaluation. Her general dentist, an oral surgeon who evaluated her TMJ and the orthodontist who treated her as an adult to achieve better occlusion had all concluded that she had no "TMJ disorder." She had been diagnosed with migraines by a neurologist and had been on various migraine, nausea and muscle relaxant medications for maintenance and to abort migraines. Otolaryngologists, allergists, pain management specialists, three chiropractors, a physical therapist, four neurologists and numerous massage therapists had treated her over the 15 years. Yet she also had back pain, neck pain, pain behind the eyes, shoulder pain, etc. When she took Zomig to abort a migraine onset, she would have to lie down in a dark room for a day and it often took another day for her to feel normal again. Because she had two to three migraine attacks a week, most days she was either in bed with a migraine or recovering from one.

Oral examination of the hard and soft tissue was done. Findings were:

- Teeth Nos. 1, 5, 12, 16, 17, 21, 28 and 32 had been removed for orthodontia.
- Bilateral mandibular buccal exostoses, bilateral antegonial mandibular notching and a scalloped tongue were noted.
- Mandibular range of motion: vertical = 54 mm, right lateral excursion = 11 mm, left lateral excursion = 9 mm, protrusion = 10 mm.
- Upper cervical rotation range of motion was measured: 65 degrees to the right side, 60 degrees to the left side.
- Blood pressure: 122/77, pO2: 99% and pulse rate: 62 were

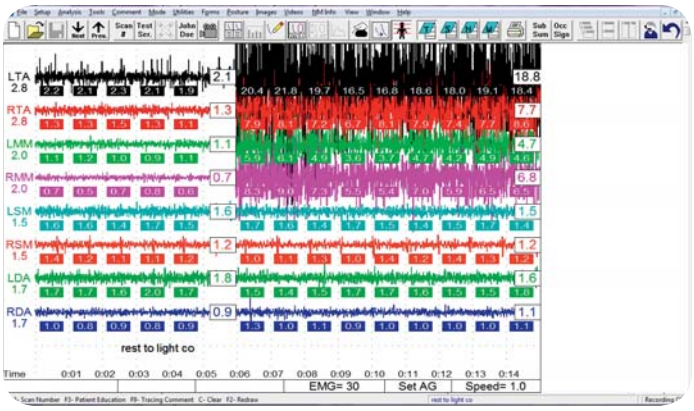

FIGURE 3. Pretreatment sEMG scan of mandibular and cervical posture muscles at rest versus at light occlusion. LTA = left temporalis anterior, LMM = left medial masseter, RSM = right sternocleidomastoid and RDA = right digastric anterior.

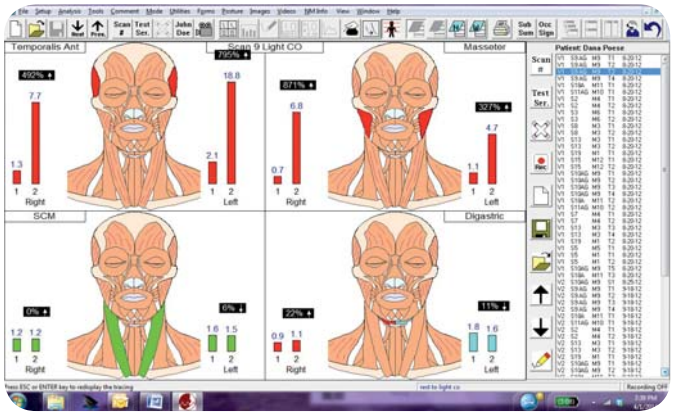

FIGURE 4. Comparison of muscle recruitment at rest versus effort needed to bring teeth into just light occlusion prior to chewing. RTA and LTA posture the mandible and bring it through space into occlusion.

recorded with pulse oximetry.

- Palpation of TMJ, jaw and cervical muscles was performed and recorded.
- Severe tenderness was noted at left shoulder trapezius and bilateral lateral pterygoids; moderate tenderness was noted at bilateral medial pterygoids, right posterior scalene and bilateral stylomandibular ligaments; mild tenderness was noted at left temporal tendon, right levator scapula, right neck trapezius, left posterior scalene, right anterior scalene, right sternocleidomastoid muscle (SCM), bilateral occipital, bilateral middle scalenes, bilateral posterior TMJ space and bilateral joint capsules.

Cone beam CT evaluation of the TMJs was within normal limits with slight reduction of joint space. It was negative for condylar deformation or deterioration (**FIGURES 1** and **2**).

A Myotronics K7 evaluation system was utilized. The patient's resting EMG, shown on the left half of the image, was within the norms noted on the left margin. However, the effort it took for her temporalis muscles just to bring the teeth into occlusion, shown on the right half of the image, increased 5X on the left and 8X on the right side compared to resting posture (**FIGURES 3** and **4**).

Her cranial nerves V, VII and XII (trigeminal, facial and spinal accessory nerves) were pulsed for 60 minutes by ultra-low-frequency transcutaneous electroneural stimulation (ULF-TENS). Every muscle innervated by these nerves was pulsed for 0.5 second every 1.5 seconds so they would contract and relax, essentially massaging each of these muscles to improve oxygenated blood flow, eliminating waste products such as lactic acid from the muscles to reestablish a biochemical and physiologic optimum. A repeat EMG showed even lower recruitment of these muscles, denoting relaxed muscles. From this optimal physiologic condition, the true magnitude of the mandibular discrepancy was revealed when the patient brought her teeth into light occlusion requiring 7X on the right side and 12X on the left temporalis (**FIGURES 5** and **6**).

Once the 3-D relationship of the mandible to maxilla was diagnosed, a temporary anatomic fixed orthotic was constructed of Integrity resin (DENTSPLY, Milford, Del.) on the mandibular arch to allow for physiologic economy of the posturing muscles. The patient functioned with this fixed orthotic that she could not remove but that could be removed by the dentist if the treatment was unsuccessful in symptom resolution. At a follow-up visit seven days after delivery, the mandibular function was again objectively evaluated and coronoplastied. The same act of bringing the teeth into occlusion was almost effortless with the orthotic (**FIGURES 7** and **8**).

While this objective measure of improvement is encouraging, the most important measure is that all of Dana's symptoms resolved 70 percent within 30 days, far exceeding her expectations. Therefore, she chose the option of orthodontically moving her teeth, guided by the physiologic metrics to permanently change her mandibular alignment. One year later, she is currently undergoing physiologic neuromuscular orthodontics and remains 90 percent symptom-free. The improvement in Dana's quality of life and that of her family is immeasurable, according to her and her husband.

Dentists who choose to treat TMD patients should acknowledge that TMD is multifactorial.[33-36] They should use objective measurements of physiology[37] to supplement anatomical data such as radiographic imaging and subjective reports in the diagnosis and treatment. TMJ radiographic imaging does not make a diagnosis of etiology in and of itself. Qualified medical professionals interpret imaging records and those data facilitate the overall diagnosis. Similarly, surface EMG studies provide objective clinical information about masticatory muscle status, which a properly trained dentist interprets to aid in his or her

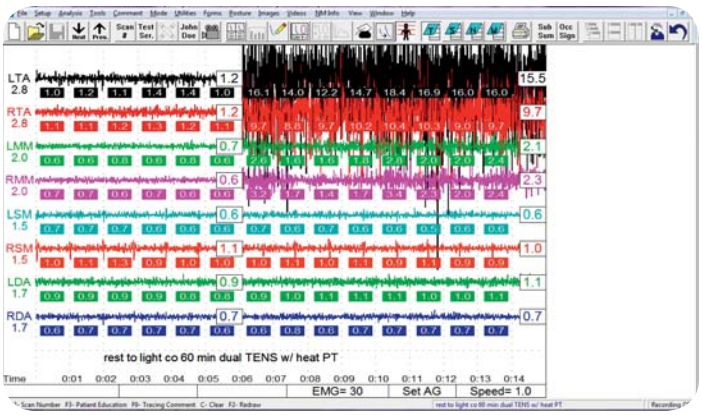

FIGURE 5. Post ULF-TENS treatment sEMG scan of mandibular and cervical posture muscles at rest versus at light occlusion reveals the actual level of mandibular discrepancy to maxilla.

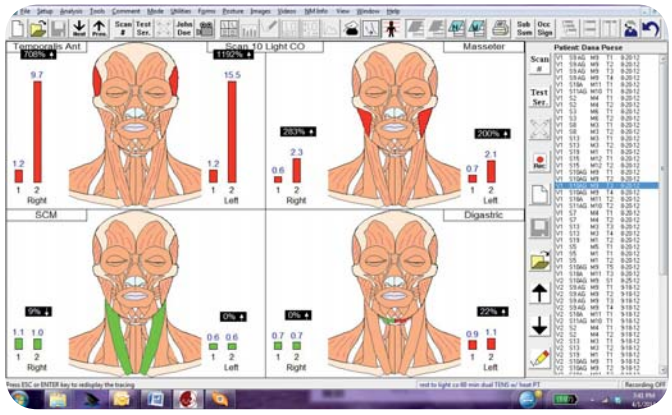

FIGURE 6. Comparison of muscle recruitment at rest versus effort needed to just bring teeth into light occlusion prior to chewing.

diagnosis. The bioelectronic devices commonly known as neuromuscular measurement devices are used to provide the diagnosing clinician with much expanded, precise, objective measurements and clinical information to reach an accurate diagnosis. The role of these instruments in reliably documenting and providing objective data is well documented in numerous studies.[38-40]

As dentists, our training and license to practice limit us to the orofacial region. At the outset, it is necessary to determine whether the primary etiology of the patient's complaints is related to a discrepancy of mandibular posture. If so, a comprehensive gathering of data is needed to facilitate an accurate diagnosis. These may include the following:

- Comprehensive history, including medical and dental history.
- Thorough examination of the dentition and periodontium.
- Diagnostic photographs of the dentition, face and posture.
- Palpation of the muscles of mastication, TMJs and cervical muscles.
- Range of motion records of mandible and upper cervical spine.[41]
- Surface electromyographic (sEMG) studies of muscles of mandibular and cervical posture.[42] These may include sEMG measurements of muscles of mandibular posture at rest,[43,44] with teeth in light habitual occlusion,[45] maximum clenching[46] and contraction frequency of muscles that indicate muscle fiber types and fatigue levels.[47] The utility and reliability of sEMG is well established in research literature.[48-50]
- Computerized jaw tracking studies of mandibular movement.[51]
- Electrosonography (ESG) recordings of TMJ sounds during function.[52]
- Cone beam CT views or corrected tomograms of the TMJs in habitual occlusion, maximal opening and maximal protrusion.
- Static posture and gait analyses to identify postural compensations.
- ULF-TENS of muscles of mastication and cervical posture through neurally mediated pulses.[53-57]
- Determination of the physiologic neuromuscular mandibular position within a neutral zone when muscles of mastication and cervical posture are optimally unstrained.[58] Objective, real-time EMG measurements of the posture muscles guide the clinician in diagnosing this position.[59] There is universal agreement on comfortable, unstrained masticatory muscles as a requisite for a healthy stomatognathic system. PNMD protocols actually measure physiologic data to confirm this, rather than just relying on subjective measures. The discrepancy between the mandibular position of presenting habitual occlusion and the physiologic neuromuscular mandibular position is the starting point of therapy.[60]

A neuromuscular dental treatment plan requires minimal or no treatment when the dentist's diagnosis so indicates. Provisional, reversible treatment that accommodates chewing and speaking is used first to confirm the efficacy of therapy, validate the planned treatment and to further refine the mandibular position before any permanent alteration of the teeth is done. Because mandibular posture is a function of the overall posture, as the posture improves, the mandibular posture may change as well until stability is achieved. The patient and dentist have the option of discontinuing orthotic therapy if there is inadequate improvement. Objective measures, similar to the pretreatment diagnostic series, are used to evaluate progress. Treatment progress needs to be evaluated partly through subjective reports, as has been done traditionally. However, because there are inherent inaccuracies involved in subjective reports, objective measures are needed, as well. This is akin to a physician using electrocardiogram recordings or blood pressure readings for diagnosis as well as evaluating the efficacy of treatment and not just relying on how the patient feels.

Only when there is substantial improvement in both subjective and

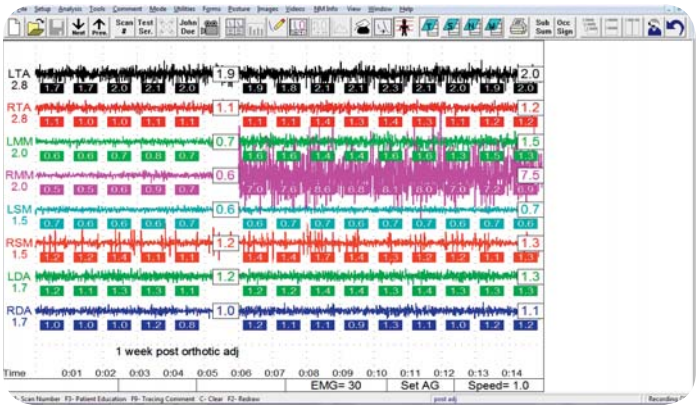

FIGURE 7. One week post PNMD fixed orthotic treatment sEMG scan of posture muscles at rest versus effortless occlusion proves that the mandibular discrepancy to maxilla has been corrected through the PNMD orthotic.

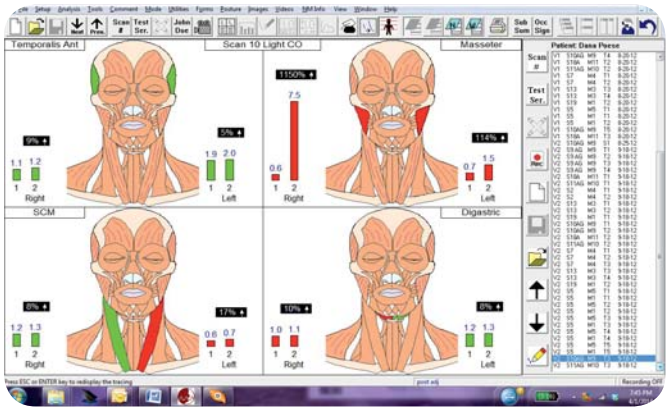

FIGURE 8. Comparison of muscle recruitment at rest versus effort needed to bring teeth into light occlusion prior to chewing shows that temporalis anterior muscles needed little effort. This correlates with symptom resolution.

objective measurements of treatment progress, thus proving the validity of the craniomandibular position, should any stabilizing steps that involve irreversible changes even be considered.[61] These include orthodontic movement of teeth, restorative treatment of some or all teeth and prosthetic replacement of missing teeth. No matter which option is chosen, objective data are used as a guide by the treating dentist to either replicate or further improve the mandibular position previously proven by the reversible orthotic therapy. Each of these options has corresponding consequences. It is the treating dentist's responsibility to educate the patient on these consequences. Ultimately, it is the patient's prerogative to make the decision on the options, including the option of no treatment, once all the consequences of each option are well understood. In this manner, any choice the patient makes is an informed decision.[62]

In discussions of evidence-based dentistry (EBD), the greatest importance is placed on literature citations. As defined at the 2008 ADA Evidenced-based Dentistry conference, "Evidence-based dentistry is an approach to oral health care that requires the judicious integration of systematic assessments of clinically relevant scientific evidence, relating to the patient's oral and medical condition and history, with the dentist's clinical expertise and the patient's treatment needs and preferences."[63] A dentist's clinical expertise and a patient's treatment needs and preferences are equally as valid as literature support. In their *JADA* editorial, Glick and Meyer acknowledge, "In reality, a lack of clinical research or insufficient clinical evidence is the rule rather than the exception in dentistry and medicine." They also state, "Scientific plausibility — or 'prior probability' — also must be considered. Good science accounts for all relevant evidence, including prior probabilities, as building blocks for new data. These prior probabilities may include the experience of having previously adhered to a specific treatment approach and … health care providers must continually seek to improve the quality of patient care through sound professional judgment based on provider experience, expertise and clinically relevant research."[64] Neuromuscular dentists have the necessary expertise and the experience of thousands of patients whose TMD symptoms were successfully resolved through a comprehensive approach for evaluation and treatment.

PNMD protocols are indeed guided by evidence-based dentistry[65] in line with the ADA's position of considering the clinical expertise of thousands of private-practice dentists around the world who successfully treat TMD patients daily. Even more important, this approach considers the treatment needs and preferences of patients who choose treatment options after being fully informed of the consequences of all options — including letting their disease continue without any intervention. All caring practitioners can support this approach that respects the patients who seek our care. ■

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Other Authors' Critiques of Dr. Raman's Paper

Dr. Fricton

Physiologic Neuromuscular Dentistry Strategy. Dr. Raman discusses the use of objective physiologic data such as surface electromyography (EMG) and jaw tracking to determine whether occlusal disharmony is causing muscle hyperactivity in the masticatory system. To illustrate his point, he presents a case showing that muscle activity was reduced when a permanent full-time occlusal splint was used. At 30-day follow-up, 70 percent of the patient's symptoms were resolved. Thus, he recommended that the patient redo her orthodontic care to move her teeth and jaw to a new "physiologic" position as determined by surface electromyography. The paper states that because this approach uses objective equipment such as EMG and jaw tracking, it follows evidence-based dentistry. Unfortunately, the paper does not review any scientific evidence related to the reliability and validity of these diagnostic tests nor the results of any placebo-controlled, randomized controlled trial evaluating the efficacy of this approach. Furthermore, the possible adverse events of this approach are not discussed.

Editor's note: See Dr. Fricton's general comments and conclusion on page 545.

Dr. Simmons

Dr. Raman's manuscript is supportive of neuromuscular dentistry concepts. Muscle dysfunction concepts and management by transcutaneous electroneural stimulation (TENS) are described. A mandibular rest position is achieved and utilized as a dental occlusal treatment position for relief of pain and dysfunction of the masticatory muscles.

Page 563 "As such, physiologic data such as electromyography (EMG) of the jaw and neck muscles drive diagnostic and clinical decisions."

Muscle pain, one of the symptoms associated with TMD, has not been shown to be consistently enough reflected in EMG data (J. Radke, president, BioResearch Inc., written communication, February 2011).[1] Internal derangement of the TMJ does not universally alter muscle function in a predictable way such that EMG data can consistently detect this condition (J. Radke, president, BioResearch Inc., written communication, February 2011).1 TMJ surface EMG in clinical use has little value in testing for the presence or absence of specific masticatory muscle and TMJ disk displacement disorders.[2-4] There is very little consensus about the use of EMG in the diagnosis and treatment of some TMDs.

Page 564. "So palpation is inadequate to provide the best possible clinical evaluation of the masticatory muscles."

On page 565, Dr. Raman uses detailed palpation of TMJ, jaw and cervical muscles in his example of a patient examination. On page 567, Dr. Raman lists "Palpation of the muscles of mastication, TM joints and cervical muscles" in his gathering of data for a diagnosis.

Page 564. "TMD patients frequently exhibit altered muscle activation patterns."

Muscles do cause most of the pain in a TMD patient, but the cause of the disorder is usually not the muscles; it is the underlying injury to the TMJ or neck vertebrae. Cyriax believes that muscles are the alarm that tells us there is something wrong in the neighborhood.[5] The question that should be asked is, "Why are these muscles in involuntary contraction?" Isberg believes that chronic contraction in the muscles of mastication may be caused by a displaced TMJ disk.[6] Cyriax believes that if one can treat the joint's arthritis and/or internal derangement, the muscle contractions resolve on their own.[5] Neuromuscular dentistry seems to be treating the secondary, not the primary, cause of a patient's pain and dysfunction.

CONTINUES IN SIDEBAR ON 570

OTHER AUTHORS' CRITIQUES, CONTINUED FROM 569

How does the neuromuscular dentist treat an acute disk displacement without reduction or intermittent acute displacement without reduction? If a practitioner is solely focused on the muscles, how is a TMJ internal derangement treated?

Care of the TMD patient is broken down into assessment, diagnosis and management.[7] Diagnostic tests, beyond range of motion, anatomic site palpation and diagnostic anesthetic blocks, have a minimal role in determining who needs TMD care.[1] The diagnosis of the TMD patient is properly based upon history (82 percent); then confidence in the diagnosis is added with examination (9 percent) and testing (9 percent).[8]

This paper is supportive of neuromuscular dentistry as the method of diagnosing and treating TMDs. Any significant opening of the mouth through muscle pulsing with TENS or other method causes anterior repositioning of the mandibular condyles in their fossae. The reviewing author believes that this technique accomplished its goals because of the underlying repositioning of the condyles to a more physiologic orthopedic position in the fossae. This anterior repositioning of the condyles may have caused the muscles associated with the joint to sense that the joints were more normal and therefore the muscles to reduce in contraction and the pain and dysfunction diminished.

I would like to thank Dr. Raman for participating in this journalistic endeavor. His patients appreciate his care in relieving their pain and dysfunction.

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Dr. Gelb

The physiologic neuromuscular dental paradigm puts a premium on the muscular and reduces the significance of the TMJ, articular disk and airway.

The TMJ is objectively measured with MRI and cone beam CT and the airway with a polysomnogram and home sleep testing. The physiology of the airway affects the growth and development of the face and with it the mandible and TMJ.

Dr. Raman states, "Occlusal disharmony can result in hyperactivity and a disturbed pattern of muscle contractions, leading to muscular pain and joint overload." AC looks at airway first, TMJ and myofascial second and occlusion third. Occlusal disharmony is not the driver in AC TMJ philosophy.

When considering the actual interdigitation of the teeth, it is not "the effort" needed by the muscles to bring the teeth into occlusion that is crucial, but more important, the efforts of the individual to breathe and maintain an open airway that affects the autonomic nervous system, oxidative stress and systemic inflammation.

CONTINUES IN SIDEBAR ON 571

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OTHER AUTHORS' CRITIQUES, CONTINUED FROM 570

When discussing postural stability, cervical posture and mandibular posture, no mention is made of altered posture due to increased nasal resistance and mouth breathing, which have been shown to significantly affect growth and posture.

In the Dana P. case, the joints are clearly loaded, with greatly reduced joint space. Her improvement could be attributed to the relative decompression of the TMJ and improved airway, breathing and sleep.

The need for physiologic neurologic orthodontics is questionable at age 49. In the AC philosophy, 90 percent of patients are cognitively and behaviorally weaned off appliance wear during the day, avoiding the need for case finishing.

In the data-gathering section, joint auscultation is missing, which is a basic part of joint evaluation, either manually or by stethoscope.

The neuromuscular paradigm popularized by Jankelson focuses primarily on muscle without recognizing the contribution of TMJ and AC in therapeutic treatment.

Dr. Raman's Response to Critiques

I agree with Dr. Fricton that there is no "one-size-fits all" approach to TMD. He states that the three authors besides him "rely on the same general treatment approach — that of primarily correcting the mandibular jaw position through splints." The more one knows, the more one understands the nuances. However, only dentists have the necessary skills to correct mandibular position, which has an enormous impact on the whole body.

Dr. Fricton questions the reliability and validity of neuromuscular dentistry bioinstrumentation. That sounds like the oft-repeated canard about "specificity and sensitivity" of these instruments in diagnosing TMD, as though it were a simple condition that could be addressed with a binary answer.[1] With 66 markers of this syndrome, including intraoral signs, headache, neck pain, ear pain, etc., the mathematical possibility of presentations is 2^{66} = over 73 quintillion; ergo the improbability of randomized controlled trials. Bioinstruments measure parameters accurately.[2] The FDA cleared them in 1994 and the ADA accepted them in 1996 because "these products were found to meet the Council's Guidelines for Instruments as Aids in the Diagnosis of Temporomandibular Disorders."[3] Electromyography (EMG) is a widely used medical diagnostic test. Why is it less valid than digital palpations?

Dr. Gelb appears unaware that physiological neuromuscular dentistry (PNMD) has progressed exponentially on the foundation laid by Dr. Jankelson. The PNMD approach includes achieving unstrained masticatory and cervical musculature, decompressed TMJs and improved airway. The resultant position of the TMJ in the example case demonstrates this point. Doppler and electrosonography were used in the diagnosis of this case but were not included above due to space constraints. Age 49 is not too old to move the teeth to permanently support an optimal jaw/neck position. The patient made an informed choice.

Dr. Simmons raises several good points. EMG provides information that an astute clinician uses along with other data for diagnosis and treatment. While many studies support this,[4] of more importance are the complex cases that were resolved. Palpation is used to augment objective data, not to take its place. He states that "muscles are the alarm" and "neuromuscular dentistry seems to be treating the secondary, not the primary cause of a patient's pain and dysfunction." PNMD treatment consists of

structural corrections so that the "alarms" will be silenced. That includes recapturing displaced disks. The PNMD approach is not either the muscles or the structures or the airway — it includes all of these.

All TMD philosophies, including PNMD, seek pain-free, unstrained muscle balance.[5] I invite everyone to study PNMD. My own journey began 30 years ago, when my wife was diagnosed with disabling migraine as she was completing her four bicuspid extraction orthodontics, including anterior retraction. Refusing to accept that the two were unrelated, I studied work by many mentors, including Drs. John Witzig, Jay Gerber, Robert Jankelson, James Garry, Bill Dickerson and Mariano Rocabado. Not only was I able to relieve her of migraine many years ago, my single practice focus has become helping patients who were given incurable medical diagnoses, with lifelong pain management as the only choice, to actually resolve myriad symptoms from TMD through PNMD. I invite every dentist to explore PNMD through serious study with an open but skeptical mind.

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