RWISO Journal

Volume 4, No. 1 Fall 2012

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The Roth Williams International Society of Orthodontics is the embodiment of a philosophical and technological transformation: addition of physiologic to anatomics from a foundation of function and esthetics.

Letter from the President

Dr. Renato Cocconi
RWISO President

"If you want things to stay as they are, things will have to change"
—Giuseppe Tomasi di Lampedusa

Giuseppe Tomasi di Lampedusa, an Italian writer, might have been on to something with this quote. Change will come, even with the greatest desire not to change.

As the field of orthodontics evolves, it is our responsibility to stay focused on our patients and their treatment. While we adapt to new ways of managing their care, we need to be mindful of our commitment to the philosophy that we have been trained to practice. It is important that we continue to learn from each other and sharpen our clinical skills.

This is why our *RWISO Journal* and conferences are so important. We need to continuously learn and adapt to new developments to maintain our goals and standards. Our *Journal* serves to educate our members, build our reputation, and strengthen our philosophy worldwide. Our annual conference provides the forum for in-depth discussion and uniting orthodontists worldwide. By building upon our knowledge and increasing our awareness of advancements in our philosophy, we will better prepare ourselves to face the coming changes of our profession and the evolution of orthodontics.

For all of us to enjoy the benefits of a journal and an annual conference, it takes a great deal of effort that often goes unnoticed. I would like to thank our *Journal* editor, Dr. Joe Pelle, for the many hours he has given to the successful completion of our fourth scientific publication and first electronic version of the *RWISO Journal*. Our annual conference involves hundreds of hours of work to coordinate speakers, attendees, and exhibitors for three days. I would like to thank Dr. Jina Linton for all she has done to ensure another successful conference for all of us.

For those of us who are trained in our philosophy, we know that it is not enough to read the *Journal* and attend the annual conference. We need to actively support our philosophy. Our support is given through membership in RWISO and donations to the RW Legacy Fund. Membership in RWISO is an investment in our future. It allows us to continue to maintain connections with our fellow orthodontists who share the knowledge of their professional journey. Support of the Roth Williams Legacy Fund ensures that we have a vehicle for research and development of our philosophy. Many thanks go to Dr. Milt Berkman who has been instrumental in the development of the RW Legacy Fund and continuing to champion our philosophy.

Speaking of our philosophy, we will soon have a very tangible and lasting tool at our fingertips. No small thanks are due to our very own Dr. Andy Girardot for his countless hours over the last several years to bring us our first textbook on the Roth Williams philosophy. I know I speak for the entire organization when I express my excitement at the anticipation of having this textbook finally published. A big "thank you" also goes to the many contributors who authored the various chapters. Their involvement will be part of our history that we will never forget.

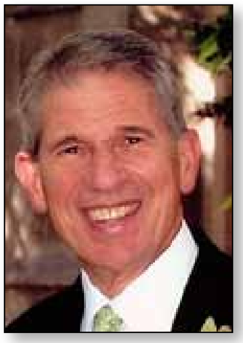
Has there ever been a more exciting time in our almost 20 year history? Please join me in continuing to support RWISO by introducing more orthodontists to the Roth Williams philosophy and encouraging them to join us. Together we can make our organization stronger to continue to pass down our knowledge and philosophies to the next generation of orthodontists.

As the Italian writer Giuseppe Tomasi di Lampedusa reminds us, "things will have to change," but let us be the leader of change and not the ones wanting things to stay the same.

Dr. Renato Cocconi
RWISO President

Letter from the Editor

Dr. Joseph M. Pelle
Editor-In-Chief of *RWISO Journal*



Evidence-Based Care Versus False Evidence-Based Allegations

Evidence, as defined in the dictionary, is that which tends to prove or disprove something; grounds for belief; proof. Misuse of evidence, or false evidence, on the other hand, can cause a distortion of the truth and hence the destruction of belief systems held by individuals, groups, or society in general.

The Duke Lacrosse case was a criminal investigation into a false accusation of rape made against three members of the men's lacrosse team at Duke University in Durham, North Carolina, in 2006. This false accusation caused irreparable damage to the reputations and livelihood of the accused. The fallout from the resolution of this case led to, among other things, the disbarment of lead prosecutor Mike Nifong; and in 2011 a federal judge ruled that a civil lawsuit could proceed against Nifong, including claims of "malicious prosecution" and "fabrication of false evidence." (This is according to Wikipedia, which quoted Associated Press.)

Today, in orthodontics, something similar seems to be occurring as we see more and more use—and sometimes misuse—of the term evidence-based care. There have been debates in our specialty for many years on various topics and in many venues, but none has been as notorious as the ongoing debate that has raged regarding occlusion and its relationship to TMD. Although the mid-1990s saw many debates on this topic in the *American Journal of Orthodontics and Dentofacial Orthopedics*, one of the first major, face-to-face exchanges of viewpoints occurred at an orthodontic meeting in New York City, if memory serves, in 1997. The debaters were our own late Dr. Ronald Roth and Dr. Donald Rinchuse,[1,5] a Pennsylvania orthodontist and educator. Although Roth was the consensus winner of that debate, it didn't stop Rinchuse from continuing his assault on the Roth Group's treatment philosophy. From time to time, over the years, challenges from Rinchuse have appeared in the *Am J Orthod Dentofac Orthop*. Such was the case in a recent issue, in a debate that featured, on the Roth Group side, Domingo Martin and Renato Cocconi, (Point:) Orthodontic dental casts: the case for routine articulator mounting,[5] versus Donald J. Rinchuse and Sanjivan Kandasamy, (Counterpoint:) Orthodontic dental casts: the case against routine articulator mounting.[6]

Both position statements make interesting reading; they can be seen by clicking the hot links at the end of this editorial. In addition, and what made the debate more compelling, were the four reader comments, and the authors' response to one of them, that appeared in the May issue of *Am J Orthod Dentofac Orthop*, which can also be seen by clicking their respective hot links below.

Rinchuse and Kandasamy basically took the position that the "best available evidence" on the routine mounting of study casts "currently points away from articulator mountings in orthodontics." However, if we take a look at their references, the evidence they present is weak at best due to questionable methodology used by many of their authors that has been brought to light recently (see Cordray, FE. The relationship between occlusion and TMD, in this issue of *RWISO Journal*.) Both Martin and Cocconi made strong cases for mounting, and the four reader comments[7,9,10,11] generally seemed to agree. While both sides presented their arguments supporting their positions, reader J. Michael Hudson tended to best summarize this debate when he stated, "Drs. Martin and Cocconi listed 8 reasons for mounting casts. Apparently Drs. Rinchuse and Kandasamy saw no reason to disagree with 7 of them. Good. Something perhaps both sides can concur on." Furthermore, he stated, "Drs. Rinchuse and Kandasamy acknowledged that articulators are useful in prosthodontics, restorative dentistry, and orthognathic surgery. Assumedly, this is because these specialties do significant or full-mouth reconstructions. Is that not most of what we do in orthodontics?"

These points, among others, are also made by Dr. Frank Cordray. Dr. Cordray brings up for questioning the "evidence" used by those opposed to the Roth Williams philosophy of treatment to a condylar center-seated position. His article features a remarkably thorough review of the literature that not only supports his position, but points out the weaknesses in the so-called evidence used by Rinchuse and others to argue against it—such as the absence of deprogramming, questionable methodology, and the lack of instrumentation (articulator mounting and axiography), to give just three examples.

We are certainly not at the point in this discussion to make claims of "malicious prosecution" and "fabrication of false evidence" as in the Duke Lacrosse case. However, a thorough reading and understanding of Dr. Corday's paper gives our group confidence that the best evidence available favors the Roth Williams philosophy.

Dr. Joseph M. Pelle
Editor-in-Chief
jpelle@verizon.net

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- PDF

News from the Roth Williams Teaching Centers

CHINA

Dr. Bob Williams and Dr. Jina Linton are currently teaching their fifth session of the second group in China. There are presently 39 doctors in the class. The first group of 36 doctors completed their program about a year ago. They hope to have a new teaching center in Shanghai by the end of 2012.

COLOMBIA

The Colombian Center is continuing to grow. Currently, we have a total of 105 students and 9 graduates. By the end of 2012, the center will offer three new continuing- education courses and open two additional CCOs, one in Guadalajara, Mexico, and the other in Arequipa, Peru. A Roth-Williams, Colombia meeting is being planned for our students. In 2013, we plan to offer two new continuing-education courses in Venezuela and Ecuador, respectively. The center also plans to distribute a magazine containing articles written by the students. Director Dra. Claudia Casanova Arambula would like to thank all of the teachers, professionals, and students who have worked so hard during this exciting time of growth.

SPAIN

After 20 years, the center has decided to take a 1-year sabbatical in order to restructure its courses and update all its materials. The new courses will be organized into three levels: Basic, Intermediate, and Advanced. All six FACE teachers (Drs. Domingo Martín, Alberto Canabez, Iñigo Gomez, Eugenio Martins, Gonzalo Facal, and Raul Ferrando) recently came together to work on this reorganization. They will hold their final meeting in Paris, and the new and improved program will begin in the spring of 2013. Updates on the program will be posted on the Osteoplac page, at www.rwiso.org.

ROMANIA

Under the leadership of Adina Suciu, the center in Cluj Napoca has developed a 2-year course, which is already under way. The faculty includes Drs. Domingo Martin, Renato Cocconi, Claudia Aichinger, Alberto Canabez, and Iñigo Gomez. The course is held at Cluj University, and the facilities are fantastic. Approximately 30 students are enrolled, and will soon be attending their third session. They are all enthusiastic, and they are learning a great deal.

TURKEY

Under the leadership of Dr. Murat Demirhanoglu, the center in Istanbul has started its third group, with approximately 35 students. The course is held at Yedditepe University, and the second session will begin shortly. The faculty includes Drs. Domingo Martin, Renato Cocconi, Guillermo Ochoa, Mirco Raffaini, and Alberto Canabez. Many of their former students are returning to take more courses. We are excited that word of the FACE courses is spreading all over Turkey, and they are in high demand.

RUSSIA

Drs. Domingo Martin and Renato Cocconi recently gave a 2-day introductory course on the FACE philosophy. There were nearly 300 students in attendance. Drs. Martin and Cocconi plan to establish a two-year FACE program under the leadership of Dr. Andrey Kovalev, and many doctors have already signed up. The program is tentatively scheduled to begin in 2013.

KOREA

RWKSO members were delighted to have Dr. Andrew Girardot and Dr. Bob Williams offer a half-day seminar last June on their way back to the United States from China. Dr. Williams came to Korea again later that month and spoke to new student members on “Goal-Directed Orthodontics.” The ninth group at the Korean Teaching Center began its session last September. An oral surgeon has joined the group, so its prospects for orthognathic surgery are bright. The director of the Korean center, Dr. Jina Linton, has been assisting Dr. Williams in China for the past 4 years. She is currently serving as vice director of the Chinese Teaching Center.

The Roth Williams Legacy Fund Committee Report

Dr. Milton D. Berkman, Chairman, RWLF

Dr. Milton D. Berkman
Chairman RWLF

Fund-Raising

RWLF has raised over $300,000 toward our goal of $1 million to advance the scientific and clinical benefits of the Roth Williams Philosophy.

Journal

RWLF has provided $60,000 for the publication of the first three issues of the *RWISO Journal*. This is part of our stated mission to disseminate research, education, and problem-solving evidence-based papers and reports regarding goal-directed orthodontic and interdisciplinary diagnosis and treatment to the worldwide orthodontic community. We want to express our gratitude to Tom Chubb, who was the first editor of the Journal, and to Joe Pelle, who is the present editor. They have shown great dedication and have created a Journal that we can all be proud of. As a testimonial to their success, Jeff McClendon and I use a number of articles published in the Journal as part of the literature review and handouts for the CORE course.

Research Committe

RWLF has established a Research Evaluation and Approval (REAC) subcommittee, which is responsible for awarding research grants. Each research investigator is required to sign a Memorandum of Understanding (MOU). The MOU stipulates how funds are to be used and the reporting required for incremental funding. The MOU also stipulates that the final incremental payment will not be received until the researchers present a letter stating that their project will be published in a scientific and/or clinical journal related to orthodontics. REAC looks forward to seeing more investigators submit research proposals for funding. If you are interested in discussing or submitting a proposal, please contact Straty Righellis or myself. .

Research Grant 1

Drs. Edson Illipronti and Solange Mongelli de Fantini of Brazil received a research grant to fund in part CBCT and MRI imaging for a research project entitled “Evaluation of functional morphology in children with unilateral posterior crossbite before and after rapid maxillary expansion.” They are scheduled to present a paper entitled “Morphofunctional assessment in children with unilateral posterior crossbite” at the RWISO Conference in Paris in early October. This presentation will be a wonderful opportunity to learn more about their research project, progress made to date, and what to look for in the future from their research. It is also a great opportunity to see at first hand the work of the Legacy Fund in supporting orthodontic researchers who wish to investigate the scientific and clinical benefits of goal-directed orthodontic and interdisciplinary diagnosis and treatment. The grant is for $16,000 over a 3-year period. The Committee looks forward to hearing your response to this research project, and to the work of the Legacy Fund in supporting evidence-based research on goal-directed treatment.

Research Grant 2

Drs. Carol Weinstein and Sigal Bentolila Weiner (postgraduate student) of Chile received a research grant to fund in part CBCT imaging for a research project entitled “Degree of apical root proximity, periodontitis, and root resorption of the maxillary canine and first bicuspid found in a sample of Roth prescription-treated orthodontic cases using CBCT compared to panoramic radiography.” Last year at the RWISO Conference in Chicago, this project was displayed as a poster board presentation at the RWLF exhibit booth. The grant is for $3,000 over a 3-year period. The poster board presentation will be displayed at the Paris Conference, and the researchers will be available to discuss their progress to date. A research paper on their progress to date will be given at the Chilean Orthodontic Society meeting in Santiago in November 2012. They also plan to present their findings at the 2013 RWISO Conference in Brazil. The Legacy Fund looks forward to the eventual publication of this study, which will provide better clinical evidence- based research to answer questions that have been raised regarding the Roth prescription for canines and first bicuspids.

Textbook

The publication of a textbook has been a major financial undertaking of RWLF in conjunction with the editor, Dr. Andy Girardot. As editor, Andy has spent an enormous amount of time working to make this textbook a reality, and he deserves our gratitude, appreciation, and support for taking on this monumental responsibility. The textbook, which will run over 700 pages, consists of 26 chapters by 24 authors representing orthodontics, oral maxillofacial surgery, periodontics, and restorative dentistry. It is divided into three sections: Philosophy, Diagnosis and Planning; Treatment; and Advanced and Interdisciplinary Treatment. RWLF created a restricted textbook fund in 2009 to allow individuals to donate specifically to this project. A number of doctors and friends of RWISO have donated the $110,735 that has been spent producing this textbook.

Planning

Development, planning, and marketing consultant Diane Benson of Mooresville, North Carolina, has been working directly with me since the Chicago meeting to develop a long-term marketing plan for RWLF. The first step was to review fund-related accounting, and to ensure absolute transparency and confidence in the organization's fiscal accountability. It is our fiduciary responsibility to make certain that funds are being used as set forth by the Legacy Fund and the Board of Directors of RWISO. This step took more time than we expected, but the time spent has been well worth the effort. The next step is to start an electronic newsletter to improve communication with donors, members of RWISO, colleagues, and friends. We must communicate with these groups to remain connected with them, and to remain viable. The goal of the newsletter is to create interest in, excitement about, and desire to support, the Legacy Fund's work.

Donations and Pledges

Mission Statement: To advance, promote, improve, and assist the scientific, clinical, research, and educational benefits of goal-directed orthodontic and interdisciplinary dento-facial diagnosis and treatment as the basis of the Roth Williams Philosophy.

Donations to RWLF can be made in the following ways:

- Professional Courtesy/Grateful Patient. Individuals who are offered orthodontic services as a courtesy are invited to demonstrate their appreciation by making a contribution to RWLF in the treating doctor's name.
- Case for the Future. RWLF doctors can select one new case and donate the money received to RWLF.
- Doctors giving courses or lectures can donate a portion of the tuition or honorarium to RWLF.
- Donations can be made in honor of, or in memory of, a colleague, friend, relative, or parent.
- Donate because of what the Roth Williams philosophy has meant to your professional life.
- Donate out of appreciation to RWLF for supporting the creation of the RWISO Journal.
- Donate because you understand the importance of a textbook about goal-directed orthodontic and interdisciplinary treatment.

- Donate because you understand the importance of documented research on the benefits of goal-directed orthodontic and interdisciplinary patient care.

Donations can be designated:

- to the General Fund;
- to the Research and Education Fund; or
- to the Textbook Fund.

For more information on how to donate, visit the RWISO Web site at www.rwiso.org.

RWLF Committee

Thank you to all the donors who support RWLF and the work being done by the Legacy Fund Committee.

Dr. Milton D. Berkman, Chairman RWLF
Dr. Peggy Brazones
Dr. Domingo Martin
Dr. Joe Pelle, Editor in Chief, *RWISO Journal*
Dr. Straty Righellis, Chairman REAC
Dr. David Way
Dr. Carl Roy

A special thank you to Jeff Milde, Executive Director RWISO, for all the work he does to make RWLF successful.

Roth Williams Legacy Fund Donors

Tribute to Donors

We thank all of our loyal and faithful donors for their support of the Legacy Fund. Below, we pay tribute to those donors who have given from January 1, 2006, through through August 31, 2012.

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Thank you to these donors who have pledged donations to the Legacy Fund over multiple years.

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The Relationship Between Occlusion and TMD

Frank E. Cordray, DDS, MS

Frank E. Cordray, DDS, MS
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- Recipient, Distinguished Service Award, Dawson Center for the Advancement of Dentistry
- Recipient, B. Holly Broadbent Sr. Memorial Lectureship
- Member, Edward H. Angle Society, Eastern Component
- Board-Certified Orthodontic Specialist
- Assistant Clinical Professor, Ohio State University, Department of Orthodontics
- Guest Lecturer, Children's National Medical Center, Washington, DC

Summary

The purpose of this paper is to conduct an extensive review of the literature on the relationship between occlusion and occlusal factors and temporomandibular dysfunction (TMD). This paper attempts to explore why the link between occlusal factors, which have historically been implicated in producing TMD, and dysfunction has not been clearly evident from the dental literature.

Introduction

The role of occlusion as an etiologic factor in TMD is a controversial subject. It sometimes elicits strong emotions and is often discussed at a highly empirical level. Many dentists believe that occlusal discrepancies are an important etiologic factor in TMD, and their belief is reinforced by successful results following occlusal treatment. However, other clinicians claim equal success following the use of nonocclusal treatments. This being the case, it would be unwise to base any theory on the etiology of dysfunction solely on subjective assessments of pain relief.[1]

Studies on the role of occlusal factors in TMD fall broadly into four categories. They may be (1) experimental, (2) electromyographic, (3) epidemiologic, or (4) clinical. The evidence contained in these studies is often conflicting, and some of the studies have serious shortcomings. For example, had occlusal factors not been dismissed as unimportant in some studies, the results could have been interpreted differently.[1]

The signs of TMD include muscle and joint tenderness, joint sounds, limitation and incoordination of mandibular movement, parafunction, occlusal wear, attrition, and headache. It is now generally accepted that headache should be included as an additional sign,[2] especially since muscle contraction headaches have been reported to account for up to 90% of all headache pain.[3] Epidemiologic and clinical studies indicate that some signs of dysfunction may be present without producing pain. However, pain is the main cause of complaint and the principle reason why patients seek treatment.[1]

The etiology of pain and dysfunction remains unclear. Some authors believe that there is a single etiologic factor, either occlusal[4-6] or psychological.[7] Others reason that because there is no consistent pattern of presentation, the etiology is probably multifactorial.[8] Nonetheless, there is general agreement that external trauma is a predisposing factor.[1, 8–10]

The primary focus in the study of TMD has traditionally been neuromuscular (extracapsular).[8] However, the pathologic processes occurring within the joint (intracapsular) have also become a significant area of focus in recent years. Intracapsular and extracapsular dysfunction are often superimposed and pose a considerable diagnostic problem in determining to what extent each condition is dependent upon the other. Clinicians treating these problems are well aware that extracapsular (muscular) problems have a significantly better prognosis for resolution than intracapsular (structural) problems.

Experimental Studies

Table 1 shows the incidence of TMD as determined by muscular and/or temporomandibular joint (TMJ) pain 1 week after placement of various interferences in small samples of subjects.[1,11-15] Surprisingly, the incidence of dysfunction varied from high (7/8) to low (0/6) in these five studies. Two glaring weaknesses of these studies are the extremely small sample sizes and the short periods over which symptoms were monitored—long-term follow-ups would have been more useful. The outcome of this type of experiment is probably determined by the subject's neuromuscular adaptive capacity, or in other words, the subject's ability to "absorb" an interference without producing significant degrees of muscular incoordination, hyperactivity, or parafunction.[1] This range of individual accommodation determines the likelihood of pathologic sequelae.

Investigator (Yr)	n =	Posterior interference	Subjects With Dysfunction After 7 Days
Randow '76	8	0.5mm high inlay	7/8
Riise '82	11	0.5mm high amalgam	4/11
Plata '82	6	Lateral deflective contact	0/6
Rugh '84	10	Crown with 0.5–1mm shift ant+lat from CR	4/10
Magnusson '84	12	Bilateral nonworking composites	7/12
	12	Control: simulated	3/12

Table 1 Experimental studies in which various occlusal interferences were incorporated.[1] The incidence of dysfunction after 7 days is reported in the last column.

Electromyographic Studies

Electromyography measures the character and intensity of electrical activity associated with muscular contraction. Studies comparing dysfunctional and nondysfunctional subjects found that most TMD patients showed increased and uncoordinated electromyographic (EMG) activity of the masticatory muscles.[1,5,16] Studies also found that in many cases the EMG silent period (the temporary pause in ongoing EMG activity of jaw-closing muscles during maximal clench) is also longer in TMD, which implies a possible neuromuscular difference between TMD and non-TMD subjects.[1,17,18] The exact cause of the abnormal EMG activity is unclear. However, bruxism has been implicated.[1,19,20]

Finally, studies have found that bruxists with TMD showed a decrease in both diurnal EMG hyperactivity and incoordination following occlusal adjustment.[1,21,22] Patients who developed TMD following restorative treatment also showed a decrease in diurnal EMG activity after the occlusal discrepancies were removed from their restorations after occlusal adjustment.[1,23]

Epidemiologic Studies

Several studies have investigated the prevalence of TMD in the general population. Rugh and Solberg have reviewed these studies;[24] their findings may be summarized as follows.

The prevalence of symptoms (12% to 59%) and signs (28% to 86%) was generally high. However, most cases were subclinical, and it was estimated that no more than 5% required treatment. Interestingly, the female-male ratio of dysfunctional subjects was 1:1 in these studies, whereas the ratio of TMD patients actively seeking treatment had a female-male ratio of 3:1. Peak age on presentation was 20 to 30 years.[25] The ability of a subject to adapt to occlusal discrepancies may be influenced by psychic stress.[26-28] A number of occlusal factors have been linked with TMD.[1] These include loss of vertical dimension,[4] number of contacting teeth,[29] orthodontic malocclusion (specifically, crossbite, anterior open bite, and deep bite)[30], occlusal interferences, and deflective contacts.[21,22,26,31–34] However, the link between occlusal factors, which have been implicated in producing TMD, and dysfunction is not always evident from the literature.[1]

There has been much speculation on the way in which occlusal factors may produce dysfunction. It can be understood that posterior tooth loss, particularly in the presence of parafunction, can predispose to overloading the TMJ.[4] The mode of action of occlusal interferences and deflective contacts is more difficult to determine. However, there are two principle theories. The first theory is that occlusal factors induce the subject to *parafunction*.[26] The second theory is that functional movements (mastication, swallowing and mandibular posturing) are adversely affected when the subject subconsciously avoids the aberrant tooth contact.[35] This is known as *aberrant function*.[1] Both theories acknowledge that psychic stress may combine with an unfavorable occlusion to produce dysfunction. Parafunction and aberrant function may produce muscular hyperactivity[21,22] and incoordination.[36] Balancing interferences may act as pivots that produce adverse leverages, thus overloading the TMJ components in compression or tension.[1,37]

Clinical Studies

Clinical studies have historically been the method of choice for studying occlusion and the effectiveness of occlusal alteration on the reduction of TMD signs and symptoms.

Occlusal therapy review. Consider first the effectiveness of occlusal therapy in treating TMD. Over the last four decades, occlusal therapy has included reconstruction (often at an increased vertical dimension[38]) and occlusal adjustment (reshaping heavy intercuspal contacts[39] and deflective interferences[26]) to enhance functional relationships. The response of TMD patients to occlusal therapy has been assessed both subjectively by patients' reports of pain remission[40,41] and objectively, utilizing EMG data,[17] the Helkimo dysfunction index,[42] pantographic tracings,[36,43–46] condylar radiography,[47] gnathosonic recording,[39] and three-dimensional condylar graph registrations.[33,34]

Small yet significant interferences may be clinically difficult to detect and the characteristics of pantographic tracings have been shown to be useful in revealing their existence.[1] The identification of the interference and its removal have been shown to result in the establishment of normal border movements.[43] Clayton introduced a method of detecting and quantifying mandibular incoordination using the pantograph; the degree of divergence of three consecutive tracings forms the basis for his pantographic reproducibility index (PRI). Pantographic tracings quantitated by the PRI can be used to detect the existence of uncoordinated mandibular movements, a symptom of TMD.[44] When the masticatory muscles are uncoordinated, mandibular border movements become nonreproducible.[45] Splint therapy has been shown to produce a fall in this index and an immediate rise to dysfunctional levels upon splint removal.[48] The findings of these PRI studies support the epidemiologic studies cited earlier, which found that signs associated with dysfunction can exist without pain.[1]

Ramfjord[21,22] used electromyography to evaluate the effects of occlusal adjustment on a population of 35 bruxists with symptoms of TMD. Excessive EMG activity was normalized after adjustment, and all symptoms were alleviated. This study is often cited in support of occlusal adjustment as an effective mode of therapy. However, the study has several methodological problems: no controls were used; long-term follow-up was not reported; and the study has not been duplicated.

Magnusson and Carlsson utilized the Helkimo dysfunction index to monitor the effect of further occlusal adjustment in patients who had residual signs and symptoms of TMD 2 to 5 years after initial occlusal adjustment. The treatment was found to be effective in removing the preadjustment signs and symptoms.[1,49]

Thus occlusal adjustment studies suggest that occlusal adjustment can reduce the clinical signs of TMD. However, the problem with studies of this type are that they lack controls, that treatment is not randomly allocated, and the occlusal adjustment method is sometimes questionable.[1]

Splint therapy review. Early studies[5,50] demonstrated that the provision of a full-coverage stabilizing splint adjusted to the seated condylar position in all situations produces an immediate drop in EMG, which returns to its previous level upon splint removal. (Note: synonymous and interchangeable terms are used here to describe two key reference positions: Seated Condylar Position/Centric Relation (SCP/CR) and Maximum Intercuspation/Centric Occlusion (MIC/CO). The anterior guidance provided by the splint has been shown to be significant.[51] In his comprehensive review of splint designs, Clark concluded that there is sufficient evidence to support the use only of the stabilizing splint adjusted to the SCP.[52,53] Wahlund, in a prospective randomized clinical trial, showed that stabilization splints are highly effective for treatment of TMD, especially in adolescents.[54] In addition, a 23-year clinical study has shown that the stabilizing splint is more effective long term than an anterior-repositioning splint[55] and is less likely to lead to difficult orthodontic and restorative problems caused by unwanted tooth movement.[1,10] Some authors advise an initial period of stabilization splint wear for therapeutic or diagnostic purposes.[46,48] Therapeutic goals are to alleviate the symptoms of TMD and to test the patient's response to an altered occlusal scheme. The diagnostic goal is to reveal occlusal interferences and maxillomandibular relationships previously hidden by guarding of the neuromuscular system. Thus splint therapy is used to locate the seated condylar position, to test the stability of the joints, and to determine if changing the patient's existing occlusal scheme may be of benefit.

Review of Three-Dimensional Determination of Condylar Position

The seated condylar position (SCP) or Centric Relation (CR) is anatomically determined; thus it is repeatable and reproducible.[26,56,57] It is defined as the relationship of the mandible to the maxilla when the condyles are seated against the thinnest avascular portion of the articular disc in their most superoanterior position in the glenoid fossae and are centered transversely, regardless of tooth contact.[57-58] Okeson[57] describes this as the most orthopedically and musculoskeletally stable position of the mandible, while Sicher,[59] Hylander,[60] and Gibbs and Lundeen[61] consider this position to be the essence of optimal TMJ form and function. It is considered to be the most reliable and reproducible reference point for accurately recording the relationship of the mandible to the maxilla.[56,57,62–67] Therefore, determination of the SCP/CR is a prerequisite for analyses of the dental arch, condylar position, and skeletal relationships.

Maximum intercuspation or centric occlusion (MIC/CO) is defined as the most closed position that the mandible can assume, determined by full intercuspation of opposing teeth, regardless of condylar position.[58] CR defines a condylar-determined position of the mandible, whereas CO defines a tooth-determined position. It is generally agreed that a difference exists between the three-dimensional dental arch relationships in CO and CR. [68–72] It is also generally agreed that a difference exists between the three-dimensional condylar position in MIC/CO (the occlusion-dictated condylar position) and in SCP/CR (the three-dimensional condyle position when the condyles are seated).[33,34,66,69–71,73–84] In the naturally occurring dentition, the SCP/CR does not usually coincide with the position the mandible assumes when the teeth are in MIC/CO.[26,33–36,48,51–53,56–58,62–84] This positional difference is known as the condylar displacement, or condylar distraction.[34,63,64,72–79,84]

Howat, et al[56] state that the discrepancy between the seated and unseated condylar position should be identified and eliminated when the operator reorganizes the occlusion. The occlusion must be reorganized when the operator is restoring posterior occlusal stability by occlusal adjustment or tooth restoration; is treating mandibular dysfunction; is treating with orthodontics; or is positioning the condyle during orthognathic surgery. The occlusion must also be reorganized prior to multiunit restorations or complete denture prosthetics. Thus, treatment success in each of these areas is completely dependent upon the operator's ability to attain a comfortable, stable, repeatable seated condylar position as a reference point.

Various clinical methods have been proposed to determine condylar position as it relates to the dentition. One popular method is a chairside assessment through intraoral visual estimation, using mandibular manipulation to attempt to seat the condyles.[49] However, attempts to assess the CR/CO shift in the general population through intraoral visual estimation are not reliable, because the muscles of mastication and nerve reflexes protect the teeth by overriding the guidance of the joint.[33,34, 56,62,69–71,84–92] Another popular method is to estimate the degree of condylar displacement by measuring the hit-and-slide at the occlusal level.[93] However, studies have shown that observation of a slide or shift at the level of the occlusion may not accurately represent the three-dimensional change in position of the condylar axis.[33,34,63,64,73–78,79,81–84]

The American Dental Association[94] and the American Academy of Craniomandibular Disorders[95] have concluded that radiographs are contraindicated to assess condylar position for diagnostic purposes.[96-112] Radiographs include panoramic and transcranial radiographs, lateral cephalograms, arthrograms, and corrected tomography. These are two-dimensional images and are therefore inadequate to assess condylar position, which exists in three planes of space. As with all radiography, there is a certain percentage of distortion inherent in the production of a radiographic image. A problem with tomography is the variation in soft tissue thickness within the joint, which creates joint space that is not three-dimensionally uniform. Hatcher[113] has shown that the evaluation of condylar position is very sensitive to the depth of cut, and that head position is critical. Thus, a large variation in condylar position, as seen tomographically, has been found in normal asymptomatic subjects.[33,75,99–101, 112,113] Girardot[33] observed that measurements obtained with the MPI were different from those obtained with oriented tomograms, even though the same condyles were being measured. He concluded that MPI instrumentation is a more reliable method of measuring changes in condylar position than tomographic radiographs and questioned the validity of using tomograms as a means of measuring changes in condylar position. Arthrography and arthroscopy are expensive and invasive procedures that often yield information of questionable value, while MRIs[75] and CT scans are expensive, are not readily available, and are not three-dimensional recordings.

The use of study models articulator mounted in the SCP/CR in conjunction with condylar position instrumentation is another method of assessing three-dimensionally both the interdental arch relationship and position of the condyles. The magnitude and direction of any discrepancy between the SCP/CR and MIC/CO is determined with condylar position instrumentation, designed to record, measure, quantify, and compare the positional changes of the condylar axis between the SCP/CR and MIC/CO in all three spatial planes. Specifically, this means that this instrumentation is capable of recording mm. measurements of condylar position in the horizontal (AP), vertical (SI), and transverse (ML) planes. The accuracy, reproducibility, and reliability of condylar position instrumentation have been confirmed.[33,34,63,64,73–79,81–84,114–117]

A number of articulator systems incorporate this type of condylar position instrumentation. They include the Cranio-Mandibular Positioner (CMP) (formerly Veri-check), by Denar Corporation, Anaheim, California; the SAM Mandibular Position Indicator (MPI), by Great Lakes Orthodontics, Ltd., Tonawanda, New York; the Modified Buhnergraph, by Whip-Mix Corporation, Louisville, Kentucky; and the Condylar Position Indicator (CPI), by Panadent Corporation, Grand Terrace, California.

Condylar graph measurement using condylar position instrumentation has many advantages. It is simple and easy to perform; it is widely available; it is inexpensive and noninvasive; it is suitable for screening large numbers of patients; and it is highly accurate. It is the most accurate method for determining condylar position in all three planes of space to within 0.2 mm horizontal and vertical and 0.1 mm transverse).[33,34,63,64, 73–79,81–84,114–117] The seated condylar position is a three-dimensional entity that is most accurately assessed with a three-dimensional measuring device, such as those listed above.

Therefore, a definitive description of occlusion includes not only an assessment of models articulated accurately in the SCP/CR, but also an assessment of condylar position resulting from intercuspation of the teeth. It follows that a definitive description of occlusion must answer the following questions. Does the maximum intercuspation of teeth allow the condyles to remain seated? Is the occlusion-dictated condylar position (the position of the condyle in MIC/CO) coincident with the SCP/CR? Or are the condyles displaced as the teeth are brought into MIC/CO? If the condyles are displaced, what is the magnitude and direction of this displacement in three planes? What is the normal range for condylar displacement in an asymptomatic population? Is it different in a symptomatic population? All of these questions must be addressed in order to determine whether occlusion is associated with the production of the signs and symptoms of TMD.

Problems with Researching Occlusion

It is apparent that further work needs to be done to clarify the confusing situation that exists relating TMD to deflective dental contacts and interferences and thus to condylar displacement. To address this problem, it is necessary to determine why the link between TM dysfunction and occlusal factors, which have been implicated in producing TM dysfunction, has not been sufficiently evident in the literature.[1] The fact that a number of previous studies[100,101,112,118–129] have failed to find a strong link between occlusal factors, condylar position, and TMD does not prove there is no such link. The most recent literature denying the existence of a link has shown only that (1) there is no correlation in random samples between the location of the condyles on a radiograph and TM symptoms[96–113]; or (2) that there is only a weak association between occlusal factors in MIC/CO and TM symptoms.[1]

For example, occlusal characteristics such as overbite and overjet have been shown to be poor indicators of condylar position.[33,34,58,63,73,81–84,113–117] Recent studies have also shown that the frequency, magnitude, and direction of the displacement between the SCP/CR and MIC/CO at the level of the condyles cannot be predicted by age, gender, Angle's classification ANB angle, or mandibular plane angle.[76,78] Conversely, many studies have shown a positive correlation between occlusal factors, condylar position, and TMD.[26,31,33–35,47,49,103,130–158] Why does a dichotomy exist in the results and conclusions of these two sets of studies? Methodology is one area that can be implicated.

Methodologic Inaccuracies

The overwhelming majority of studies researching a possible link between occlusal factors, condylar position, and TMD are methodologically flawed in one or more of the following aspects. First, researchers have not adequately addressed the influence of the neuromusculature on condylar position and the resulting dental interarch relationship. Researchers have not routinely used deprogramming to achieve neuromuscular release before conducting occlusal and condylar position evaluations. Second, condylar position and condylar displacement have not been isolated as a specific etiologic factor in the possible production of TM signs, symptoms, and dysfunction. Third, condylar position and condylar displacement have not been accurately evaluated in three dimensions. Fourth, instrumentation is required to assess and compare the three-dimensional dental interarch relationships and condylar displacement between MIC/CO and the SCP/CR. Fifth, the use of instrumentation is technique sensitive. Sixth, and finally, the study sample may simply be too small to render the conclusions clinically valid.

These methodologic inaccuracies blur the distinction between the SCP/CR and MIC/CO both at the level of the occlusion and at the level of the condyles. For example, many studies have attempted to evaluate condylar displacement without the use of instrumentation through measurement of the apparent hit-and-slide at the occlusal level by intraoral visual estimation and chairside mandibular manipulation of a nondeprogrammed symptomatic subject, or through assessment of study models hand-articulated in MIC/CO. Others have attempted to evaluate condylar displacement on a nondeprogrammed symptomatic subject radiographically. Add to this the fact that accurately registering the SCP/CR is technique sensitive to the point that many dental practitioners and researchers find it difficult to do, and thus, it becomes clearer why only a weak association has been found between occlusal factors in MIC/CO and TMD symptoms. It is also apparent that very few studies that attempt to evaluate the difference between the SCP/CR and MIC/CO in asymptomatic and symptomatic subjects actually register the SCP/CR accurately, for this requires deprogramming prior to the registration of the SCP/CR and the use of instrumentation by a researcher versed in these techniques to measure the interdental arch and condylar position discrepancies.

Influence of the Neuromusculature

To study the dental arch and condyle positional changes between MIC/CO and the SCP/CR, it is important to use a method that reduces or eliminates the influence of the occlusion on the musculature. Only then can the condyles be accurately seated. A number of studies have shown that the neuromusculature positions the mandible to achieve maximum intercuspation regardless of the position of the condyles.[21,33,45,48,50,69,71,79,84,86,91] Engrams (as a result of muscle splinting and activation of the premature avoidance system) develop due to repetitive closure in a deviated position. This causes the proprioceptive neuromuscular system to memorize muscle activity and thus become patterned to the deviated closure, which may prevent complete condylar seating when registering the SCP/CR.[57,79,85] The resultant muscle function can be so dominant that the clinician will mistake the acquired mandibular position (the occlusion-dictated condylar position) for the seated condylar position. Thus clinical mandibular manipulation is an unreliable means of determining the seated condylar position. This finding is consistent with Calagna's statement that "there is no known scientific method available to determine which patients require neuromuscular conditioning."[69] (p. 598)

Neuromuscular Deprogramming Is the Key to Reproducibility[21,33,45,48,50,56,57,62,64,68–71,79,84–92]

A tangible result of more complete condylar seating is that the clinician is provided with a more accurate representation of both the three-dimensional dental arch and condylar position spatial relationships. Deprogramming allows location of the seated condylar position and resultant occlusal analysis that correlates condylar position with tooth contacts. Studies have shown that the neuromusculature positions the mandible so that the teeth fit into MIC/CO regardless of condylar position.[33,34,56,62–64,69–71,73–79,84–92] Thus it can be difficult to identify deflective dental contacts and to register the SCP/CR in dysfunctional subjects.[1]

If dysfunctional subjects have not been symptomatically resolved and neuromuscularly deprogrammed on a stabilization splint prior to registration of the SCP/CR, then the occlusal and condylar position evaluations were performed while the subjects were still dysfunctional.[1] Failure to register the SCP/CR results in studies in which all samples (both control and experimental) are the same with regard to condylar position. Therefore, only occlusal factors in MIC/CO are being measured in each sample. The result is that only minimal discrepancies in condylar position are observed between MIC/CO and the assumed SCP/CR.

The Need for Instrumentation

Few studies have examined occlusion-dictated condylar position and condylar displacement with condylar position instrumentation. Instead, previous researchers have attempted to study occlusion, intraorally, with study models hand articulated in MIC/CO, with radiographs, or with a magnetic resonance imaging (MRI) or computed tomography (CT) scan. One possible reason for this is that the methods for registering the SCP/CR and measuring condylar displacement are highly technique sensitive. Studies conducted by unskilled or inexperienced clinicians or researchers result in erroneous, invalid, or flawed conclusions.[1] A second possible reason is that the use of instrumentation can be labor intensive, making it difficult to secure a sample size sufficient to prove a strong statistical significance or to provide accurate conclusions.

Why The Epidemiologic Evidence Implicating Occlusion As A Causative Factor In TMD Is Weak

No clearly defined link has been determined from the epidemiological literature relating occlusal factors or condylar position and TMD. How can this be? There may, in truth, be no link, because the dysfunction may arise as a result of other factors. However, other reasons must be considered. The literature relating occlusal factors and condylar position to TMD must be assessed in the context of the clinical problems that affect this possible relationship and these problems may be summarized as follows:

1. TMD is multifactorial and the etiology and extent of TMD are difficult to diagnose precisely.[1]

2. Occlusal and condylar position evaluations that form the basis of these studies may have been inadequate. For example, dental interarch relationships may have been estimated visually. Study models may have been hand articulated in MIC/CO. The registration technique may have been improperly conducted (e.g. no instrumentation, radiographic evaluation, MRI, CT scans, etc.).

3. The identification and full extent of deflective occlusal contacts in dysfunctional subjects may be hidden by guarding of the neuromusculature. For example, it is difficult to identify deflective dental contacts in subjects with TMD.[1] Numerous studies[50,51,57,69–71,79,84,86, 93,159] have shown that properly conducted splint therapy or neuromuscular deprogramming reveals previously undetected contacts as a result of masticatory muscle relaxation and subsequent mandibular repositioning. This implies that in dysfunctional subjects, effective treatment must be implemented before precise occlusal analysis is undertaken. Many studies have ignored this consideration. Some of these studies[160–163] report no relationship between deflective dental contacts and the occlusal slide between MIC/CO and the SCP/CR, but in these studies, the subjects' proprioceptive response to the occlusion was not eliminated. Thus, the occlusal evaluations were conducted while the subjects were still dysfunctional. And even if mandibular posturing can be overcome, an appropriate method must be used to assess deflective dental contacts and interferences. Some studies have used study casts mounted on non-arcon semiadjustable articulators.[164] This method of assessment is inappropriate because the posterior determinants are insufficiently accurate to identify working and balancing interferences reliably.[1]

4. Occlusal factors may cause little or no dysfunction because they lie within the subject's neuromuscular adaptive capacity.[1, 26, 56] However, the same factors may exceed the adaptive capacity of a subject susceptible to TMD, causing muscular hyperactivity and incoordination.[1] The type and severity of deflective dental contact and interference may be less important than the way the dysfunctional subject reacts to it. Thus the differences in occlusion between dysfunctional and asymptomatic subjects may be minimal.[1] However, the transverse condylar displacement has been implicated in the production of muscular hyperactivity and incoordination.[34, 76,117,156]

5. The neuromuscular adaptive capacity may be lowered by stress and emotional problems.[1]

It is probably for these reasons that the epidemiologic evidence to implicate occlusal factors in dysfunction is weak. Nevertheless, despite their shortcomings, experimental, electromyographic, and clinical studies have demonstrated the effect of deflective occlusal contacts on muscle activity. And there is no doubt that experimental and iatrogenic interferences in susceptible individuals will produce excessive and uncoordinated muscle activity. Similarly, the removal of interferences in many TMD subjects will reduce and coordinate muscle activity. Occlusal therapy has been shown in the literature to have both subjective and objective effects on dysfunction. Most other therapies have been shown to improve pain only.[1]

Recommendations For Occlusion Research

While researchers and practitioners accept that the etiology of TMD is multifactorial, and the etiology and extent of TMD are difficult to diagnose precisely, this author would like to propose the following research guidelines to, hopefully, improve upon the methodologic problems described above.[1, 161]

Sample Selection Requirements

Pain in the head, neck, and TMJ region may involve many etiologic factors and the specific source of pain is often misdiagnosed by both medical and dental clinicians and researchers. For example, the term "headache" can mean many things to both the patient and the clinician, either medical or dental. In addition, medical practitioners rarely consider a structural or functional impairment, and the majority treats these problems with nonspecific pain medications only. This leads to the following recommendations:

1. Differential diagnosis of pain must be an inclusion criterion during sample selection.

2. Simple, universally accepted systems of assessing the location and degree of dysfunction must be developed and applied to TMD research protocol. By definition, TMD is limited to muscular and structural impairment.

3. Samples must be large enough to prove statistical significance and render the conclusions clinically valid.

Methodologic Requirements

The influence of the neuromusculature on condylar position must be eliminated to accurately register the SCP/CR as a reference, and to determine the resultant dental interarch relationships and condylar position in three spatial planes. The identification and full extent of deflective occlusal contacts and condylar displacement may be hidden by guarding effect of the neuromusculature. Thus, subjects (both symptomatic and asymptomatic) must be deprogrammed prior to occlusal and condylar position evaluations. Stabilization splint therapy is the method of choice to resolve symptoms of symptomatic and dysfunctional subjects. Deprogramming is necessary for asymptomatic subjects prior to the registration of the SCP/CR, to eliminate the subject's neuromuscular response to habitual occlusion.

Condylar displacement must be isolated and considered as a specific etiologic factor in the production of TM signs, symptoms, and dysfunction. The occlusal and condylar position evaluations must be accurate and appropriate. Instrumentation is required to assess and compare the three-dimensional dental interarch relationships and condylar displacement between MIC/CO and the SCP/CR. Dental instrumentation (an articulator mounting in the SCP/CR and condylar graph measurements) has proven to be valid, reproducible, accessible, cost-effective, noninvasive, and highly accurate.[33,34,63,64,73–79,81-84,114–117] Inadequate methodology includes intraoral visual estimation, study models hand articulated in MIC/CO, improper registration techniques, radiographic evaluation, MRI, CT scans, and failure to use dental instrumentation.

When using these more sophisticated techniques, researchers need to compare dental interarch and condylar position displacement to joint imaging techniques[26,33] in asymptomatic and symptomatic subjects, and, before and after occlusal treatment. For example, if it is accepted that the etiology of TMD is multifactorial and the individual's adaptive capacity and tolerance level are important factors in the development or absence of symptoms, then it is imperative to assess both dental interarch and condylar displacement in individual subjects before and after treatment.

In addition, long-term instrumentation studies with long-term follow-ups are needed to assess the effectiveness of occlusal treatments. Furthermore, deflective occlusal contacts can produce signs and symptoms other than muscle and structural impairment. These include occlusal wear, pulpitis, tooth abfraction, dental mobility, shifting of teeth, and aggravation of periodontal disease. Properly designed studies must consider these factors as well as excursive mandibular movements and closure position in SCP/CR and MIC/CO since wear facets occur in lateral and protrusive premature contact positions.

Recommendations for Occlusal Treatment of TM Dysfunction[1,107,165,166]

A complete diagnosis and conservative treatment are keys to successfully addressing dysfunction over the long term.

Diagnosis

A clinical history and examination are usually sufficient to indicate that the subject is suffering from TMD. The purposes of making a diagnosis are to differentiate the condition from other conditions and to plan effective treatment. The diagnosis should involve the elimination of other pathology (e.g., caries) which may cause referred pain or aggravate the dysfunction. A clinical assessment of the extent of dysfunction should be noted so that any improvement in the dysfunctional muscles and/or the TMJ can be monitored.[1]

Treatment

At present, treatment is best provided by attending to the traumatic, psychological, or occlusal factors that clinically seem to predispose the subject to TMD, precipitate a problem, or prolong a problem. Patients whose problems began after an adverse life event need counseling, possible medication or drug therapy (e.g. muscle relaxants), or, provision of an occlusal stabilization appliance. A caring attitude is important and proper psychological advice is often indicated. The occlusal component may require further investigation if these measures prove unsuccessful.

Many subjects have no obvious etiologic factors to account for their TMD. Most of these would benefit from a detailed analysis of their occlusion. However, occlusal therapy may not always be effective, and there is a danger that the subject may receive extensive, expensive, and inappropriate treatment. A consensus of dental practitioners advocates reversible therapy for the treatment of TMD,[1,107,165,166] thus eliminating unwanted tooth movement. At present, the sole method with which to diagnose the occlusal factors in dentate subjects is by the patient's response to stabilization splint therapy. Only the full-coverage stabilization splint, adjusted to give even posterior contacts in the retruded axis position (SCP/CR) and anterior guidance in excursive movements, fulfills both of the criteria of reversibility and effectiveness of design.[1,40,52,53]

Those subjects who respond to stabilization splint therapy may require no further treatment. However, if the signs and symptoms of dysfunction return following splint removal, an appropriate occlusal analysis should be performed. Depending upon the needs of the patient, long-term stabilization splint therapy, occlusal adjustment, restoration, orthodontic therapy, or orthognathic surgery may be required to provide a stable occlusion that is within the patient's adaptive capacity or tolerance level. This requirement obviously cannot be assessed until dysfunction has been reduced as far as possible by conservative means.[1]

Faulty Methodology Leads to Erroneous Conclusions

Numerous studies have attempted to infer condylar displacement (1) through intraoral visual estimation of the apparent slide between the SCP/CR and MIC/CO at the occlusal level, (2) through an assessment of study models hand articulated in MIC/CO, or (3) radiographically. These studies have found either weak or no association between occlusal factors and TMD.[100,101,112,118–129,150,167–171] For example, Pullinger et al,[124,125] evaluated 222 dental and hygiene students in a study utilizing a questionnaire, intraoral visual estimation (clinical exam), and study models hand articulated in MIC/CO and found no definite relationship between TMD and occlusal factors, such as the displacement between the retruded contact position (RCP) and the intercuspal position (ICP). However, the RCP was determined by passive mandibular manipulation and by study models hand articulated in MIC/CO. *No instrumentation* was used to evaluate condylar position as dictated by the occlusion, and *no deprogramming* was used. Thus, the possible effect of the neuromusculature was not considered.

In their review of the literature, McNamara et al,[171] found a relatively low association between occlusal factors and signs and symptoms of TMD. They concluded that although treatment to a gnathologic ideal was desirable, failure to so treat would not result in TMD. In the studies that they reviewed the occlusion was evaluated by chin-point manipulation and intraoral visual estimation (clinical exam). No attempt was made to override the effects of the neuromusculature (that is, *no deprogramming* was conducted), and condylar position was determined by radiographic evaluation, *not by dental instrumentation*.

Lindauer et al,[172] "geometrically constructed" the center of mandibular rotation from Dolphin Digital images (instead of lateral cephalograms) of eight subjects and found that none of these subjects had a center of mandibular rotation (terminal hinge axis) located in the condyle. They concluded that "this finding supports the theory of a constantly moving, instantaneous center of jaw rotation during opening," (p. 577) implying that location of the terminal hinge axis is not reliable for use in predictable dental treatment planning or treatment. This is contrary to the conclusion reached by the overwhelming majority of occlusion investigations published in the dental literature.[1,2,11,12,15,23,25,26,30,31,33–36,42-49,51-53,56–93,103,114–117,130–158,163,167,174–197] Upon closer inspection of the data, however, Lindauer found that the *constructed* center of mandibular rotation was different not only in every subject, but *in the same subject every time it was measured*. It would be difficult to reach this conclusion if the researchers had used simple dental instrumentation (articulator-mounted study models and condylar position instrumentation) instead of geometrically constructing the center of rotation.

Braunet et al,[173] estimated condylar position with "enhanced sagittal cephalometry" (instead of corrected tomography) and mandibular manipulation alone (after leaf gauge deprogramming) instead of using simple dental instrumentation. He concluded that "CR is not a habitually assumed position, it is not a functional position, and it is not static or reproducible. An isolated hinge axis does not exist." And finally, "mandibular manipulation and leaf gauge positioning are not effective in seating the condyles—both 'methods' revealed considerable variation of condylar location within the fossae." (p. 370) Again, these conclusions run contrary to the conclusions found in the overwhelming majority of occlusion investigations published in the dental literature.[1,2,11,12,15,23,25,26,30,31,33–36,42-49,51-53,56–93,103,114–117,130–158,163,167,174–197]

Thus it is apparent that there are serious conceptual and methodologic problems with occlusion research that can lead to erroneous or flawed conclusions. The conclusions of these studies, based on faulty methodology, reinforce the need for a standardized methodology for determining condylar position. Considerable variation of condylar position can be produced *depending upon the methodology utilized*, the least accurate being intraoral visual estimation of the apparent slide between the SCP/CR and MIC/CO at the occlusal level, assessment of study models hand articulated in MIC/CO, or radiographic imaging. Deprogramming, accurate registration of the SCP/CR, articulator-mounted study models, and condylar position instrumentation are required to determine condylar position in three dimensions.

Occlusal Factors and Condylar Displacement as Possible Etiologic Factors In TMD

Yet even in investigations using methodology that does not meet the above suggested criteria, occlusal factors have been implicated as possible etiologic factors in TMD.[10,22,26,31,33–35,47,49,103,130–158,168,169] For example, many studies have shown that the overwhelming majority of human subjects exhibit an occlusal interference and premature occlusal contact on a posterior most tooth.[25,33,34,56,63,64,73–79,81–84,114–117,198-200] Study models hand articulated in MIC/CO do not reflect this finding. Yet balancing interferences have been positively correlated with signs and symptoms of TMD,[146–155] while larger "slides" between the SCP/CR and MIC/CO are regarded as possible etiologic factors in TMD, because, these larger slides are more likely to include a significant lateral component.[26,140,156–160,168,169,171]

Egermark-Eriksson et al,[174] in a study of 240 subjects, utilized only intraoral visual estimation to conclude that TM joint sounds were positively correlated with lateral deviation of the mandible between the RCP/CR and ICP/CO in all age groups, and that TM joint sounds were positively correlated with unilateral contact in the RCP/CR, findings that have been duplicated in other studies of both children[135] and adults.[146,150,168,171] They concluded that "these associations between unstable occlusion in the RCP/CR and ICP/CO and TM joint sounds may deserve closer experimental study." (p. 70) Magnusson and Carlsson,[49] in a study of 9 subjects, utilized chin-point guidance only to position the mandible, determine occlusal contacts, and perform occlusal adjustment intraorally. They found that 6 weeks post adjustment 7 of the 9 subjects reported a decrease in TMD signs and symptoms and concluded that "by the use of simple principles and procedures occlusal adjustment is beneficial in treatment of TM dysfunction." (p. 709) However, utilizing this intraoral methodology, they also found a "surprisingly high percentage of subjects with occlusal interferences 1 year post-adjustment." (p. 709)

Surprisingly few studies have utilized the methodologic recommendations described above (deprogramming of the neuromusculature, diagnostic study casts articulator mounted in the SCP/CR and condylar position instrumentation). Even fewer studies have conducted a three-dimensional statistical analysis of condylar position in the SCP/CR as compared to MIC/CO utilizing condylar position instrumentation.

Deprogramming

To date, few studies of dental arch spatial relations and condylar position have incorporated neuromuscular deprogramming prior to registering the SCP/CR. This is an important consideration, for the neuromusculature may change the arc of closure of the mandible in the presence of occlusal interferences, in order to protect the interfering teeth from absorbing the entire force of the closing musculature.[33,45,56,57,62,68,79,84–86]

The usefulness of an adjunct deprogramming procedure depends on three factors. These are ease of fabrication, cost-effectiveness, and minimal patient compliance required to render it effective. Dawson[85] and Slavicek[64] advocate having the patient bite on cotton rolls for deprogramming prior to registering the SCP/CR. The anterior jig advocated by Lucia[89]; the leaf gauge advocated by Long,[90] Williamson,[80] Woeffel,[92] and others[50,70,71,87,88,91]; and the anterior flat plane jig utilized by Calagna,[69] Karl and Foley,[84] and Greco and Vanarsdall[175] are examples of registration techniques incorporating anterior deprogrammers, which separate the posterior teeth, deprogram the neuromusculature, and discludes premature occlusal contacts and tooth interferences that guide the mandible into MIC/CO.

Calagna evaluated four neuromuscular conditioning techniques—the insertion of cotton rolls, and deprogramming with the myomonitor, an anterior jig, or a maxillary anterior biteplate. He found that deprogramming with the maxillary anterior biteplate revealed a condylar displacement that was, on average, twice the displacement found with the other three methods, all of which found comparable displacements.[69] Greco and Vanarsdall found that the function of the masseter and temporalis muscle muscles significantly decreased after the patient wore a maxillary Hawley biteplate or superior repositioning splint 8 hours per day for 2 weeks.[175] Karl and Foley, utilizing deprogramming and condylar position instrumentation, found a larger discrepancy between the SCP/CR and MIC/CO than had been reported previously by using a hard anterior flat plane jig for deprogramming prior to registering the SCP/CR. They also found that while there was an 18% chance of detecting a condylar displacement of more than 2 mm in either the horizontal (AP) or the vertical (SI) direction with the Roth two-piece wax registration technique alone, this percentage more than doubled (to 40%) with the addition of a hard anterior deprogramming appliance prior to registration of the SCP/CR. They concluded that deprogramming provides a registration of condylar position that reveals a greater condylar displacement from MIC/CO than a centric registration taken without prior deprogramming.[84]

Splint Therapy

Splint therapy has proven to be the most effective technique for deprogramming the neuromusculature.[33,45,48,50,62,69–71,79,84–86,175] Studies[10,46,48,50,51,54,57,69–71,79,84,86,93,159] have shown that properly conducted splint therapy and/or neuromuscular deprogramming reveals previously undetected contacts as a result of masticatory muscle relaxation and subsequent mandibular repositioning. The most reliable deprogramming is achieved through full-time wear of a full-coverage upper stabilization splint constructed in the SCP/CR, especially in patients who present with signs and symptoms of TMJ dysfunction.[52,53]

Williamson utilized condylar position instrumentation with true hinge axis recordings and studied the effect of full-time wear of a full-coverage upper stabilization splint on the location of the mandibular hinge axis in both asymptomatic and symptomatic subjects. He found that the axis moves anterior-superiorly with deprogramming, and that the axis locations following two different periods of stabilization splint wear, were highly reproducible. Williamson concluded that "with relaxed musculature (e.g., deprogramming) the hinge axis location is highly reproducible… In the presence of erroneous maxillo-mandibular skeletal relationships, inaccuracy is inherent for occlusal alteration [occlusal adjustment, restorative, orthodontics]." (p. 32) Fifteen of the sixteen symptomatic subjects increased their maximum opening following stabilization splint therapy.[79]

Johnston and Huffman[93] deprogrammed[92] orthodontically treated subjects and 83 controls with full-time wear of a full-coverage upper stabilization splint and found that the mean occlusal slide for both groups, as measured from articulated study models, was slightly higher than that found in previous studies. They attributed this finding to unmasking the discrepancy with splint wear. They concluded by advocating that occlusal treatments (occlusal adjustment, restorative, orthodontics) be designed not necessarily to eliminate centric slides but rather to avoid any increase in the pretreatment slide.[93] This could be interpreted to mean that occlusal treatments should result in no increase in the condylar displacement present pretreatment.

Occlusal splint therapy has been shown to be an effective treatment in the relief of symptoms associated with craniomandibular disorders.[40,176] Kemper and Okeson also proved that it is an effective treatment modality for the relief of headache pain.[177] In their 1983 study, 33 subjects with at least one headache a week were treated for 4 weeks with full-time wear of a full-coverage upper stabilization splint. Of these subjects, 63.6% reported a decrease in the frequency of headaches, and 30.3% reported complete elimination of headaches. No patient reported an increase in the frequency of headaches. For the group, the average number of headaches per week before treatment was 5.06; after occlusal splint therapy the average number of headaches per week was 2.15 ($P < .001$). The authors concluded that occlusal splint therapy can be useful in the diagnosis and treatment of headache pain.

In 1989 Girardot[33] deprogrammed 19 symptomatic subjects with full-time wear of a full-coverage upper stabilization splint until symptoms were relieved and tracked condylar position before and after splint therapy with measurements obtained with condylar position instrumentation (MPI, Great Lakes Orthodontics, Tonawanda, NY). He proved that decreasing the condylar displacement (seating the condyles with stabilization splint therapy) positively correlated with the relief of TMD (*P* < .001).

An investigation by Wahlund and List was a randomized, prospective clinical trial to determine the effectiveness of a flat-plane occlusal stabilization splint, compared to a control splint consisting simply of palatal acrylic. The results showed that stabilization splints are highly effective for the treatment of TMD. First, subjects with the stabilization splint showed a statistically significant improvement in facial pain and headache. Second, subjects with the stabilization splint showed improvement in the intensity of the pain in the joint area compared to subjects with a control splint. Finally, there was a decrease in the need for further TMD treatment with the use of a stabilization splint.[178]

Instrumentation

In 1952 Sears[179] studied horizontal, vertical, and sagittal condylar position changes with the condyle migration recorder. The molars of complete-denture patients were set into a supraocclusal position to create a molar pivot, which resulted in patient accommodation by descending the condyle to reduce anterior open bite. Roentgenograms of the condyles were used to correlate the condylar position findings. This was the first study to document the molar fulcrum theory. Long[180] used the Buhnergraph (a stylus adapted to an arcon articulator) to locate the hinge axis, to verify the terminal hinge axis location, and to verify registrations of the SCP/CR. Hoffman,[73] using a modified Ney articulator to measure the differences in condylar position between CR/SCP and CO/MIC in the horizontal (anteroposterior) vertical (superoinferior), and transverse (mediolateral) dimensions in 52 adult subjects, found that CR does not correlate with CO in the majority of cases.

Williamson, using leaf gauge deprogramming and condylar position instrumentation (Veri-Check, Denar Corporation, Anaheim, California), outlined the rationale for articulating diagnostic study models in the SCP/CR and demonstrated how to measure occlusion-dictated condylar position and condylar displacement in three spatial planes.[80] He[79,80] used the Veri-Check to analyze variability of CR records, and Shafagh[181,182] used the Veri-Check to compare condylar position using different interocclusal records. Rosner[74,117] used the modified Buhnergraph for a three-dimensional assessment of condylar position in the RCP and the ICP for 49 and 75 subjects respectively, and found a remarkable lack of symmetry for right and left condylar displacement between the two positions. Slavicek[64] described the use of the SAM articulator with the MPI (Great Lakes Orthodontics, Ltd., Tonawanda, New York) to quantify differences between the joint-determined position (SCP/CR) and the tooth-determined position of maximum intercuspation (MIC/CO).

In 1989 Girardot[33] deprogrammed nineteen symptomatic subjects with full-time wear of a full-coverage upper stabilization splint until symptoms were relieved, and tracked condylar position before and after splint therapy with measurements obtained with condylar position instrumentation (MPI, Great Lakes Orthodontics). Study casts articulated post-stabilization splint therapy revealed premature occlusal contacts and occlusal interferences on the distal-most molars in all nineteen subjects. The nature of condylar displacement in TMD patients was found to be primarily downward (inferior) and backward (distal) and secondarily downward (inferior) and forward (anterior). The condyles moved superiorly as symptoms were relieved with stabilization splint therapy (*P* < .001). Stabilization splint therapy was shown to be an effective modality to reduce symptoms related to structural and/or functional disharmony in the gnathic system. This finding led Girardot to conclude that TMD may be related to the occlusion, since closure of the mandible to the intercuspal position in the presence of a posterior occlusal interference can displace the condyle away from the optimal anterior-superior position within the glenoid fossa. Girardot also compared condylar position measurements obtained with condylar position instrumentation to those obtained with oriented (corrected) tomograms and concluded that the registration of condylar position with MPI instrumentation was more accurate than tomographic representation of condylar position (*P* < .001), thus questioning the validity of using tomograms as a means of measuring condylar displacement and changes in condylar position.

Alexander[75] studied condylar position in 1993, comparing MPI instrumentation to MRI imaging. He concluded that MIC/CO and SCP/CR are distinctly different condylar positions, with MIC/CO being inferior to SCP/CR. He further concluded that the articulator analysis of MIC/CO and SCP/CR is statistically replicable, thus confirming that the MPI system accurately represents condylar position in three planes. Wood and Elliott found that the two-piece power centric wax registration technique is highly reproducible.[63] In Shildkraut's sample of 131 consecutive patients, 52% (68) had a condylar displacement of > 2 mm in either the horizontal (A-P) or the vertical (S-I) plane, and 25% (33) had a condylar displacement of > 3 mm.[114] Utt measured the discrepancy between the SCP/CR and MIC/CO in 107 patients before orthodontic therapy with MPI instrumentation and found that 18.7% of the patients had S-I or A-P condylar displacements of at least 2 mm on one or both sides. He found that 15.9% of the patients had transverse (mediolateral) shifts at the condylar level of 0.5 mm or greater. No correlation was found between the frequency, magnitude, or direction of condylar displacement and patient age, gender, Angle's classification, or ANB angle. Thus these parameters are not accurate predictors of condylar displacement.[76]

Crawford used the Panadent articulator with the Panadent Condylar Position Indicator (CPI; Panadent, Grand Terrace, CA) to measure condylar position and concluded that a very strong, statistically significant relationship exists between occlusion-dictated condylar position and signs and symptoms of TMD ($P < .001$).[34] In 2001 Girardot proved that there is a statistically significant greater condylar displacement in hyperdivergent facial skeletal types than in hypodivergent facial skeletal types ($P <. 01$), in both the horizontal and vertical planes.[82] In 2002 Hidaka measured the condylar displacement present in pretreatment Japanese orthodontic patients. Of 150 patients, 38.7% (58) had a Horizontal or Vertical displacement of > 2 mm or a transverse displacement of > 0.5 mm. This led him to conclude that orthodontists should be aware of a high incidence of condylar displacement in pretreatment Japanese orthodontic patients that could help them to diagnose the skeletal and dental discrepancies more accurately.

Reproducibility of the Registration Technique

Alexander found that the articulator analysis of MIC/CO and the SCP/CR is statistically replicable,[75] and Shafagh,[181,182] using deprogramming and the Veri-Check to compare condylar position produced by different interocclusal records, determined that the condylar RCP (retruded contact position = SCP = CR) has a variability in any three planes of space of +.2 mm. Rosner found the condylar position measurements to be accurate to 0.15 mm.[74,117,144] The high reproducibility of the SCP/CR registration technique was confirmed by Wood and Elliott.[63] Hicks and Wood demonstrated that the condylar registrations produced by the SAM MPI and Panadent CPI condylar instrumentation systems are reproducible on the same patient.[116]

The accuracy and repeatability of the MPI instrument was proven by Wood and Korne,[115] who found the instrument error of the MPI system to be + 0.2 mm for each component in the horizontal and vertical planes. They also determined that measuring condylar displacements with condylar position instrumentation utilizing either the estimated or the true hinge axis to mount the maxillary cast is highly reproducible. In other words, the recording of condylar displacements with condylar position instrumentation was proven to be highly repeatable, regardless of the hinge axis used. Because of its practicality and reliability, these authors recommended use of the estimated hinge axis for examining the mandibular position of mounted diagnostic casts and for producing MPI condylar position values with which to convert lateral cephalograms taken in MIC/CO to SCP/CR cephalograms. However, for the study of mandibular movements, for diagnostic and definitive equilibration, for extensive restorative reconstruction, and for maxillary surgical movements resulting in autorotation of the mandible, they recommended that only the true hinge axis be used.

The Relationship between Dental Interarch Displacement (Occlusal Slides and Functional Shifts) and Three-Dimensional Condylar Displacement

A source of confusion in occlusion research has been that the nature of the apparent shift at the level of the occlusion (the dental interarch displacement between the SCP/CR and MIC/CO) does not accurately reflect the three-dimensional nature of the displacement at the level of the condyles.[33–35,58,63,73–79,81-85,113–117] Hodge and Mahan showed that only a small part of the AP component of an SCP/CR-to-MIC/CO slide as seen at the incisal level is due to AP translational displacement of the condyles. Most of the AP component of the "slide" seen at the incisal level is due to the mandible swinging posteriorly when it opens and anteriorly when it closes, as it rotates around the horizontal axis in the terminal hinge closing arc.[183]

Rosner states, "The difficulty in aligning occlusal landmarks in a sagittal plane when a slide from the SCP/CR to the MIC/CO position is present does not entirely reflect the amount of translation of the hinge axis between those two points. In the null line significant translation of the hinge axis can occur due to rotation of the mandible without obvious movement in the anterior region of the dentition."[74] (p. 717)

Rosner and Goldberg further state, "From our analysis of the condylar position in three dimensions, it is difficult to determine asymmetric condylar movement when measuring the dental midline displacement between the SCP/CR and MIC/CO. The complex way that movement is transmitted to the condylar centers of rotation in the form of skew, tilt, length of vertical and horizontal rotational distances, and medial-lateral displacement[144] in combination with the degrees of freedom possible make it difficult to determine condylar movements by observation or measurement of the dental midline displacement between the SCP/CR and MIC/CO."[117] (p. 230)

The findings of Rosner's studies[74, 117,144] support the findings of Hoffman,[73] Wood and Korne,[115] Utt,[76] and Hidaka,[78] who also found a remarkable absence of symmetrical condylar displacement between the SCP/CR and MIC/CO.

Measurement of Condylar Displacement

The *direction* of the condylar displacement found in more recent condylar position instrumentation studies (Wood and Elliott,[63] Shildkraut's and Wood,[114] Utt,[76] Girardot,[33,82] Crawford,[35] Karl and Foley,[84] and Hidaka[78]) has been most commonly posterior-inferior, next-most commonly anterior-inferior, and least commonly straight inferior. These findings support the concept of vertical condylar displacement as a result of posterior premature occlusal contacts.[35,57,58,68,85,116,136,165,179,184] No relationship has been found between the transverse (mediolateral) displacement and either the horizontal or vertical displacements.[73,74,76,78,115,117,144]

The *magnitude* of condylar displacement for an asymptomatic population reported in previous research investigations utilizing models articulated in the SCP/CR and condylar position instrumentation to measure condylar displacement in three planes is given in Table 2.[73–78, 82,84,115-117]

INVESTIGATOR (YR)	(mm) AP (HORIZ)	(mm) SI (VERT)	(mm) ML (TRANSV)	n=
Hoffman (1973)	0.28	0.25	0.1	52
Rosner (1986)	0.56	0.84	0.34	75
Wong (unpub)	0.7	1	0.3	250
Wood+Korne (1992)	--	1.2	--	39
Alexander (1993)	0.25	0.3	0.3	28
Utt (1995)	0.61	0.84	0.27	107
Esmay (1995) (MS)	0.63	1.53	0.37	46
Hicks+Wood (1996)	--	1.2	0.27	37
Girardot (2001) brachyfacial	0.66	1.2	--	19
Girardot (2001) dolichofacial	1.21	1.7	--	19
Hidaka (2002)	--	1	0	150
Karl+Foley (1999) **	1.54	1.76	0.51	40
Cordray (2006) asympt**	0.86	1.8	0.26	596
Cordray (2003 unpub) sympt**	1.02	2.2	0.82	596
Weffort (2010) asympt	0.63	1.26	0.23	35
Weffort (2010) sympt	0.64	1.6	0.41	35

Table 2 *Magnitude of Condylar Displacement in Three Planes (mm) as Measured from Asymptomatic Populations.*

--: Magnitude either not measured or averaged using – and + values instead of absolute values
** : Neuromuscular deprogramming utilized prior to registration of SCP/CR
Note:
1. Displacement values for deprogrammed subjects larger than for non-deprogrammed subjects
2. Displacement values for symptomatic subjects larger than for asymptomatic subjects
3. Displacement values for dolichofacial patterns larger than brachyfacial patterns

The larger discrepancies reported by Karl and Foley[84] and Cordray are most likely due to methodology. Both studies used deprogramming with a hard anterior stop prior to registration of the SCP/CR, which results in more complete condylar seating and more accurate measurement of condylar displacement than are found in those studies which have utilized traditional chin-point guidance alone (without deprogramming) in an attempt to clinically capture the SCP/CR.[34,63,73–78,80, 83,114–117] Girardot[82] found larger horizontal and vertical condylar displacements in dolichofacial (open-bite) skeletal patterns than in brachyfacial (deep bite) skeletal patterns. The vertical component of the condylar displacement was almost always greater than the horizontal component, and this supports the concept of vertical condylar displacement as a result of posterior premature occlusal contacts.[35,57,58,68,85,116,136,165,179,184] Larger displacements were observed in all dimensions for symptomatic subjects, especially in the transverse (medial-lateral) plane.

The Relationship between Displacement and Dysfunction

Transverse dental inter-arch displacement & TMD.

When analyzing the potential relationship between displacement and TMD, it is important to determine which type of displacement was actually measured—dental interarch displacement or condylar displacement. For example, occlusal discrepancies (slides, functional shifts, and dental interarch discrepancies between the SCP/CR and MIC/CO, most often measured intraorally) have been implicated as possible etiologic factors in TMD,[26,31,33–35,47,49,103,130–158,167,169,171] but a discrepancy at the level of the occlusion gives no information on the three-dimensional nature of the discrepancy or displacement at the level of the condyles.[33–35,58,63,73–79,81–85,113–117]

Nevertheless, studies that have attempted to measure the dental interarch discrepancy between the SCP/CR and MIC/CO intraorally have inferred that condylar displacement as a result of dental interarch displacement, especially in the transverse plane, may be an etiologic factor in TMD.

Larger slides between the SCP/CR and MIC/CO have been regarded as possible etiologic factors in TMD. Not so with smaller slides that include a significant lateral component.[26,140,156–158,167,169,171] Occlusion texts have noted the potential significance of a transverse (medial-lateral) dental interarch discrepancy or displacement in the production of

TMD,[11,25,56,57,62,66,85,87,185] and this is supported by numerous independent research investigations. Reider's epidemiologic survey led him to conclude that "the considerable prevalence (25% = 81/323) of transverse mandibular [dental interarch] displacement in a diversified sample (n = 323) emphasizes the need for recognition and analysis of the etiologic factors in occlusal mandibular dysfunction."[158] (p. 299) Solberg found a higher prevalence of TMD signs and symptoms in subjects with a transverse occlusal slide (dental interarch displacement) between the SCP/CR and MIC/CO ($P < .01$). Asymmetry in the dental interarch displacement was observed in 15.6% of the 739 subjects examined intraorally. Significantly more dysfunctional subjects had asymmetrical dental interarch displacement ($P < .01$), and subjects with larger occlusal slides tended to have longer, asymmetrical dental interarch displacement ($P <. 01$). Tenderness of the TMJ and capsule was associated only with asymmetrical dental interarch displacement ($P < .01$). These findings suggest that the direction of the dental interarch displacement—that is, its lack of symmetry—is of greater clinical importance than its magnitude in the production of dysfunction.[1,151]

Droukas found that 27% of his sample (n = 48) had a transverse (mediolateral) dental interarch displacement of > 0.5 mm at the occlusal level.[163] Egermark-Eriksson observed that TMJ sounds positively correlated with lateral deviation of the mandible between the SCP/CR and MIC/CO in all age groups (n = 240) ($P < .01$ ages 11–15; $P <. 001$ age 20).[174] From a sample of 4724 children 5 to 17 years old, Thilander et al, proved that mediolateral dental interarch displacement was significantly associated with clicking ($P <. 001$), temporalis muscle tenderness ($P < .01$), and TMJ pain ($P < .01$). Non-working-side interferences (as observed clinically) were significantly associated with clicking ($P < .01$) and masseter and temporalis muscle tenderness ($P < .01$). TMD was significantly associated with posterior crossbite, anterior open bite, Angle's Class III malocclusion, and extreme maxillary overjet, leading them to conclude that "sliding [displacement] of the mandible laterally from SCP/CR to MIC/CO will explain the significant association between TM dysfunction and posterior crossbite, and hence the association with clicking and muscle tenderness."[186] (p. 153) Egermark proved that "lateral forced bite" (transverse or mediolateral mandibular displacement) and unilateral crossbite were positively correlated with TM dysfunction signs and symptoms ($P < .01$) and considered them to be potential risk factors in the development of TMD.[187] Mohlin observed that crossbite was more common in TMD patients than in controls.[188] Lindblom[189] and Mongini[190] have published clinical techniques for the treatment of transverse (mediolateral) dental interarch displacement.

The relationship between condylar displacement and TMD. As stated previously, it is important to determine which type of displacement was actually measured—dental interarch displacement or condylar displacement, when analyzing the potential relationship between displacement and TMD. The relationship between *dental interarch displacement* and TMD has been studied at length and with large population studies. The body of research on the relationship between *condylar displacement* and TMD is much smaller due to the limitations listed previously with regard to the use of dental instrumentation.

The relationship between transverse (mediolateral) condylar displacement and TMD. The nature of the apparent slide at the level of the occlusion does not accurately reflect the three-dimensional nature of the displacement at the level of the condyles.[33–35,58,63,73–79,81–85,113–117] It has been postulated in occlusion circles that a transverse (mediolateral) condylar displacement of > 0.5 mm is the most clinically critical type of displacement and is significant in the production of signs and symptoms of TMD.[11,26,56,57,62,66,76,85,87,117, 140,144,151,157,158,163,188,191] For example, Hansson stated that "mediolateral (transverse) deflection of the condyles from the seated position is most critical to asymptomatic function."[192] Yet the number of investigations comparing transverse condylar displacement in asymptomatic and symptomatic populations and utilizing deprogramming and instrumentation is remarkably small. Nevertheless, studies that have attempted to measure the dental interarch discrepancy between the SCP/CR and MIC/CO intraorally have inferred that condylar bilateral displacement in an inferior and distal direction (p=.012). No statistical difference was noted between genders.[196] Displacements resulting from dental interarch displacement, especially in the transverse plane, may be an etiologic factor in TMD. Weffort and Fantini measured condylar displacement in three dimensions between the SCP/CR and MIC/CO in 35 symptomatic and 35 asymptomatic non-deprogrammed subjects with the Panadent CPI instrumentation and found statistically significant differences between the two groups. The symptomatic subjects had increased displacement in the horizontal, vertical, and transverse planes. The transverse displacement of the asymptomatic subjects was nearly doubled in the symptomatic subjects (p=.015), who also exhibited increased frequency of bilateral condylar displacement in an inferior and distal direction (p=.012). No statistical difference was noted between genders.[193]

It is not possible to detect a transverse (mediolateral) condylar displacement by clinical examination (intraoral visual estimation with mandibular manipulation) or by the manipulation of hand-articulated study casts. Neither is it possible to detect a 0.5 mm transverse (mediolateral) condylar displacement with joint imaging, either radiographically (with posterior-anterior cephalograms or joint imaging in the sagittal plane), or by conducting an MRI or CT scan. Condylar position instrumentation is required to determine transverse (mediolateral) condylar displacements of this magnitude. Studies utilizing condylar position instrumentation have measured the frequency of transverse (mediolateral) condylar displacement, but have not related this measurement to the production of dysfunction. In addition, no relationship has been found between the transverse condylar displacement and either horizontal or vertical displacement.[73,74,76,78,115,117,144]

Condylar displacement studies utilizing radiography. Radiographic studies of condylar position have inferred that condylar displacement may be an etiologic factor in TMD. Weinberg, using transcranial radiography, reported on the role of condylar position in TMD and emphasized the importance of condylar position in the diagnosis and treatment of TMD and pain. He found that the 71% of the condyles measured in TMD subjects were displaced distally and defined condylar concentricity within the fossa as the optimal condylar position.[141] Mongini reviewed the role of radiography in the diagnosis of TMD dysfunction and the significance of condylar displacement in gnathic dysfunction, muscle dysfunction, and muscle pain.[194] Krueger and Dale described a means of transferring information from transcranial radiography to articulator instrumentation and projected condylar displacement as an etiologic factor in TMD.[195] Williams compared symptomatic and nonsymptomatic TM joints using laminagraphs (corrected tomograms) and found significantly more condylar displacement in the symptomatic subjects. He suggested that a submental vertex film be used to more accurately determine depth of cut of the condylar image.[142]

Condylar displacement studies utilizing condylar position instrumentation. The most promising research on the relationship between condylar displacement and TMD comes from studies that have used condylar position instrumentation to determine condylar position in three dimensions. Of the studies utilizing instrumentation, Utt[76] reported that 17% of his nondeprogrammed asymptomatic sample (18/107) had a transverse (mediolateral) condylar displacement of > 0.5 mm, while in Hidaka's nondeprogrammed sample 31.3% (47/150) had a transverse (mediolateral) displacement of > 0.5 mm.[78] In Rosner's studies 12% of the nondeprogrammed sample (9/75) had a transverse (mediolateral) displacement of > 0.6 mm and this positively correlated with TMD symptoms ($P < .01$). Another measure of transverse (mediolateral) displacement (mean index of intercuspal asymmetry) was found to be high (1.29 mm).[117,144]

Rosner[117, 144] measured condylar position in 75 subjects using the Whipmix articulator and the modified Buhnergraph instrument. Condylar position data were collected and put into scattergram form, from which Rosner created a sagittal peripheral outline (SPO) of condylar position measurements. The dimensions of the SPO were determined by nearly tripling the average horizontal (AP) displacement found (0.5 mm) and doubling the average vertical (SI) displacement found (0.8 mm) to 1.4 mm and 1.7 mm respectively. Rosner correlated the condylar position data with a questionnaire and found that the sagittal condylar positions of symptomatic subjects were most often outside the SPO, and that these larger displacements positively correlated with joint noise (P <. 01). Of the 26 subjects who reported joint noise, 20, or 76.9% were outside the SPO.

According to Rosner's data, subjects with mandibular dysfunction had at least two condylar positional characteristics. First, the condylar position was outside the SPO in symptomatic subjects, In addition Rosner found that noise in the TM joints positively correlated with condylar positions outside of the SPO while condylar positions within the SPO were silent (P <.01). Second, subjects with mandibular dysfunction exhibited an increased *mean index of intercuspal asymmetry (1.29 mm [SD 0.57]*). The index of intercuspal asymmetry was statistically significant at the $P < .01$ level between the group of 38 subjects without primary symptoms and the group of 37 subjects with one or more primary symptoms and mandibular dysfunction. The fact that the index of intercuspal asymmetry was statistically significant at the .01 level is in keeping with the assertion that lateral displacement of the mandible is an important finding. The discovery that subjects with one or more primary symptoms had an index of intercuspal asymmetry similar to the mean and SD of subjects *seeking treatment* of mandibular dysfunction was an unexpected finding. The smallest values for mediolateral displacement were seen in subjects without primary symptoms.

Finally, the angular values of the least-squares straight lines were calculated for condylar positions in the y (vertical=SI) axis. When the angular difference of the right and left sides was compared between a group of subjects with primary symptoms and mandibular dysfunction and a group of subjects without primary symptoms, there was a more than 16-fold increase in the angular difference for the group of subjects with primary symptoms and mandibular dysfunction.

Utt[76] set criteria for an abnormal or excessive magnitude of condylar displacement by doubling the mean values he observed. Using these criteria, he noted that 19% of his sample of 107 subjects had a condylar displacement of > 2 mm horizontally or vertically. Similar studies have shown a range from 16% to 52% > 2 mm horizontally or vertically. (Hidaka,[78] 16%; Utt,[76] 19%; Esmay,[77] 33%; Shildkraut,[114] 52%). In Hidaka's sample, 38.7% (58/150) had a horizontal or vertical displacement of > 2 mm or a transverse displacement of > 0.5 mm.[78] In Shildkraut's sample of 131 consecutive patients, 52% (68) had a condylar displacement of > 2 mm in either the horizontal or vertical plane and 25% (33) had a condylar displacement of > 3 mm.[114]

Girardot, using the MPI, found that the condyles were displaced inferiorly in the majority of TMD patients and that symptoms were alleviated as the condyles moved toward a more seated position ($P < .001$).[33] Cacchiotti observed that the MPI-measured discrepancies between the SCP/CR and MIC/CO of subjects with TMD complaints were significantly larger than those of a control group consisting of non-complaining dental students.[197]

Crawford's study[34] represents a landmark breakthrough in occlusion research, utilizing many of the research recommendations presented previously. The rationale for his study was that very few studies have examined occlusion-dictated condylar position using instrumentation and none have compared an "ideal" sample against an untreated control group with regard to TM dysfunction signs and symptoms. In this study a written patient history, clinical exam, and CPI measurements (Panadent articulator) were used to compare TMD symptomatology and CPI values of an experimental sample of 30 subjects with "ideal" occlusions. The sample was selected from a population that had undergone full-mouth reconstruction using gnathologic principles that included the SCP/CR coincident with MIC/CO and a mutually protected occlusal scheme. This ideal sample was compared against a control sample consisting of thirty untreated subjects from the general population selected to match the ideal sample as closely as possible according to sex. A duplicate written exam [anamnestic questionnaire] was given to the subjects in the restored ideal sample to assess TMD symptoms prior to reconstruction. The amount of time post-reconstruction averaged 10.6 years and ranged from 2 to 23 years.

In this study the concept of deprogramming was employed, as the restored ideal sample underwent full-time splint wear until the subjects were asymptomatic and stabilized prior to reconstruction. Instrumentation was utilized to articulate and reconstruct the dental arches in the SCP/CR position and to measure condylar displacement throughout the process. This was a long-term instrumentation study with long-term follow-ups (2 to 23 years) to assess the effectiveness and stability of the occlusal reconstruction. The TMJ evaluation consisted of two parts: an anamnestic evaluation and a clinical exam, both based on the Helkimo index. In addition, the reconstructed group completed an anamnestic questionnaire evaluating TMD symptoms prior to reconstruction.

Crawford documented a high correlation ($P < .001$) between signs and symptoms of TMD and increased condylar displacement. First, he found that in the restored ideal group there was an 84% reduction in symptoms post-treatment; the number of subjects reporting severe symptoms decreased from 16 to 1; the number of subjects reporting no symptoms increased from 8 to 18; and no subject showed an increase in anamnestic score. These findings are especially important in light of the fact that the treated subjects were an average of 10.6 years post-reconstruction, (range of 2 to 23 years). Second, Crawford found that average anamnestic scores were much higher in all groups where condylar displacement was greater than 1 mm, and that this finding was statistically significant ($P < .001$). Third, Crawford documented a very strong statistically significant relationship ($P < .001$) between condylar displacement and TMD signs and symptoms in all of the subjects of the study. As the magnitude of condylar displacement increased, TMD symptoms increased. The magnitude of condylar displacement and symptoms (both clinical and anamnestic) was significantly smaller in the restored ideal group than it was in the untreated control group. Fourth and finally, Crawford found that occlusal attrition was less prevalent in the restored ideal group than it was in the untreated control group. This is especially important in light of the fact that 8 of the 30 restored ideal subjects underwent full-mouth reconstruction specifically to restore tooth material lost as a result of severe wear and attrition (cusps worn to the gingival level).

The clinical implications of Dr. Crawford's study are that:

1. SCP/CR is a desirable treatment goal for reorganization of the occlusion. It is especially desirable in the following cases:
   - When restoring posterior occlusal stability by occlusal adjustment or tooth restoration.
   - When treating mandibular dysfunction.
   - When restoring the dentition with multiunit restorations.
   - When treating patients with complete denture prosthetics.
   - When treating patients orthodontically.
   - When positioning the condyle during orthognathic surgery.
2. When occlusal correction is performed accurately (that is according to the methodologic principles

outlined in this paper), it is clear that the correction of both the occlusion and condylar position is remarkably stable.

3. An individual's tolerance to condylar displacement may be less than previous studies have suggested and is certainly less than has been previously understood in the field of dentistry.
4. Orthodontic cases should be compared to gnathologically restored cases, not to an untreated population.
5. Since an increase of condylar displacement (CPI value) from 1 to 2 mm was shown to aggravate symptoms of TMD dramatically, it may be in the patient's best interest for the clinician to reduce or minimize the pretreatment condylar displacement as much as possible.

Weffort and Fantini measured condylar displacement in three dimensions between the SCP/CR and MIC/CO in 35 symptomatic and 35 asymptomatic non-deprogrammed subjects with the Panadent CPI instrument and found statistically significant differences between the two groups. The symptomatic subjects had increased displacement in the horizontal, vertical, and transverse planes. The transverse displacement of the asymptomatic subjects was nearly doubled in the symptomatic subjects (p=.015), who also exhibited increased frequency of bilateral condylar displacement in an inferior and distal direction (p=.012). No statistical difference was noted between genders.[193]

Conclusions

The role of occlusion in the development of signs and symptoms of TMD continues to be a source of controversy. There has even been a movement within dentistry over the past few decades to minimize the role of occlusion in TMD and to de-emphasize the study of occlusion in dental education. This review of the current literature, however, shows that, despite the fact that the etiology of TMD is multifactorial; discounting the role of occlusion may be an inappropriate interpretation of published data. Based on the studies cited herein, a prudent goal of clinical dental correction would be to minimize condylar displacement whenever possible.

The three-dimensional analysis of dental interarch and condylar displacement from the SCP/CR to MIC/CO utilizing articulated study casts and condylar position instrumentation suggests that correlation between TMD and occlusion has been difficult to recognize due to omission of these principles and techniques in research methods. This correlation has not always been evident due to the failure to address it accurately or extensively in the dental literature. A reform of occlusion/TMD research protocol is needed for progress.

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The Condylar Position Indicator Revisited Through a Case Review: Part 1

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Summary

Retreatment of a patient with counterclockwise growth is presented. This patient was initially treated with four bicuspid extractions in early permanent dentition. She came back 5 years later with TMJ symptoms and crowding of the upper anterior teeth. After splint therapy, the patient was retreated orthodontically. The core of RW philosophy includes consists of diagnosis, CPI, splint, and hinge axis mounting. The accessibility of CT in private practice enabled us to evaluate CPI in relation to actual condylar position changes. This case report raised questions concerning our understanding of CPI.

Click on group images for larger view.

Introduction

In Roth Williams, teaching CO-CR discrepancy in CPI has been one of the key diagnostic parameters. According to the author's observation, discrepancies exist between CPI interpretation of mandibular positional changes and the actual mandibular positions, hence the validity of current CPI interpretation needs to be re-examined.

Figure 1 *Facial photographs. Before the first orthodontic treatment.*

Case Report

A routine orthodontic case is reviewed in lieu of CPI findings.

First Orthodontic Treatment

The patient first presented at 11 years and 5 months of age with the chief complaint of a protruding upper lip and crooked teeth. In addition to the slight upper-lip protrusion, the patient had a slightly retrusive mandible, but overall was otherwise symmetric (Figure 1). In maximum intercuspation (MIP, CO) the left and right molars were in Angle's Class I molar relations. The upper lateral incisors were in crossbite, and there was 12 mm of crowding on the upper and 8 mm of crowding on the lower arch (Figure 2). The second molars were not fully erupted.

Figure 2 *Intraoral photographs. Pretreatment.*

The patient's cephalogram was traced and analyzed (Figure 3). Jarabak's posterior-anterior facial height ratio (62.5%) indicated that the patient's growth direction was most likely neutral (Table 1). The ramal height-posterior cranial base ratio was within normal range, and the body length was longer than the anterior cranial base, even though the patient's chin looked retrusive. The sum of the saddle, sella articular, and gonial angles was larger than normal, implying a possible clockwise growth tendency. The maxilla was protrusive, and the mandible was retrusive and divergent. Though the length of the mandible was greater than the cranial base length, her overall skeletal pattern was neutral to the clockwise growth pattern. Dental analysis showed flared-out maxillary and mandibular incisors.

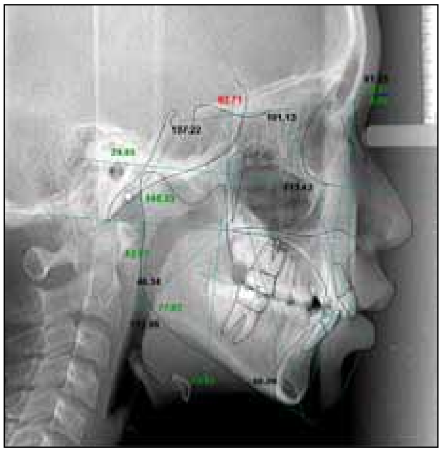


Figure 3 *Cephalogram and tracing. Pretreatment.*

Group	Measurement	Value	Norm	Std Dev
Dental and esthetics				
	U-incisor protrusion (U1-APo)(mm)	7.4	6.0	2.2
	L1 protrusion (L1-APo) (mm)	1.9	2.7	1.7
	Interincisal angle (U1-L1)	120.8	130.0	6.0
	U-incisor inclination (U1-APo)	35.7	28.0	4.0
	L1 to A-Po	23.5	22.0	4.0
	Occ plane to FH	8.3	6.8	5.0
	Commeasure height (Stm-FOP) (mm)	5.1	4.5	2.0
	Lower lip to E-plane (mm)	3.8	-2.0	2.0
Skeletal				
	Convexity (A-NPo) (mm)	7.2	0.7	2.0
	Maxillary depth (FH-NA)	93.5	90.0	3.0
	Facial taper	65.6	68.0	3.5
	Facial axis-Ricketts (NaBa-PtGn)	80.9	90.0	3.5
	FMA (MP-FH)	27.7	23.9	4.5
	Gonial/jaw angle (Ar-Go-Me)	124.0	122.9	6.7
	Palatal/mand angle (PP-MP)	29.1	25.0	6.0
Growth: = meso, < brachy, > dolicho				
	Saddle/sella angle (SN-Ar)	127.2	124.0	5.0
	Articular angle	148.8	140.3	6.0
	Gonial/jaw angle (Ar-Go-Me)	124.0	122.9	6.7
	Sum of angles (Jarabak)	400.0	386.6	6.0
Growth: UGA > horz tendency; LGA > vert tendency				
	Upper gonial angle (Ar-Go-Na)	46.3	52.0	7.0
	Lower gonial angle (Na-Go-Me)	77.6	71.2	6.0
Mandibular body growth rate: = normal, > augmented, < diminished				
	Anterior cranial base (SN) (mm)	62.7	75.3	3.0
	Mandibular body length (Go-GN)(mm)	70.8	75.2	4.4
	Jarabak anterior ratio (x 100)	88.5	93.0	4.0
Ramus growth rate: = normal, > augmented, < diminished				
	Posterior cranial base (S-Ar) (mm)	29.9	35.0	4.0
	Ramus height (Ar-Go) (mm)	42.1	48.5	4.5
	S-Ar/Ar-Go (%)	71.2	75.0	5.0
Growth: = normal, < divergent, > convergent				
	Anterior face height (NaMe) (mm)	111.1	128.5	5.0
	Posterior face height (SGo) (mm)	69.4	82.5	5.0
	P-A face height (S-Go/N-Me) (%)	62.5	65.0	4.0
Lower 1/3 facial vertical problems: yes/no				
	Anterior face height (ANS-ME(mm)	65.4	71.5	5.0
	ANS-Me/Na-Me (%)	58.8	55.0	0.1

Table 1 *Ricketts-Roth-Jarabak analysis. Pretreatment.*

The arbitrary centric relation (CR) mounting[1] prior to treatment revealed that the mandible in CR was repositioned posteriorly and opened anteriorly compared to the mandible in CO (Figure 4). Though the condylar position indicator (CPI) showed a larger CO-CR discrepancy on the right side (Figure 5), the mounted model revealed a larger CO-CR discrepancy on the left side. The implications of a large CO-CR discrepancy were discussed with the patient's guardian, but she chose to seek incomplete treatment in the CO position.

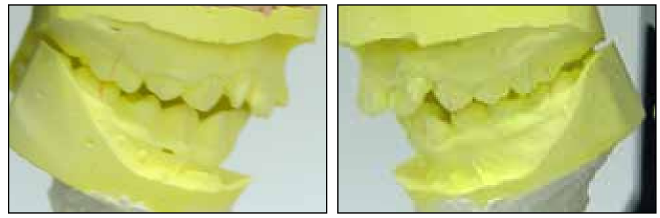


Figure 4 *First-day CR and arbitrary mounting. Pretreatment.*

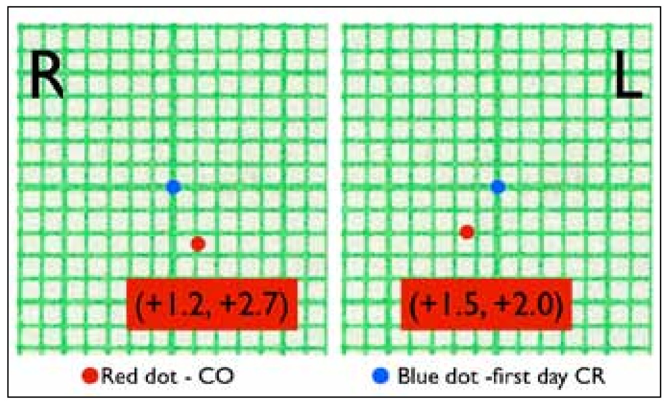


Figure 5 *First-day CR and arbitrary mounting. Pretreatment.*

All four of the patient's second premolars were extracted to relieve the crowding and to control the vertical opening of the mandible during treatment. A transpalatal bar was also used to enhance bite-closing mechanics (Figure 6).

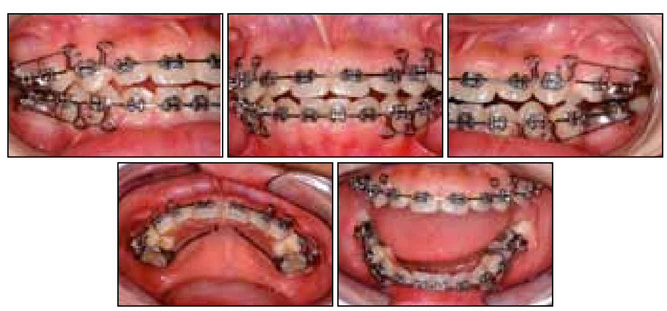


Figure 6 *Intraoral photographs of the first orthodontic treatment at 10 months.*

Near the end of the space closure, though the second molars were not fully erupted, an open bite was gradually appearing at the incisors. When the second molars were banded, the open bite continued to increase (Figure 7).

Figure 7 *Intraoral photographs of the first orthodontic treatment at 14 months.*

In order to correct the open bite that had developed during treatment, miniscrews were used to control torque and intrude the molars (Figure 8).

Figure 8 *Intraoral photographs of the first orthodontic treatment at 25 months.*

Proper overbite and overjet were obtained at the end of 32 months of fixed-appliance therapy (Figure 9).

Figure 9 *Intraoral photographs of the first orthodontic treatment at 32 months.*

After treatment, the patient's face attained balance, the lips were relaxed, adequate gum and incisor exposure was achieved, and the upper-lip protrusion was resolved (Figure 10).

Figure 10 *Facial photographs. After the first orthodontic treatment.*

The panograms taken before and after orthodontic treatment were compared. The posterior crowding of the mandibular second and third molars was resolved after extraction treatment (Figure 11).

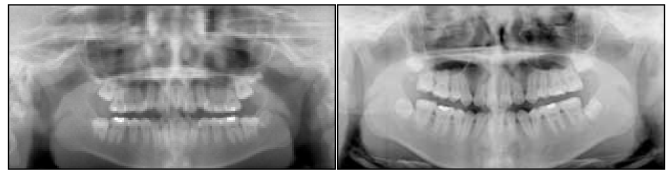


Figure 11 *Panograms. Before and after the first orthodontic treatment.*

It was also noted that the condylar heads in both panograms had a distal angulation rather than a forward curve. This characteristic usually implies a short posterior face or a hyperdivergent mandible. A cephalogram was taken after the end of the first orthodontic treatment (Figure 12) and was compared to the cephalogram taken before treatment (Table 2).

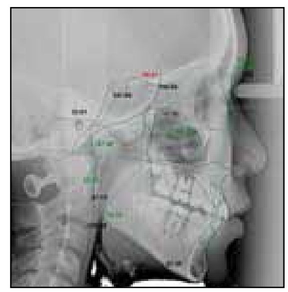


Figure 12 *Cephalogram and tracing. After the first orthodontic treatment.*

Group	Measurement	Value	Value	Norm	Std Dev
Dental and esthetics					
	U-incisor protrusion (U1-APo)(mm)	7.4	6.5	6.0	2.2
	L1 protrusion (L1-APo) (mm)	1.9	3.4	2.7	1.7
	Interincisal angle (U1-L1)		115.9	130.0	6.0
	U-incisor inclination (U1-APo)	35.7	31.8	28.0	4.0
	L1 to A-Po	23.5	32.3	22.0	4.0
	Occ plane to FH	8.3	15.4	6.8	5.0
	Commeasure height (Stm-FOP) (mm)	5.1	4.3	4.5	2.0
	Lower lip to E-plane (mm)	3.8	1.4	-2.0	2.0
Skeletal					
	Convexity (A-NPo) (mm)	7.2	1.8	0.7	2.0
	Maxillary depth (FH-NA)	93.5	88.6	90.0	3.0
	Facial taper	65.6	63.1	68.0	3.5
	Facial axis-Ricketts (NaBa-PtGn)	80.9	82.7	90.0	3.5
	FMA (MP-FH)	27.7	30.0	23.9	4.5
	Gonial/jaw angle (Ar-Go-Me)		126.9	122.9	6.7
	Palatal/mand angle (PP-MP)	29.1	28.2	25.0	6.0
Growth: = meso, < brachy, > dolicho					
	Saddle/sella angle (SN-Ar)		127.1	124.0	5.0
	Articular angle		147.8	140.3	6.0
	Gonial/jaw angle (Ar-Go-Me)		126.9	122.9	6.7
	Sum of angles (Jarabak)		401.8	386.6	6.0
Growth: UGA > horz tendency; LGA > vert tendency					
	Upper gonial angle (Ar-Go-Na)	46.3	47.1	52.0	7.0
	Lower gonial angle (Na-Go-Me)	77.6	79.8	71.2	6.0
Mandibular body growth rate: = normal, > augmented, < diminished					
	Anterior cranial base (SN) (mm)	62.7	65.5	75.3	3.0
	Mandibular body length (Go-GN) (mm)	70.8	76.6	75.2	4.4
	Jarabak anterior ratio (x 100)	88.5	85.5	93.0	4.0
Ramus growth rate: = normal, > augmented, < diminished					
	Posterior cranial base (S-Ar) (mm)	29.9	33.0	35.0	4.0
	Ramus height (Ar-Go) (mm)	42.1	43.3	48.5	4.5
	S-Ar/Ar-Go (%)	71.2	76.2	75.0	5.0
Growth: = normal, < divergent, > convergent					
	Anterior face height (NaMe) (mm)		120.6	128.5	5.0
	Posterior face height (SGo) (mm)	69.4	73.4	82.5	5.0
	P-A face height (S-Go/N-Me) (%)	62.5	60.9	65.0	4.0
Lower 1/3 facial vertical problems: yes/no					
	Anterior face height (ANS-ME(mm)	65.4	67.8	71.5	5.0
	ANS-Me/Na-Me (%)	58.8	56.2	55.0	0.1

Table 2 *Ricketts-Roth-Jarabak analysis. Posttreatment.*

The sum of Angles (Jarabak) did not change after treatment. However, the ramus and body of the mandible showed less growth in comparison to the cranial base length after treatment than they did before treatment. This resulted in a posteroanterior (P-A) face-height ratio that was smaller after treatment than before treatment.

The tracings of the cephalograms before and after the first orthodontic treatment were superimposed on the sella with the best fit on the cranial bases (Figure 13).

Figure 13 *Superimposition of tracings.*
Best fit on the cranial base and superimposed on the sella.
Before and after the first orthodontic treatment.

The forward growth of the maxilla had been restrained with treatment, and the posterior impaction using mini-screws had resulted in a steeper occlusal plane than before treatment. The cranial base flexure showed little change. However, the condylar position was changed inferiorly and backward after treatment. The lips were retracted in alignment with the E line. The facial axis decreased with vigorous bite-closing treatment mechanics (Figure 14).

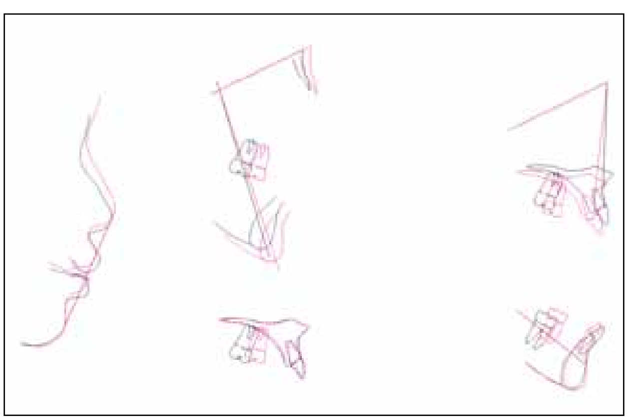


Figure 14 *Five point superimpositions.*
Before and after the first orthodontic treatment.

Second Orthodontic Treatment

When the patient came back for retreatment, it was possible to obtain the true hinge axis after splint therapy. The CPI was re-examined with utilization of computerized tomograms.

Clinical examination. The patient returned at age 19, complaining that her upper lip had become protrusive and that the upper anterior teeth had become crowded (Figure 15).

Figure 15 *Facial photographs.*
Before the second orthodontic treatment.

Her lips had become slightly more protrusive and showed more gum in full smile when compared with photographs of the patient at age 14 (Figure 10). Intraorally the overbite and overjet had become shallower (Figure 16).

Figure 16 *Intraoral photographs.*
Before the second orthodontic treatment.

The right side molar was in a Class I and the left side was in a Class III relationship. In both right and left lateral excursions, there was inadequate canine guidance (Figure 17).

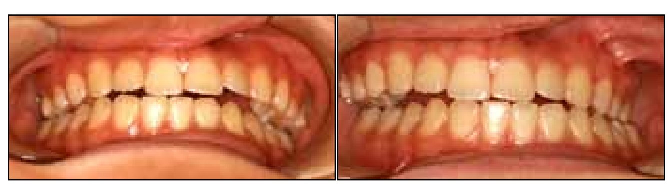


Figure 17 *Right and left lateral movements.*

Further examination revealed that the patient experienced a chronic headache of 8 (on a scale from 0 to 10, 0 being no pain and 10 being unbearable pain); shoulder pain of 3; and ringing in the ears. It was recommended that she start splint therapy to relieve these symptoms and to establish an accurate diagnosis. At that time, it was noted that the upper third molars were erupting and possibly applying mesial force to all of the teeth in the maxillary arch (Figure 18).

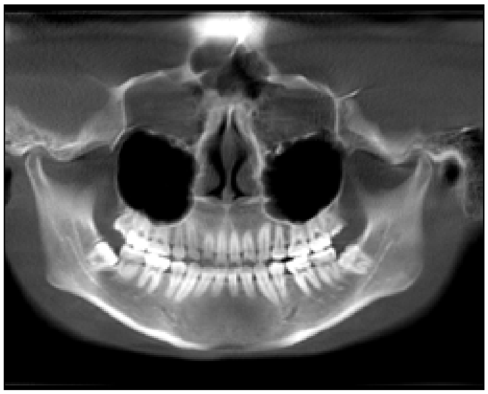


Figure 18 *Panograms. Before the second orthodontic treatment.*

Cephalometric findings. When the cephalograms taken at age 14 (Figure12) and at age 19 were compared (Figure 19), it was noted that the maxillary incisor inclination (SN-U1) had become flared from 104.7 degrees (Table 2) to 106.9 degrees, and the interincisal angle (U1-L1) had decreased from 115.9 degrees to 114 degrees, which explained why the patient felt that the upper lip was protruding (Table 3).

Group	Measurement	Value	Norm	Std Dev
Dental and esthetics				
	U-incisor protrusion (U1-APo)(mm)	114.2	6.0	2.2
	L1 protrusion (L1-APo) (mm)	3.3	2.7	1.7
	Interincisal angle (U1-L1)	114.2	130.0	6.0
	U-incisor inclination (U1-APo)	34.9	28.0	4.0
	L1 to A-Po	30.9	22.0	4.0
	Occ plane to FH	13.9	6.8	5.0
	Commeasure height (Stm-FOP) (mm)	2.4	4.5	2.0
	Lower lip to E-plane (mm)	1.7	-2.0	2.0
Skeletal				
	Convexity (A-NPo) (mm)	3.8	0.7	2.0
	Maxillary depth (FH-NA)	90.4	90.0	3.0
	Facial taper	62.9	68.0	3.5
	Facial axis-Ricketts (NaBa-PtGn)	83.5	90.0	3.5
	FMA (MP-FH)	30.1	23.9	4.5
	Gonial/jaw angle (Ar-Go-Me)	124.6	122.9	6.7
	Palatal/mand angle (PP-MP)	26.4	25.0	6.0
Growth: = meso, < brachy, > dolicho				
	Saddle/sella angle (SN-Ar)	123.7	124.0	5.0
	Articular angle	152.6	140.3	6.0
	Gonial/jaw angle (Ar-Go-Me)	124.6	122.9	6.7
	Sum of angles (Jarabak)	400.9	386.6	6.0
Growth: UGA > horz tendency; LGA > vert tendency				
	Upper gonial angle (Ar-Go-Na)	44.5	52.0	7.0
	Lower gonial angle (Na-Go-Me)	80.1	71.2	6.0
Mandibular body growth rate: = normal, > augmented, < diminished				
	Anterior cranial base (SN) (mm)	69.1	75.3	3.0
	Mandibular body length (Go-GN) (mm)	80.5	75.2	4.4
	Jarabak anterior ratio (x 100)	85.8	93.0	4.0
Ramus growth rate: = normal, > augmented, < diminished	Posterior cranial base (S-Ar) (mm)	32.0	35.0	4.0
	Ramus height (Ar-Go) (mm)	49.0	48.5	4.5
	S-Ar/Ar-Go (%)	65.3	75.0	5.0
Growth: = normal, < divergent, > convergent				
	Anterior face height (NaMe) (mm)	126.1	128.5	5.0
	Posterior face height (SGo) (mm)	78.7	82.5	5.0
	P-A face height (S-Go/N-Me) (%)	62.4	65.0	4.0
Lower 1/3 facial vertical problems: yes/no	Anterior face height (ANS-ME(mm)	70.9	71.5	5.0
	ANS-Me/Na-Me (%)	56.2	55.0	0.1

Table 3 *Ricketts-Roth-Jarabak analysis. Before the second orthodontic treatment.*

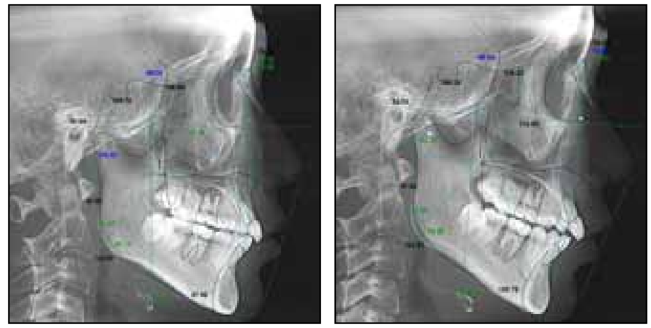


Figure 19-a *Cephalogram and tracing. Before splint.*
19-b *Cephalogram and tracing. After splint.*

Overall there were only minor changes in the skeletal relations and the dentition, and the mandibular plane angle had decreased by only 1.5 degrees between age 14 and age 19. CO-CR conversion of cephalometric tracing (Figure 20) was done by redrawing the mandible of the initial tracing according to the CPI reading of CO-CR discrepancy, that is, CO coordinates in relation to the CR.

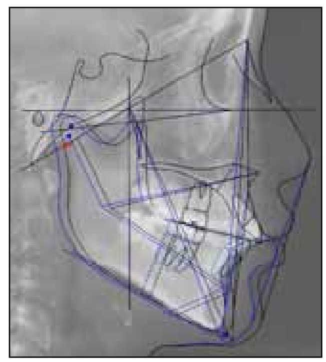


Figure 20 *CO-CR conversion tracing and CPI. Before the second orthodontic treatment.*

This discrepancy is measured with models mounted at the first-day CR. (Figure 21). The converted CR tracing put the mandible in full Class II molar relationship with 7 mm of overjet, and this magnitude of A-P discrepancy requires about 14 mm of space in the upper arch. Based on this finding, it was decided to extract the upper second molar while limiting mesial drift of the upper third molar. This way the space for retraction of the anterior teeth could be provided, keeping the molars in Class I key.

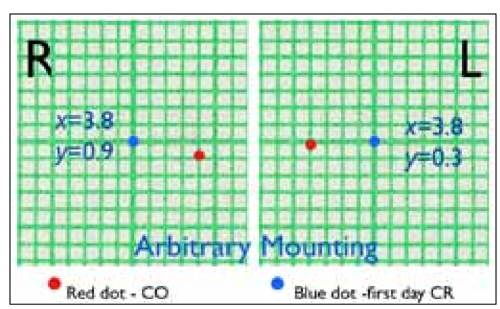


Figure 21 *First-day CR and CPI. Arbitrary mounting.*

Splint therapy and true hinge axis recording. After 12 weeks of splint therapy, all of the patient's previous symptoms—back pain, headache, and ringing in the ears—had disappeared (Figure 22).

Figure 22 *Facial photographs. After splint therapy.*

The patient's stable condylar position was verified clinically, and by plotting subsequently taken CR bites each month on the same graph of the arbitrary mounting (Figure 23).

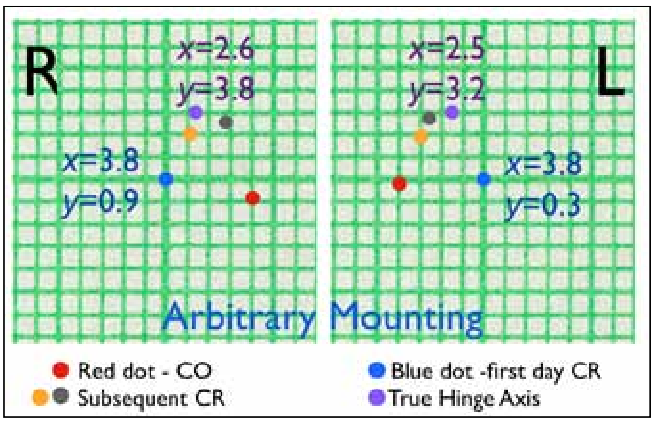


Figure 23 *Subsequent CR markings on CPI. Arbitrary mounting.*

As the condylar position became stable, the CR position moved upward and forward on the CPI flag. When the condyle reached a stable position, the final CR point (the true hinge axis) moved further away from the CO. The arbitrary-mounting CPI graph[2] (Figure 21) indicated that the condyle had moved back 3.8 mm. In the subsequent plotting on the same CPI graph, the stable condyle seemed to move further superiorly by 3 mm and forward by 1.4 mm (average of the right and left side) from the first-day CR (Figure 23). The absolute distances between the COand the true hinge axis, and between the CO and the first-day CR, did not differ greatly. The discrepancy between the CO and the first-day CR was mostly horizontal, while the discrepancy between the CO and the true hinge was both horizontal and vertical in the arbitrary mounting.

True hinge axis recording. An axiograph recording was done to locate the true hinge axis, and the models were mounted accordingly. To demonstrate the topographic difference in markings between the arbitrary mounting of Figure 23 and the hinge axis mounting, the initial CO bite and the first-day CR bite were also used to mark condylar changes on the hinge-mounted flags (Figure 24).

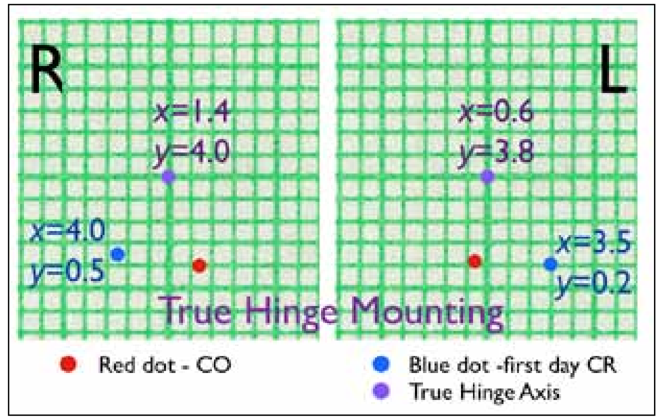


Figure 24 *CPI. Hinge axis mounting.*

The distance between the CO and the true hinge axis in arbitrary mounting was 2.6 mm on the x axis and 3.5 mm on the y axis as shown in Figure 23, while it was 1.0 mm on the x axis and 3.95 mm on the y axis in the hinge axis mounting. The CO and the true hinge axis in Figure 24 were mostly vertical.

Mounted study models. The patient's models of the arbitrary mounting and models of the hinge axis mounting were compared. The CPI graph of the arbitrary mounting in Figure 21 indicated that in arbitrary CR, both condyles were positioned posteriorly 3.8 mm from the MIP, while the magnitude of CO-CR positional change observed on the mounted models was only 1.8 mm at the first molar (Figure 25).

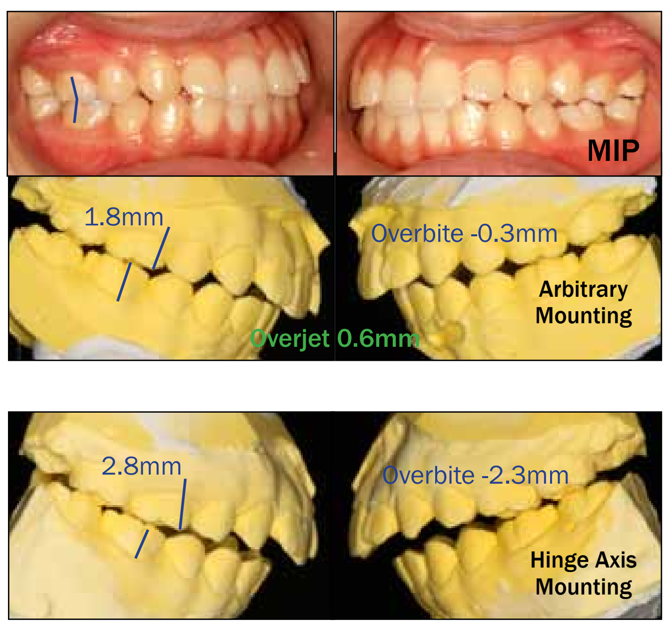


Figure 25 *Comparison of the incisor and molar relationship changes in MIP, arbitrary mounting, and hinge axis mounting.*

One would expect the CO-CR discrepancy at the condyles to be less than the discrepancy present within the dentition due to wedge effect, but changes at the teeth were far less. Another intriguing phenomenon was the CPI change of the true hinge on the hinge mounting in Figure 24. It showed 1 mm of horizontal and 4 mm of vertical repositioning of the condyles from CO, while the model measurement showed 1.8 mm of overjet increase and 2.3 mm of overbite change at the incisor. In other words, the horizontal and vertical changes at the teeth level from MIP to arbitrary mounting, and from MIP to hinge axis mounting, bore no directional or quantitative relationship to CPI changes at the condylar level.

Testing for restorability. The hinge-mounted study casts in Figure 25 were tested for restorability. When the anterior open bite was closed about 2 mm, it was noted that the first premolar on the left side was in a buccal crossbite, and the case was deemed nonrestorable (Figure 26). The buccal cusp tips of the upper third molars were erupting and causing posterior crowding.

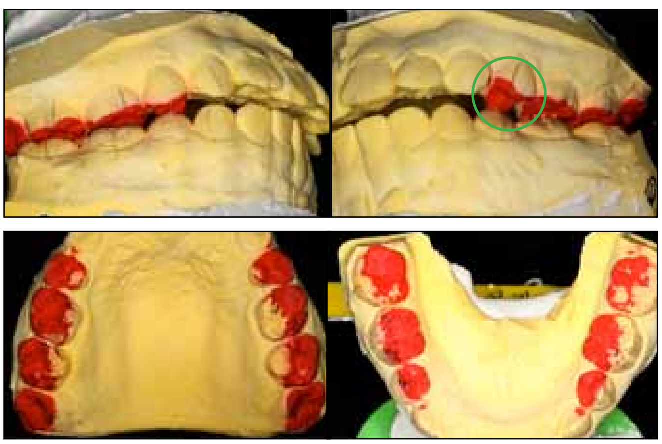


Figure 26 *Coronaplasty of the hinge-mounted models. The upper second premolar is in buccal crossbite to the lower second premolar (green circle).*

Treatment progress. For the second orthodontic treatment, only the maxillary arch was banded. The crown of the maxillary third molar was adequate in size, and the roots looked fair on the computed tomography (CT). Both of the maxillary second molars were extracted to close the open bite and provide space for retraction of the whole upper arch (Figure 27). Miniscrews were used to keep the third molars from erupting swiftly into the second-molar space, and also to provide skeletal anchorage for retraction of the whole arch (Figure 28). By attaching long crimpable hooks to the stainless steel arch wire, retraction force was applied to the center of rotation of the maxilla, and a Class I canine relationship was achieved for overcorrection after 18 months of treatment (Figure 29).

Figure 27 *Intraoral photographs. Third month of the second orthodontic treatment.*

Figure 28 *Intraoral photographs. Fifth month of the second orthodontic treatment.*

Figure 29 *Final Intraoral photographs. Eighteenth month of the second orthodontic treatment.*

Postorthodontic evaluation. The cephalogram taken after 18 months of treatment was traced (Figure 30) and measured (Table 4).

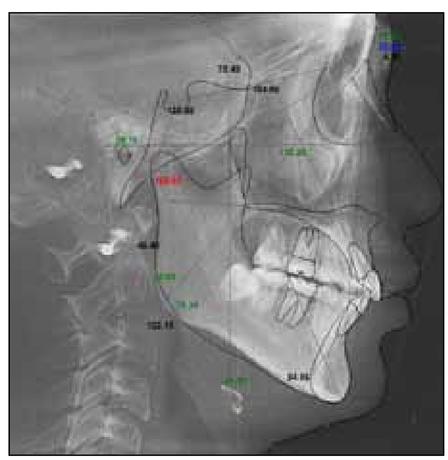


Figure 30 *Final cephalogram and tracing. Eighteenth month of the second orthodontic treatment.*

Group	Measurement	Value	Value	Norm	Std Dev
Dental and esthetics					
	U-incisor protrusion (U1-APo)(mm)	7.7	6.8	6.0	2.2
	L1 protrusion (L1-APo) (mm)	3.3	2.5	2.7	1.7
	Interincisal angle (U1-L1)		119.5	130.0	6.0
	U-incisor inclination (U1-APo)	34.9	34.0	28.0	4.0
	L1 to A-Po	30.9	26.5	22.0	4.0
	Occ plane to FH	13.9	14.2	6.8	5.0
	Commeasure height (Stm-FOP) (mm)	2.4	5.4	4.5	2.0
	Lower lip to E-plane (mm)	1.7	0.3	-2.0	2.0
Skeletal					
	Convexity (A-NPo) (mm)	3.8	4.0	0.7	2.0
	Maxillary depth (FH-NA)	90.4	90.0	90.0	3.0
	Facial taper	62.9	63.9	68.0	3.5
	Facial axis-Ricketts (NaBa-PtGn)	83.5	82.4	90.0	3.5
	FMA (MP-FH)	30.1	29.4	23.9	4.5
	Gonial/jaw angle (Ar-Go-Me)		122.2	122.9	6.7
	Palatal/mand angle (PP-MP)	26.4	25.0	25.0	6.0
Growth: = meso, < brachy, > dolicho					
	Saddle/sella angle (SN-Ar)		121.0	124.0	5.0
	Articular angle		158.8	140.3	6.0
	Gonial/jaw angle (Ar-Go-Me)		122.2	122.9	6.7
	Sum of angles (Jarabak)		402.0	386.6	6.0
Growth: UGA > horz tendency; LGA > vert tendency					
	Upper gonial angle (Ar-Go-Na)	44.5	42.9	52.0	7.0
	Lower gonial angle (Na-Go-Me)	80.1	79.2	71.2	6.0
Mandibular body growth rate: = normal, > augmented, < diminished					
	Anterior cranial base (SN) (mm)	69.1	73.5	75.3	3.0
	Mandibular body length (Go-GN)(mm)	80.5	81.4	75.2	4.4
	Jarabak anterior ratio (x 100)	85.8	90.3	93.0	4.0
Ramus growth rate: = normal, > augmented, < diminished					
	Posterior cranial base (S-Ar) (mm)	32.0	29.1	35.0	4.0
	Ramus height (Ar-Go) (mm)	49.0	49.5	48.5	4.5
	S-Ar/Ar-Go (%)	65.3	58.9	75.0	5.0
Growth: = normal, < divergent, > convergent					
	Anterior face height (NaMe) (mm)		128.1	128.5	5.0
	Posterior face height (SGo) (mm)	78.7	77.4	82.5	5.0
	P-A face height (S-Go/N-Me) (%)	62.4	60.4	65.0	4.0
Lower 1/3 facial vertical problems: yes/no					
	Anterior face height (ANS-ME(mm)	70.9	71.7	71.5	5.0
	ANS-Me/Na-Me (%)	56.2	56.0	55.0	0.1

Table 4 *Ricketts-Roth-Jarabak analysis.*
18 months of the second orthodontic treatment.

Superimposition of tracings before and after the second orthodontic treatment showed minor changes, except that the maxillary incisor angle (SN-U1) was reduced by 3 degrees (Figure 31). As a result of whole-arch retraction from the miniscrews, all of the maxillary teeth were retracted and slightly intruded into the second-molar extraction space, and even the subnasal point was retracted (Figure 32).

The mandibular plane angle stayed closed during treatment. The lower incisors uprighted spontaneously in accordance with the retracted upper incisors. Patient's facial photographs showed that the overall face and the lips looked more relaxed than before the second orthodontic treatment (Figure 33).

Figure 33 *Final facial photographs.*
Eighteenth month of the second orthodontic treatment.

Discussion

There are several discrepancies in this case between CPI interpretation and actual mandibular positions.

The actual positional change of the mandible after splint therapy was illustrated by superimposing (Figure 34-a) the initial cephalometric tracing of Figure 19-a and the after-splint cephalometric tracing of Figure 19-b. The mandibular plane was open clockwise only slightly, and it was unclear whether the condyle was repositioned to any significant degree. Rather, the upper incisors were flared out within the upper splint—a phenomenon that is frequently observed in after-splint cases.

[see next page for Figures-34]

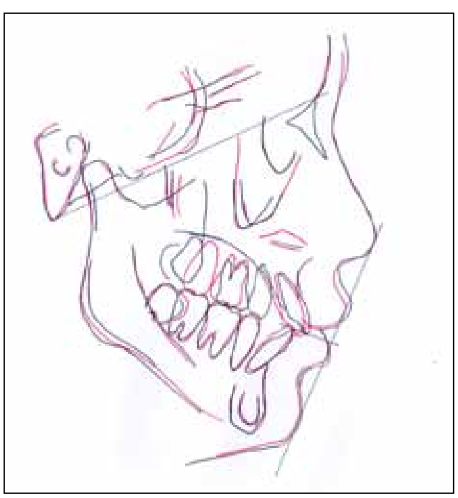


Figure 31 *Superimposition of tracings.*
Best fit on the cranial base and superimposed on the sella.
Before and after the second orthodontic treatment.

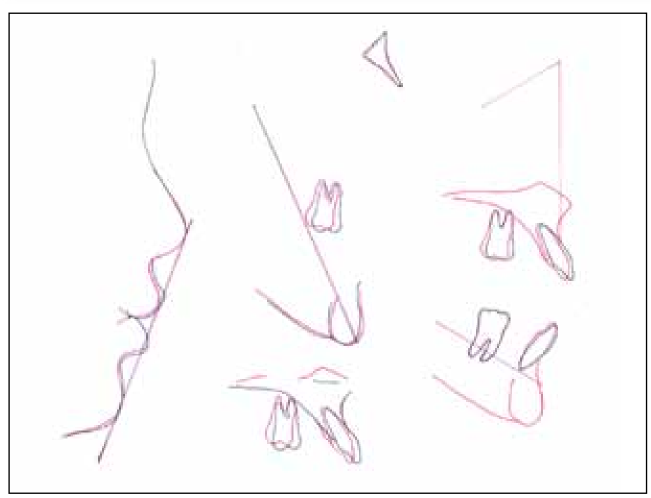
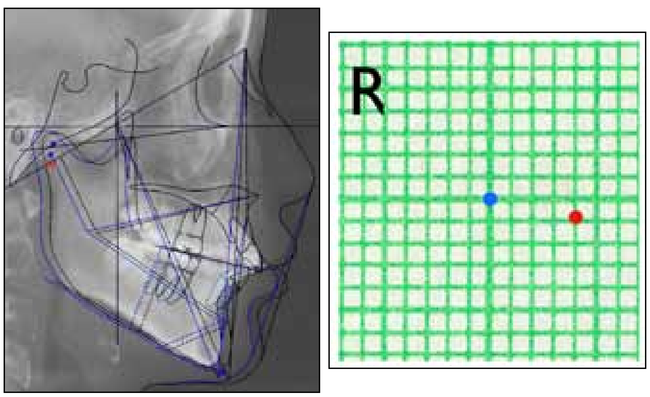


Figure 32 *Five point superimpositions.*
Before and after the second orthodontic treatment.

Figure 34-a *Superimposition of the before-splint and after-splint cephalogram tracings.*

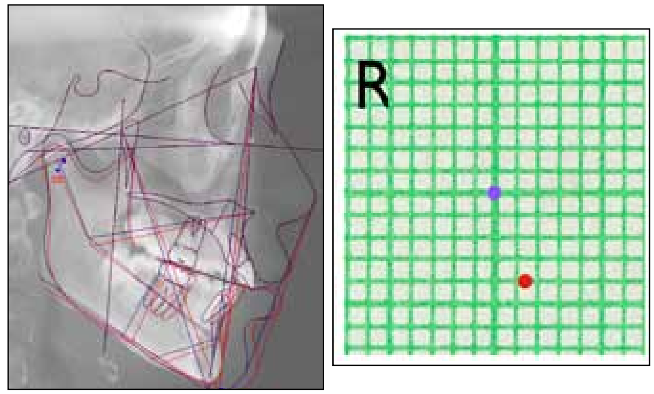
The CO-CR conversion tracing of Figure 20 has traditionally been one of the diagnostic tools for constructing visualized treatment objectives, and this conversion tracing was constructed based on the CPI chart of CO and the arbitrary CR discrepancy (Figure 34-b).



34-b *CO-CR conversion tracing based on the CPI of the arbitrary mounting.*

The purpose of conversion tracing is to predict the positional change of the mandible once it is stabilized on a splint. But the CO-CR conversion tracing was grossly different from the actual change shown in Figure 34-a.

Since the first-day CPI was measured from the arbitrary mounting and might not represent the true hinge, conversion was done again with the CO-axis corresponding to the true hinge axis CPI (Figure 34-c). Unlike the CO-CR conversion that repositioned the mandible backward in Figure 34-b, the CO-axis conversion repositioned the mandible mostly upward. When the mandibular plane was closed down to the original overbite, the A-P discrepancy between the before-splint tracing and the conversion tracing was still grossly different from the actual change as shown in Figure 34-a.



34-c *CO-axis conversion tracing based on the CPI of the hinge mounting.*

The vertical CO-axis discrepancy was 4 mm (Figure 24). The condylar position was observed from a cone-beam CT before and after splint therapy, and after orthodontic treatment (Figure 35-a, 35-b).

Figure 35-a *Sagittal views of TMJ CT of before splint, after splint, and after orthodontics. The head was oriented in the same tilt for the different time point.*

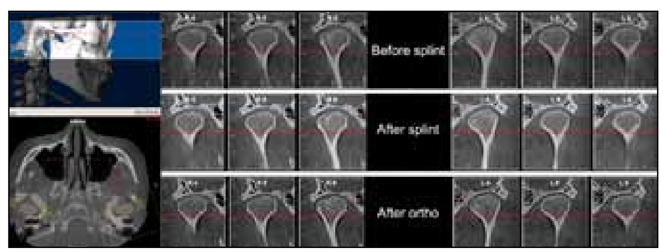


Figure 35-b *Coronal views of TMJ CT of before splint, after splint, and after orthodontics. The head was oriented in the same tilt for the different time points.*

The head was oriented to be in the same position three-dimensionally in all three observational time points. The midmost slices of the sagittal and coronal views of the condylar heads were lined up at the highest point of the glenoid fossae, and a yellow line was drawn from before- splint through after- splint to after- orthodontics (Figure 36—*see next page*). Another line was drawn 5 mm below the first line for a quick visual appraisal of the condylar position and the space around the condyle. The condyles before- splint and after- splint showed less than 1 mm of positional change.

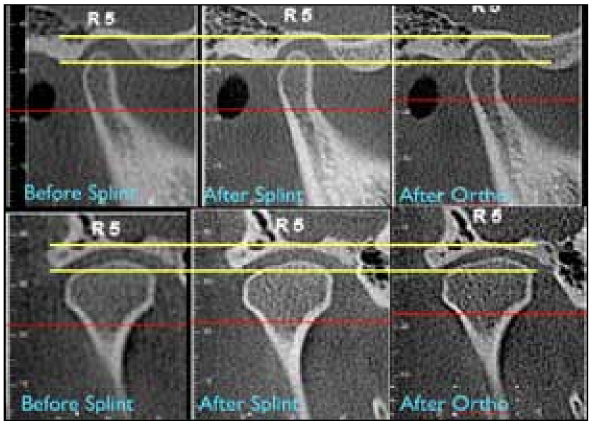


Figure 36-a *Enlarged sagittal and coronal views of right-side TMJ CT of before splint, after splint, and after orthodontics. The distance between the two yellow lines is 5 mm.*

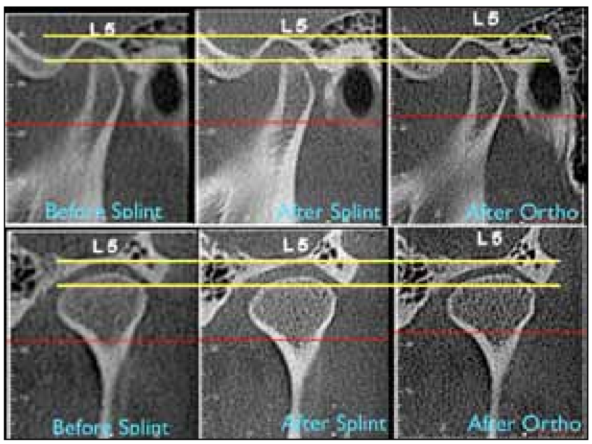


Figure 36-b *Enlarged sagittal and coronal views of left-side TMJ CT of before splint, after splint, and after orthodontics. The distance between the two yellow lines is 5 mm.*

How has the CPI or measure condylar displacement, MCD been interpreted until present? The condylar positional changes were tracked on with a number of CR wax bites taken during the course of splint therapy and CPI flags were marked with CR dots before, during, and after splint therapy time point CR wax bites. Figure 37-a illustrates current understanding of condular position indicator, CPI as the condyle "seating up and forward" in the glenoid fossa.

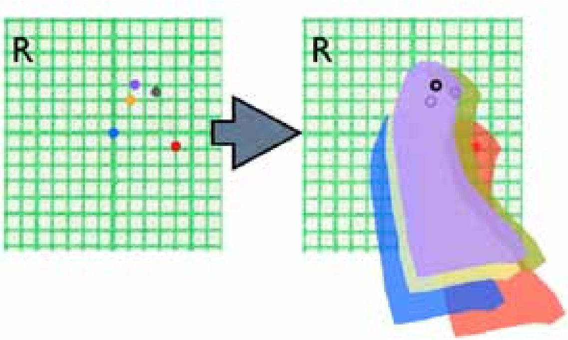


Figure 37-a *Graphic representation of CR changes to Figure 23 in the form of condylar positional changes during splint therapy.*

When the CPI flag of changed condylar positions is superimposed on temporomandibular joint computer tomogram, TMJ CT images of the same size scale, however, it becomes obvious that the condyles cannot possibly reposition as much as CO-CR discrepancy (Figure 37-b). In most cases, the supracondylar space is occupied by a TMJ disc[3], preventing the condyle from "seating up and forward". Furthermore, in this patient's case the supracondylar space was increased after splint therapy, implying that the stabilized condylar moved "downward and forward".

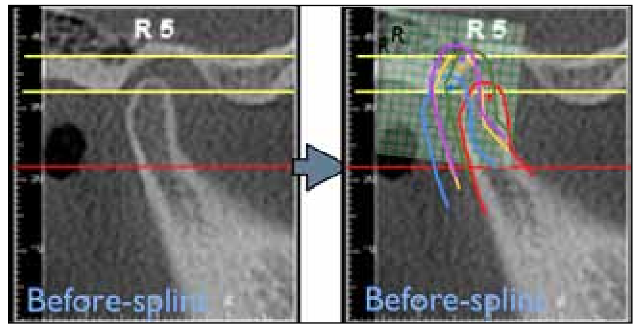


Figure 37-b *Graphic representation of condylar positional changes was overlapped on the before-splint TMJ CT. The graph paper was adjusted by 6 degrees to account for the difference between the true vertical line of the CT and the axis-orbital plane of the Axi-Path.*

Tracking the repositioning path of condyles on TMJ CT images made it possible for us to see the actual condylar positional change in metric scale. After a number of repeated observations of condyle "seating" the opposite direction from our current concept, as in this case report, the authors are planning to collect stabilized cases on splint and further analyze CPI. ■

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Evaluation of Condylar Displacement in Children With Unilateral Posterior Crossbite, Before and After Rapid Maxillary Expansion

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Summary

This study evaluated the condylar displacements between maximum habitual intercuspation (MHI) and seated condylar position (SCP) in children with unilateral posterior crossbites. It compared these displacements in the crossed and uncrossed sides, at two time points: before treatment started (T1) and at appliance removal (T2). These time points occurred 4 months apart. Eighteen patients with unilateral posterior crossbite treated with rapid maxillary expansion, using an expander with occlusal acrylic coverage, were evaluated. The Panadent Condylar Position Indicator (CPI) was used to evaluate the displacement between MHI and SCP. The mean condylar displacement was significantly higher (P = .04) at T1 than at T2. A reduction in the vertical and horizontal measurements of the CPI on both sides was observed. The mean reduced values obtained were 1.08 mm in the vertical direction and 0.48 mm in the horizontal direction for both crossed and uncrossed sides. The transverse dimension remained unchanged; only measures of the vertical and horizontal showed a statistically significant mean difference between T1 and T2, regardless of the side.

Introduction

It has been reported that the best time to correct posterior crossbite, a malocclusion often seen in early mixed dentition, is when it is first recognized, in order to reestablish the normal stomatognathic functions, such as chewing, swallowing, and respiration, and to obtain a favorable occlusion with good periodontium. This type of malocclusion is characterized by the linguoversion position of the buccal cusps of the upper teeth relative to the lower teeth. These malocclusions are classified as skeletal, dental, and/or anatomical or functional and can be unilateral or bilateral.[1–5]

The study of models mounted on an articulator in the seated condylar position (SCP), and analysis of the relationship between the internal structures of the temporomandibular joint (TMJ), make possible a more accurate orthodontic diagnosis and planning of treatment, even in younger patients, and especially in patients with either unilateral or bilateral crossbite.[6–9]

The Panadent Condylar Position Indicator (CPI) has been used to evaluate the displacement between seated condylar position (SCP) and maximum habitual intercuspation (MHI) in the three planes of space. It is a reproducible method used by other operators and does not show statistically significant differences intra- or interoperator.[10–12]

Different types of appliances have been used for the treatment of this malocclusion, and the appliance with acrylic occlusal coverage chosen for this study is one that is often recommended. It reduces the undesired effects of dental extrusion and inclination of the crowns in a vestibular direction. This promotes vertical control of the occlusion, and makes possible multiple bilateral and simultaneous contacts, and promotes some degree of neuromuscular deprogramming, especially when the appliance is being adjusted while fixed in position.[13–18]

Materials and Methods

Members of the sample were selected, following an initial clinical exam, from among patients screened for orthodontic treatment at the Department of Orthodontics and Pediatric Dentistry, University of São Paulo School of Dentistry. All parents of members of the sample agreed to participate in this study. This research had the approval of the Research Ethics Committee of the University of São Paulo (number 200/06), verifying that the project complies with the rules of the ethics committee and the University.

The sample consisted of 18 children, of whom 11 were female, with an average age of 7 years and 2 months, and 7 were male, with an average age of 8 years and 4 months. All members of the sample were in the mixed-dentition phase. All members of the sample had been accepted for the treatment of unilateral posterior crossbite through rapid maxillary expansion.

The criteria for inclusion in this study were the presence of unilateral posterior crossbite of skeletal origin, with Angle's Class I or Class II malocclusions. Exclusion criteria were the presence of caries, gingival changes, and signs and/or symptoms of TMD requiring immediate treatment. These signs and symptoms included muscle pain, occurring spontaneously or during mandibular movement; a history of trauma in the TMJ region; limitation of the buccal opening < 40 mm; and lock or subluxation the TMJ.

To insure more reliable results in this study, all measurements taken were obtained by two trained operators. The results of each were compared to confirm the reliability and reproducibility of the methods used.

The appliance used to correct the posterior crossbite was the modified Haas acrylic bondable Palate Splitting Device first described by Cohen and Silverman in the literature in 1974. This rapid maxillary expander (RME), with acrylic occlusal coverage and embedded with a hyrax screw, was bonded to the upper posterior teeth using Orthoglass LC resinous cement.

During the activation phase, on average 15 days, there was a separation of the mid-palatal suture and the acrylic occlusal surfaces of the appliance were equilibrated every week. During the stabilization phase, approximately 4 months, the occlusal surfaces were adjusted every 4 weeks. This was done to guarantee occlusal balance during the entire time the expander was in position.

The evaluations observed in this study were made at two different time points: at the start of treatment (T1) and immediately before removal of the appliance (T2). These time points were separated by a period of 4 months. This was done in order to obtain the minimum bone reparation necessary to stabilize the mid-palatal suture and to hold the results obtained. Retention appliances for daily, continuous use were placed immediately after the expander was removed, and these retainers remained in place until phase II of the proposed treatment (full braces) commenced. This study was conducted in the first of the 2 proposed phases.

Two plaster models of the dental arches of each participant and the SCP and MHI records necessary for the proposed evaluations were obtained at each time period. These models were prepared using Lauritzen's split-cast technique, and were assembled on the semiadjustable Panadent PSH™ articulator, with the aid of the respective patient's facial arch and SCP record, following the manufacturer's instructions.[19]

Two upper models were obtained at the beginning of the study. One was used for building the RME. This construction consisted of a 0.9-mm rigid metal wire structure contouring all the erupted posterior teeth, including the deciduous canines. The hyrax screw was fixed to this structure with silver solder, making sure that the screw remained in the median palatine suture region, and as close as possible to the surface of the palate. The occlusal surfaces of the teeth and the rigid wire structure were then covered with Classico™ quick setting transparent acrylic. See Figure 1.

Figure 1 *The rigid wire structure covered with ClassicoTM quick setting transparent acrylic.*

The appliance was bonded to the teeth with Orthoglass LC acrylic resin cement, being careful to remove the excess in order to avoid future gingival inflammation during treatment (Figure 2).

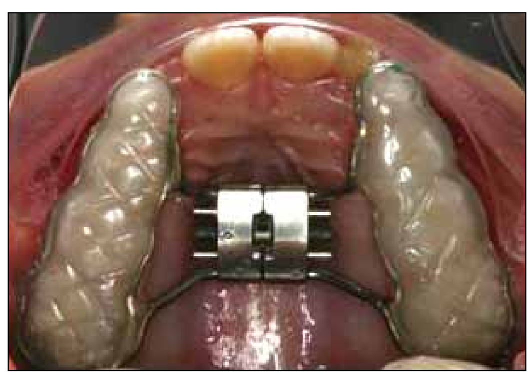
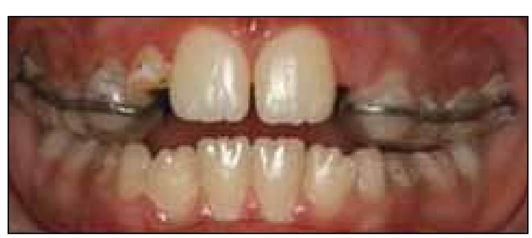


Figure 2 a-b *Rapid maxillary expander.*



The initial activation of the expander consisted of two quarter turns. Subsequent turns were performed twice daily, with one quarter turn in the morning and another quarter turn in the afternoon, totaling one half turn per day. These activations were performed until there was an overcorrection of the transverse dimension of the maxilla by approximately 2 to 3 mm in relation to the initial width. As soon as the overcorrection was obtained, the hyrax screw was locked with quick-setting acrylic resin in order to fix the results.

The displacements between SCP and MHI were recorded for each of the two time periods using the Panadent CPI with the corresponding SCP and MHI records. This instrument was developed specifically to record the position of the condylar axis in the three spatial planes. The displacements between SCP and MHI in the horizontal and vertical planes were measured using the graph paper stickers in the right and left side blocks of the CPI (Figure 3).

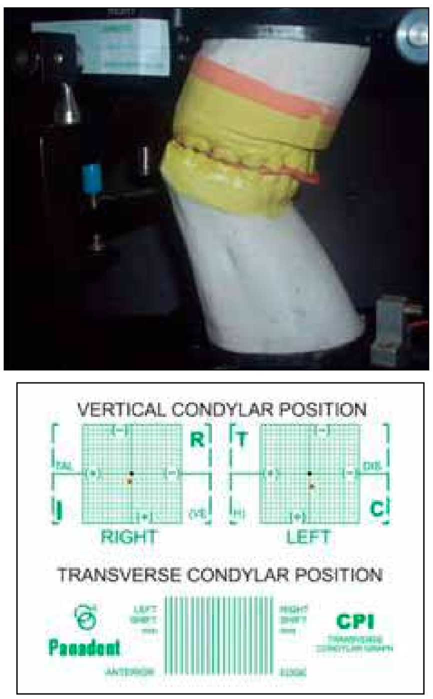


Figure 3 *Models in CP showing MHI (red) and SCP (black).*

For the interoperator evaluation, the t-student parametric test was used for the vertical and horizontal values for both the right and left side, and in the transverse evaluation, the paired Wilcoxon nonparametric test was used.

Verification of the difference between SCP and MHI in relation to the respective side, right side versus the left, used the paired t-student parametric test for the vertical and horizontal directions in T1 and for the vertical direction in T2, and also used the paired Wilcoxon nonparametric test for the horizontal direction in T2.

The paired t-student test was used to compare the difference between SCP and MHI in the transversal and horizontal in the T1 and T2. The paired Wilcoxon nonparametric test was used to compare values in the left-side horizontal direction. The t-student parametric test for independent samples and the Mann-Whitney nonparametric test were used to verify the differences for the crossbite side between SCP and MHI, as measured at T1 and again at T2; and to verify the differences between the measurements taken at T1 and T2. These last two tests were conducted with a significance level of 5% and confidence intervals of 95%.

Results

There were no statistically significant differences between the results obtained by operators 1 and 2 on any of the tests. Likewise, there was no systematic error in the CPI evaluations (Table 1).

	Operator 1	**Operator 2**	**Comparison (*p*-value)**
Vertical Left			
Average ± SD	2.15 ± 1.14	1.82 ± 1.12	Parametric Test
Median	2.00	1.88	*t*-Student (0.276)
Mínimum–Maximum	0.50–4.50	0.25–4.00	
Total	18	18	
Vertical Right			
Average ± SD	1.74 ± 1.06	1.69 ± 0.89	Parametric Test
Median	1.50	1.63	*t*-Student (0.890)
Mínimum–Maximum	0.50–4.25	0.25–3.50	
Total	18	18	
Horizontal Left			
Average ± SD	1.73 ± 1.05	1.18 ± 0.70	Parametric Test
Median	1.63	1.00	*t*-Student (0.054)
Mínimum–Maximum	0.50–3.75	0.50–3.25	
Total	18	18	
Horizontal Right			
Average ± SD	1.18 ± 0.72	1.17 ± 0.82	Parametric est
Median	1.13	1.00	*t*-Student pareado (0.951)
Mínimum–Maximum	0.25–2.75	0.25–3.25	
Total	18	18	
Transversal			
Average ± SD	0.89 ± 0.60	0.65 ± 0.54	Nonparametric Test
Median	0.75	0.38	Wilcoxon (0.188)
Mínimum–Maximum	0.00–2.25	0.00–1.75	
Total	18	18	

Table 1 *Comparison of results for operators 1 and 2.*

For the vertical and horizontal displacements of the right and left sides there was a significant difference between T1 and T2 for both the left and right sides at the proposed level of significance. The mean in T1 was significantly higher than the mean in T2, and the mean values were lower in T2 than in T1. Therefore, when comparing the values observed in T1 and T2, the study found that after the unilateral posterior crossbite is corrected, the condylar dislocations between SCP and MHI tend to be reduced. The study found no significant difference between T1 and T2 with respect to the right and left sides. Since a control group was not used in this study, we can only assume that the changes between T1 and T2 were an effect of acrylic occlusal coverage deprogramming (Tables 2 and 3) [*see next page*].

	Left	Right	*p*-value
Vertical			
Average ± SD	1.98 ± 0.95	1.72 ± 0.75	Parametric Test
Median	1.75	1.69	*t*-Student (0.110)
Mínimum–Maximum	0.5–3.875	0.5–3.375	
Total	18	18	
Horizontal			
Average ± SD	1.46 ± 0.69	1.17 ± 0.61	Parametric Test
Median	1.5	1.19	*t*-Student (**0.039**)
Mínimum–Maximum	0.5–3.125	0.25–2	
Total	18	18	

Table 2a *Comparison of left and right sides in T1.*

	Left	Right	*p*-value
Vertical			
Average ± SD	0.78 ± 0.59	0.61 ± 0.3	Parametric Test
Median	0.75	0.5	*t*-Student (0.175)
Mínimum–Maximum	0.25–2.25	0.25–1	
Total	18	18	
Horizontal			
Average ± SD	0.68 ± 0.44	0.68 ± 0.43	Nonparametric Test
Median	0.75	0.63	Wilcoxon (0.907)
Mínimum–Maximum	0–1.25	0.25–1.5	
Total	18	18	

Table 2b *Comparison of left and right sides in T2.*

	T1	T2	Comparison (*p*-value)
Vertical Left			
Average ± SD	1.98 ± 0.95	0.78 ± 0.59	Parametric Test
Median	1.75	0.75	*t*-Student (**< 0.001**)
Mínimum–Maximum	0.50–3.88	0.25–2.25	
Total	18	18	
Vertical Right			
Average ± SD	1.72 ± 0.75	0.61 ± 0.30	Parametric Test
Median	1.69	0.50	*t*-Student (**< 0.001**)
Mínimum–Maximum	0.50–3.38	0.25–1.00	
Total	18	18	
Horizontal Left			
Average ± SD	1.46 ± 0.69	0.68 ± 0.44	Nonparametric Test
Median	1.50	0.75	Wilcoxon (**0.001**)
Mínimum–Maximum	0.50–3.13	0.00–1.25	
Total	18	18	
Horizontal Right			
Average ± SD	1.17 ± 0.61	0.68 ± 0.43	Parametric Test
Median	1.19	0.63	*t*-Student (**< 0.001**)
Mínimum–Maximum	0.25–2.00	0.25–1.50	
Total	18	18	
Transversal			
Average ± SD	0.77 ± 0.44	0.58 ± 0.45	Parametric Test
Median	0.81	0.63	*t*-Student (0.155)
Mínimum–Maximum	0.13–1.50	0.00–1.50	
Total	18	18	

Table 3 *Comparison between T1 and T2. right, left, and transversal.*

There was a reduction in the vertical and horizontal measurements of the CPI on both sides between T1 and T2 on the crossed and uncrossed sides. There was no significant difference found in the transverse measurement. Only the measurements obtained in the vertical and horizontal directions showed a statistically significant mean difference between T1 and T2 on both sides. The mean values obtained by the CPI were reduced after treatment by an average of 1.08 mm in the vertical direction and 0.48 mm in the horizontal direction for both the crossed and the uncrossed side (Tables 4, 5, and 6). [*see next page*].

Discussion

The study found no statistically significant differences between the results obtained by operators 1 and 2, and no systematic error in the CPI evaluations. These findings corroborate the reproducibility of the evaluations made in other studies, as described in the literature.[18–20]

We consider the use of the model assembly in SCP, and the consequent evaluation of the condylar positions, fundamental for diagnosis, planning, and orthodontic treatment. This evaluation reveals malocclusions that would otherwise be masked by the mandibular accommodation imposed by the existing occlusal imbalance.[21–23]

The unilateral posterior crossbite malocclusion often occurs in the mixed-dentition phase of dental development. The carryover of this malocclusion into adulthood can cause changes on the face in general, and on the TMJ specifically. Although this type of malocclusion does not pose a high risk to the development of TMD, the possibility of spontaneous correction is practically zero. Therefore, diagnosis and treatment should occur as early as possible.[23–30]

Different types of appliance have been used to treat these malocclusions; the appliance with acrylic occlusal coverage chosen for this study is one of those most often recommended. It reduces the undesired effects of dental extrusion and inclination of the crowns in the vestibular direction during expansion. In addition, it promotes better vertical control of the bite. This in turn allows simultaneous bilateral and multiple contacts, which promotes neuromuscular deprogramming.

The position of the condyle in relation to the articular fossa in children with unilateral posterior crossbite has been the subject of many studies. These studies have examined the use of transcranial radiography, and more recently the use of conventional helical tomographic imaging or cone beam computed

Variable	Factor	gl num.	gl den	*F* –value	*p-value*
	Time Point	1	17	54.72	**≤ 0.001**
Vertical	Side	1	17	0.02	0.888
	Time Point*Side (Interaction)	1	17	0.02	0.888
	Time Point	1	17	11.62	**0.003**
Horizontal	Side	1	17	0.02	0.884
	Time Point*Side (Interaction)	1	17	0.02	0.884
	Time Point	1	17	0.2	0.658
Transversal	Side	1	17	2.59	0.126
	Time Point*Side (Interaction)	1	17	0.93	0.348

Table 4 *Test results for comparison of CPI.*

Variable	Side	T1			T2		
		Average	SD	N	Average	SD	N
Vertical	Crossed	1.78	1.01	18	0.68	0.44	18
	Uncrossed	1.74	1.02	18	0.68	0.51	18
Horizontal	Crossed	1.18	0.78	18	0.68	0.52	18
	Uncrossed	1.14	0.69	18	0.68	0.36	18
Transverse	Crossed	0.49	0.51	18	0.33	0.43	18
	Uncrossed	0.21	0.43	18	0.26	0.40	18

Table 5 *CPI measurements in each position and time point.*

Variable	Comparison	Estimated Mean Differences	Standard Error	*t*-value	gl	p-value
Vertical	T1 - T2	1.08	0.15	7.30	17	< 0.001
Horizontal	T1 - T2	0.48	0.14	3.41	17	0.003

Table 6 *Estimated mean differences between time points in vertical and horizontal directions.*

tomography (CBCT) and magnetic resonance imaging, to evaluate position of the condyle in relation to the articular fossa.[31,32]

Although imaging tests are of great help in identifying structural changes, such as osseous contouring of the condyle and articular fossa, as well as in examining the interrelationships of the joint structures, they are not considered the most suitable means of determining the relationship between the condyle and the articular fossa. The limitations of conventional tomography result from the fact that it provides bidimensional data. Therefore it cannot be used to conduct a three-dimensional evaluation of the position of the condyle in relation to the articular fossa. Even with the advent of CBCT and the development of programs to reconstruct images in 3-D, the evaluation of the condylar positions through imaging remains a challenge. The variation in the thickness of the soft tissues, which cannot be observed in these types of imaging, can lead to inappropriate interpretations; furthermore, they do not take into account the functional state of the muscles responsible for locating the condyles in the corresponding articular fossae.[33-35]

After extensive research, the authors found no published studies with a methodology equivalent to that used in this study. Therefore, the authors were obliged to compare the results of this study with the results of studies using different methodologies.

With respect to the reduction of the values obtained in T2 when compared to T1 in the three spatial planes, this tendency of the mandibular heads to seat in their respective articular fossae after correction of the crossbites was also cited by Hesse et al[36] who found differences between the condylar positions before and after crossbite correction. Lippold et al[37] compared the crossed and uncrossed sides in corrected lateral tomography of the TMJ obtained before and after maxillary expansion, and found a highly significant reduction between T1 and T2 when compared to the control group. Santos Pinto et al[38] also described this tendency, using images and different terminology; these authors refer to the condylar positions observed as being more concentric in T2 than in T1. Similar findings were described by Kecik et al, Matta et al, and Vitral et al imbalanced positions in T1 when compared between the crossbite and noncrossbite sides, and in T2 these imbalanced positions were eliminated.[6,39,40] On the other hand, Costa et al[7] found that the condylar displacements were between 31.45% and 32.6% in both T1 and T2; thus there was no statistically significant difference between the values for the two times. Weffort[19] also observed dimensional differences in condylar displacements when comparing symptomatic and asymptomatic individuals using CPI. Weffort observed that symptomatic individuals presented larger condylar displacements than asymptomatic individuals on the left vertical and transversal planes, and that the general means in the different spatial planes were smaller than those found in this study, in both T1 and T2.

When comparing the measurements of the right and left side displacements of the horizontal plane in T1, this study found a statistically significant difference ($p = .04$) between the two measurements. The mean on the left side was higher than the mean on the right side, a difference not observed in T2. Fantini,[41] in his study on condylar position, found a higher mean for the right side in the horizontal direction, using a methodology similar to that used in this study; Fantini's sample, however, consisted of asymptomatic patients without unilateral posterior crossbite. Hidaka et al[33] also observed considerable asymmetry using the CPI in a study of 150 orthodontic patients, subdivided into groups according to age, sex, size of the mandibular angle, and type of angle malocclusion. These authors found that the vertical displacements were higher on the left side, and the horizontal displacements were higher on the right side. On the other hand, Utt et al[42] found no significant differences between the left and right sides in a study of condylar displacements between SCP and MHI in samples of Angle's Class I, Class II and Class III malocclusions, using the same methodology.

Conclusion

According to the results obtained in this study, the condylar displacements in T1 were significantly higher than the condylar displacements in T2.

- There were no statistically significant differences between T1 and T2 in the transversal plane.
- There were statistically significant differences between the right and left sides in T1. There were no such differences in T2.
- The difference between the crossed and uncrossed side was the same in T1 as it was in T2.

Final Considerations

The results of this study seem to confirm that the correction of unilateral crossbite with an occlusal covered acrylic RME would benefit not only interdental relationships but also the intraarticular relationships. The authors hope that this study will contribute to a better understanding of interdental relationships and their possible effects on condylar positions. Future studies will contribute further to our current knowledge.

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The Orthodontic Limit—Ideal or Compromise? Camouflage of a Class II: A Case Report

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Summary

This case is a camouflage orthodontic treatment of a 13-year-old girl. Its goal was to correct the Class II skeletal and dental malocclusion by extracting the upper first and lower second premolars so the underlying bone problems would be less evident. As a consequence, and within certain limits, the dental displacement compensated for the skeletal discrepancy. Maximum maxillary dental anchorage (two TPAs) and minimum mandibular dental anchorage were employed. To maximize facial aesthetics, gingivoplasty (twice), along with composite build-up widening of the upper right and left central and lateral incisors were used. Photographic illustrations document the diagnosis, treatment plan, orthodontic appliances and treatment progress of the case. The results show dentally, a corrected Class I molar, canine and incisor relationship with midlines co-ordinated; skeletally, a balanced maxilla-mandibular relationship aided by counter-clockwise growth; and facially, a pleasing smile line with good lip support and enhanced facial aesthetics.

Introduction

When is an orthodontic treatment successful? It is successful when we are aware of our orthodontic limits from its initial planning. Today, the biggest problem posed by orthodontics is a thesis-antithesis of sorts between face and malocclusion. Unfortunately, finding a compromise between these two aspects of face and malocclusion is very difficult from a diagnostic standpoint. When this problem is solved, treatment is greatly simplified. Therefore, the difficulty lies not in the biomechanical aspects of treatment, but in planning, which must be in tune with a diagnosis that will decide where your starting point is, and where you want to arrive. In my opinion, it is an occlusal and functional ideal together with a facial compromise. What follows is a description of a limited orthodontic case, and of how I treated it. I still wonder whether this treatment is an ideal or a compromise.

A camouflage orthodontic treatment aims at correcting a malocclusion so as to make the underlying bone problems less evident. As a consequence, and within certain limits, the dental displacement can compensate for the skeletal discrepancy. By means of dental extraction, which makes room for dental movement, it is often possible to obtain a correct molar and incisive dental relationship, notwithstanding the Class II skeletal relationship.

Camouflaging also implies that tooth repositioning has a positive or neutral effect on facial appearance. In such a case, camouflaging can be a satisfactory solution. Camouflage treatment is very useful for patients in the initial stages of permanent dentition who have gone through the pubertal growth peak but still have a certain residual growth potential. The boundary between orthodontics and surgery is defined as orthodontic limit, and is a particularly delicate matter in youths with a skeletal Class II.

The problem lies, of course, in predicting whether the result of a camouflage treatment will be satisfactory to facial appearance. This depends on the patient's and the parents' perception of the smile in the facial context. Therefore, it is necessary that they take part in the decision-making process. But the results of an orthodontic camouflage in a young patient depend almost entirely on growth. And unfortunately, my own experience suggests that even with an accurate cephalometric tracking, growth is not entirely predictable. As Proffit said, an orthodontic diagnosis is not a "game of numbers."[1]

In a modern biological model, the required results consist of functional and aesthetic elements, each strongly influenced by the soft tissues of the head and neck.[2] The facial contour reflects the underlying facial bones, and thus skeletal disproportion influences the soft tissues of the face. These soft tissues impose the main constraints on orthodontic treatment.[3]

These constraints include

- pressure exerted by the lips, cheeks, and tongue upon teeth
- constraints of the periodontal tissues
- neuromuscular influences on mandibular position
- contour of facial soft tissues
- lip-tooth relationship, and exposure of front teeth in facial gestures

We may therefore speak of "reverse engineering" when we refer to the planning of an orthodontic treatment. The goal of this treatment is to establish the primary role of the soft tissues in having first identified all possible dental and bone modifications that will allow us to achieve the desired results on the soft tissues. This new way of thinking revolutionizes the orthodontic approach. Rather than being based on this new way of thinking, it is based on new schemes—schemes that depend on, but are not limited to, the documentation of odontofacial diagnosis and treatment planning. Photographic records, cephalometric measurements, and models are insufficient to obtain an adequate diagnosis and, consequently, to achieve a correct personalized treatment plan, it is necessary to consider giving emphasis to the clinical examination of the patient, i.e. to facial dynamics as a psychosocially relevant factor.

Case Report

R.A., a 13-year-old girl, came to my practice for correction of a jawbone and tooth crowding. Figure 1 shows the whole collection of records necessary to make a correct diagnosis and treatment planning.

Facial Analysis

Upon clinical examination, slight asymmetries were detected, but most of these were negligible in the context of orthodontic treatment. The exception was the nose, which showed a leftward septum deviation. This created a certain visual interference in the evaluation of the correspondence between the facial symmetry axis and the upper front tooth midline.

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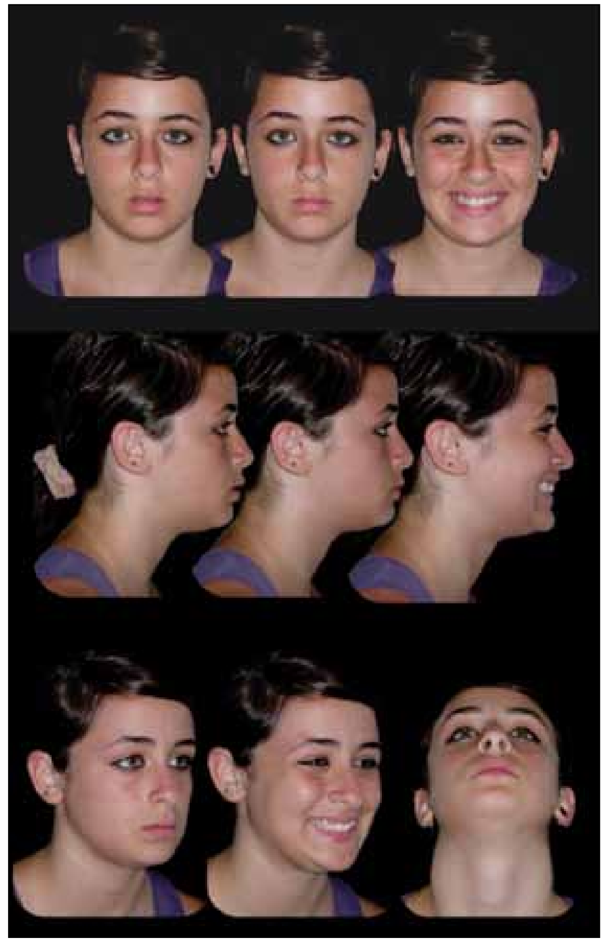

Figure 1a *Photos of face with relaxed, closed and full smile lips, with the head in natural vertical position in frontal, lateral, three quarter and sub-mento vision.*

Figure 1b *Intraoral photos.*

Figure 1c *Microaesthetics of smile. Detail shows a radiant, convex, skimming symmetry with irregularities of gingival margins.*

Figure 1d *Orthopantomography.*

Figure 1e *Articulator cast mounting according to centric relation.*

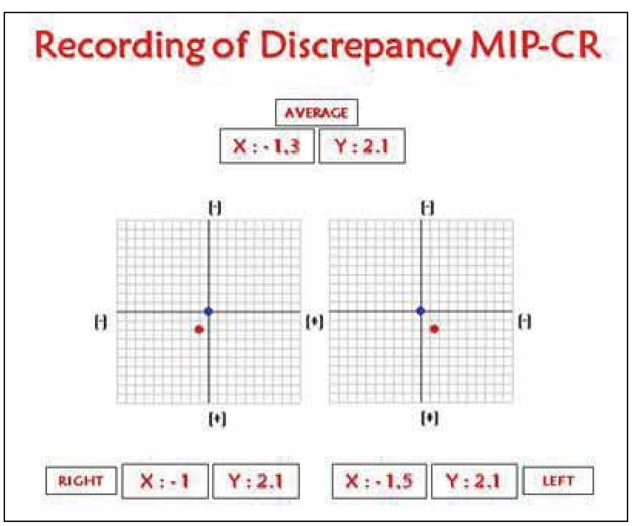

Figure 1f *Registration of the MIP-CR (position of maximum incuspidation - centric relation) maximum discrepancy.*

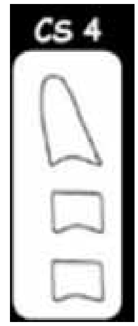

Figure 1g *Stages of cervical vertebrae in CS4 (recent peak of mandibular growth) to evaluate mandibular growth.*

Figure 1h *Tele rx in L-L projection with and without overlapping of lateral photos of closed lips face again with and without cephalometric analysis.*

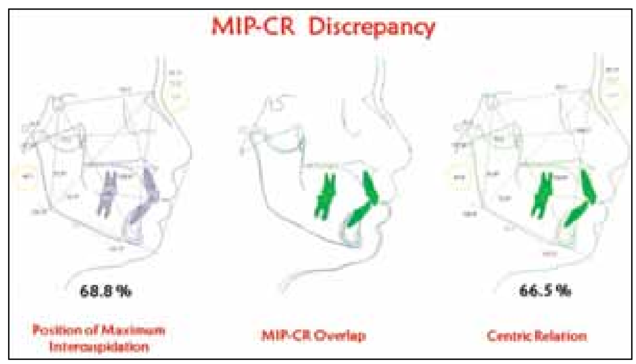

Figure 1i *Cephalometric analysis in MIP, CR and overlap.*

Figure 1j *Overlapping of tele rx in L-L with photos of face with full smile to evaluate the anterior limit of the dentition (ADL) in the facial context in relation to the inclination of the upper incisors regarding the bispinal plane (anterior nasal spine-posterior nasal spine ANS-PNS) and in relation to the sagittal position of the maxilla.*

With lips relaxed, the patient's upper incisors were underexposed for her age; and when fully smiling, she showed a medial smile line with evident irregularities in the gum margin. Therefore, in planning the orthodontic treatment, particularly in the refining phase, it was necessary to consider rebalancing the incisor gingival levels, taking into account the cause of the discrepancy.[4]

Rufenacht[5] states that a relation can be established between tooth shape and exposition on the one hand, and lip shape on the other. It follows that this patient, having fully formed and balanced upper and lower lips, should show a remarkable dominance of the anterior sector, particularly with respect to the upper central incisors; and her smile should exhibit a convex radiant symmetry.

Figure 1 shows the lateral view, with the patient's head in the natural position.[6,7] They show a normal nose, and a good nose-lip angle defining an adequate curl of the upper lip. The lower lip is excessively tilted, resulting in a narrow lip-chin angle with a good chin definition but an insufficient chin-throat distance, emphasized by an open R angle. The patient's profile with a full smile in Figure 1 shows a certain regression of the anterior tooth limit, tracing a concave profile underlined by a downward nose tip and a chin tending to prominence and in the three-quarter view, a malar deficit is seen.

Intraoral Analysis

An oral exam revealed dental misalignment with midlines centered, molar and canine Class II left and right, and numerous wear facets.

Articulator Cast Mounting

The articulator cast mounting showed a maximum intercuspal position-centric relation (MIP-CR) discrepancy with a mean value of 1.3 mm on the horizontal plane and 2.1 mm on the vertical plane. This resulted in a worsening of the molar and canine Class II relationship and a reduction of the overbite. This overbite was caused by premature posterior tooth contacts at the level of the palatal cusps of the first and second molars, due to maxillary transverse deficiency. No signs or symptoms of temporomandibular joint (TMJ) dysfunction were evident.

Cephalometric Analysis

The skeletal Class II relationship was confirmed. The upper incisors were at normal inclination, and the lower incisors were at 105.3^0 inclinations, counterbalancing the Class II malocclusion. An open saddle angle counterbalanced the posterior basal skull dimension, ramus length, articular angle and gonial angles, all of which were within the normal range. In fact, according to the Jarabak craniofacial growth projection, the mandible rotates around the hinge axis in a counterclockwise direction, and this patient shows that potential. There is still a residual skeletal growth, as shown by the cervical vertebral maturation of Franchi-Baccetti CS4[8] It is impossible to predict how long this growth will continue.

Diagnostic Considerations

The patient is in her peak growth stage, characterized by bi-maxillary retrusion; a severe Class II skeletal pattern, estimated to be about 8 mm of discrepancy, with predictable growth in a forward rotation; and a favorable soft tissue milieu.

Treatment Planning

It was decided to camouflage the Class II by using upper first bicuspid and lower second bicuspid extraction, followed by lower anchorage loss mechanics and maximum anchorage in the upper arch to close the postextraction sites. This was done to resolve dental crowding, correct the C II and redistribute the residual space in the maxillary incisor group, in order to increase the mesiodistal dimension using composite resins. The main concern here was to avoid retroposition of the incisors, and to maintain adequate anterior torque and inclination.

Materials and Methods

The vertical anchorage of the upper molars was set up by using two transpalatal arch bars and the lower molars were banded individually. Self-ligating brackets with slot size .022 x .028 were bonded to all remaining teeth completing the appliance, following the Roth prescription strait-wire method (Figure 2-a). Thermal shape-memory arch wires (.014 copper NiTi U/L 27^0) were placed to promote initial alignment.

Figure 2a *Alignment phase. Upper and lower bonding with self-ligating brackets, slot size .022x.028, Roth method. Arch wires .014 copper NiTi U/L 27°. Double transpalatal arch bars to correct the palatal-root torque.*

After eight weeks, leveling and aligning continued. During the initial leveling phase (Figure 2-b), thermal shape-memory arch wires (.020 x .020 copper NiTi U/L 35^0) were used to achieve uprighting and vertical control of all teeth to facilitate space closure.

***Figure 2b** Initial leveling phase Arch wires .020x.020 copper NiTi U/L 35°.*

Six weeks later, the alignment phase was completed and working DKHL .019 x .025 stainless steel arch wires were placed into both arches. In the lower arch, gable bends of about 30° were made on the archwire distally to 3.4 and 4.4 in order to complete the leveling and to avoid a distal tipping of the lower premolar crowns during the postextractive space closure phase (Figure 2-c). The DKHL was adjusted during the working phase so as to maintain a level curve of Spee during space closure.

***Figure 2c** Completion of initial leveling phase with arch wires .019x .025 Stainless steel SS U/L with gable bands of about 30° distally to 3.4 and 4.4.*

Space closure in the lower arch was obtained by mesialization of the first and second molars. Burning anchorage was needed to achieve the molar Class II correction and maintaining lower incisor position. In the upper arch, the postextraction space was closed through the resolution of dental crowding and a minimal loss of posterior anchorage (Figure 2-d). Refinishing and detailing were done along with alignment and space closure as bracket replacements for ideal positioning were made as needed. (Figure 2-e).

***Figure 2d** Work phase. Closure of postextraction spaces.*

***Figure 2e** Refinishing phase.*

Evaluation of the smile during the treatment phase (Figure 3-a) showed a clear worsening of the anterior limit of the dentition.

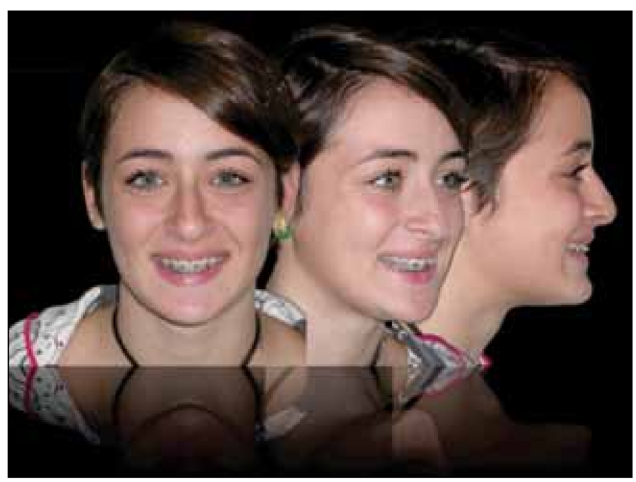

***Figure 3a** Photos of face showing reduction of anterior limit of dentition.*

In order to avoid making the problem worse and with the permission of the patient and her parents, two NiTi coil springs were installed between the upper right and left canines and lateral incisors, and, between the upper right and left lateral incisors and central incisors to increase the anterior torque by creating diastemas (Figure 3-b).

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Figure 3b *Two NiTi coil springs inserted between tra 1.3-1.2 and 2.2-2.3 to increase the palatal-root torque.*

Figures 3-c and 3-d show how this improved the anterior limit of the dentition. The diastemas caused by the coil springs were redistributed among the anterior teeth.

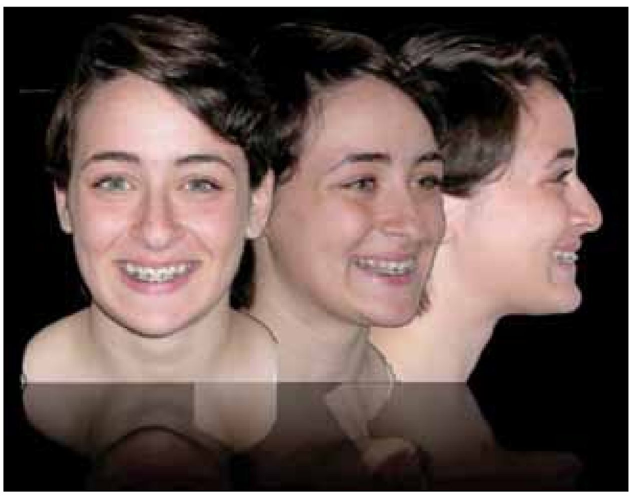

Figure 3c *Improvement of anterior limit of dentition after increased palatal root torque.*

Figure 3d *Before and after the increase of palatal-root torque.*

The refinishing process continued with .021 x .025 multi-braided wire, U/L (Figures 4-a and 4-b).

Figure 4a *Finishing phase with arch wires .021 x .028 multibraided U/L.*

Figure 4b *Finishing phase with four coil closed.*

Gingivoplasty was performed twice by diode laser (Figure 4-c), the first time prior to debonding for better gingival contour, and the second time after composite buildup.

Figure 4c *Finishing phase. Gingivoplasty with diode laser.*

Upper and lower debonding was followed by composite resin buildup restorations of the distal aspect of the upper front teeth (Figure 4-d). The second gingivoplasty was performed in the upper incisor regions with the purpose of improving the proportions between tooth width and tooth length, which showed a slight alteration after the mesiodistal restorations.

Figure 4d Finishing phase with composite resin buildup restorations of the mesial and/or distal aspect of the upper front teeth.

Lower orthodontic retention was accomplished with a Zachrisson style retainer. Upper retention was accomplished through the use of a Boston appliance.

Discussion

The orthodontic treatment in this case achieved seven goals. The first goal was to achieve molar and canine Class I occlusion with no transverse or sagittal mismatch between the dental arches (Figure 5-a).

Figure 5a Final intraoral records.

The second goal was to achieve occlusion with certain functional features.[9-11] (Figure 5-b). Anterior disclusion, for example, considering the amount of overbite and overjet, and the 104.5 degree lower incisor inclination, was executed very well.

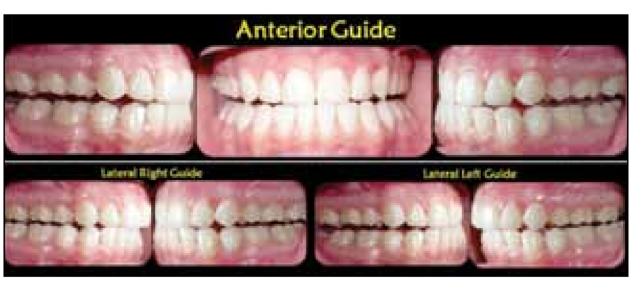

Figure 5b Control of the guides of function.

The third goal was to reduce the MIP-CR discrepancy in both the sagittal and the vertical dimension (Figures 5-c and 5-d).

Figure 5c Articulator cast mounting according to centric relation.

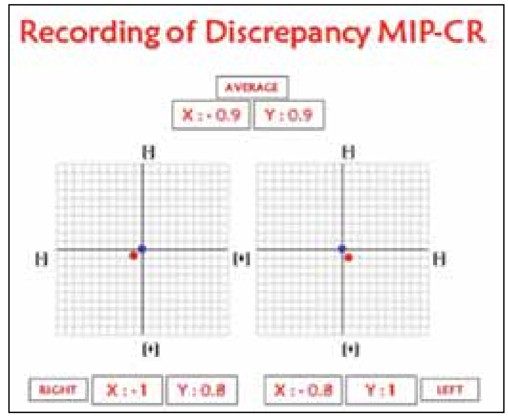

Figure 5d Registration of the MIP-CR (position of maximum incuspidation - centric relation) maximum discrepancy.

The fourth goal was to achieve a pleasant smile and adequate lip support. The cephalometric analysis shows the lips slightly behind the E-line but in balanced position considering the extraction of four teeth.

Although it was not a goal of treatment, the resulting mandibular ramus length and cranial base increase showed that the counter-clockwise growth and increase in the posterior vertical dimension, hoped for at the beginning of treatment, had taken place. This increase was caused by basal skull growth in the region of the sphenooccipital synchondrosis and by an increase in the height of the mandibular ramus. The mandibular body increased from 62.3 mm at the start of treatment to 68.4 mm at the end of treatment. This increase was favorable to the camouflage treatment since it neutralized the retrognathic appearance at the start of treatment, rendering a more mature and aesthetic facial appearance.

Goals 5, 6, and 7, the occlusal[12-13] (Figure 5-e), functional (Figure 5-b) and periodontal (Figure 5-a), were achieved with respect to facial harmony (Figures 6-a, 6-b).

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Figure 5e *Tele rx in L-L projection with and without overlapping of lateral photos of closed lips face again with and without cephalometric analysis.*

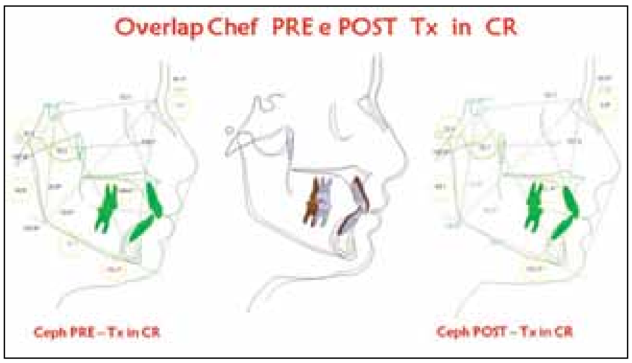

Figure 5f *Cephalometric analysis in CR pre- and posttreatment and overlap.*

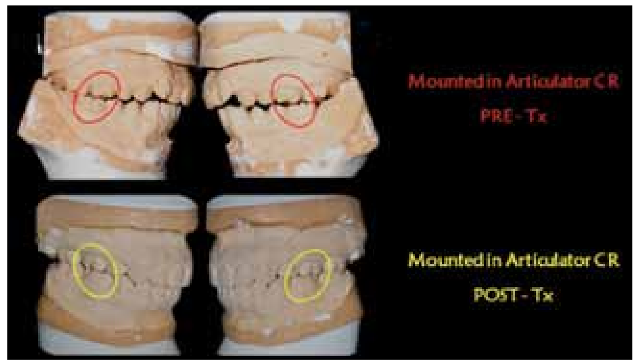

Figure 5g *Articulator cast mounting according to centric relation pre- and posttreatment.*

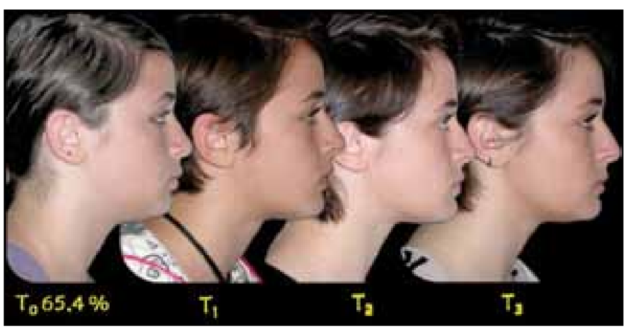

Figure 6a *Facial changes (profile in repose) during orthodontic treatment.*

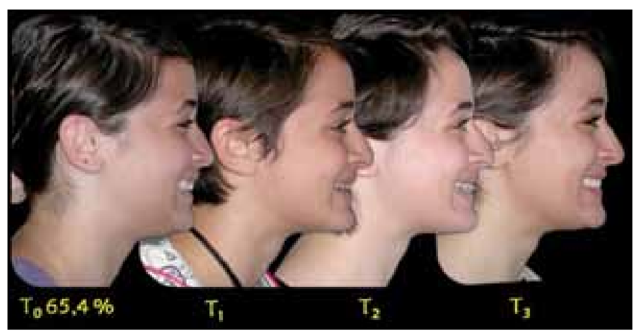

Figure 6b *Facial changes (profile, smiling) during orthodontic treatment.*

The chosen treatment caused no diminution in esthetics (Figures 7-a, 7-b, and 8-a). The patient appears totally symmetric in the frontal view, with a smile line allowing visualization of 90% of the anterior teeth and no black corridors (Figures 8-a and 8-b). In addition, the gingival contour has been rebalanced. In the lateral view (Figures 7-a and 7-b), the anterior limit of the dentition is no worse than it was despite the fact that the patient has undergone an extractive orthodontic treatment with maximal anchorage in the upper jaw. A mildly concave profile remains, however this is not a detriment to facial appearance.

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Figure 7a *Evaluation of the anterior limit of dentition before and after orthodontic treatment.*

Figure 7b *Alternate view of the evaluation of the anterior limit of dentition before and after orthodontic treatment.*

Figure 8a *Macroaesthetic of the smile before and after orthodontic treatment.*

Figure 8b *Microaesthetic of the smile before and after orthodontic treatment.*

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Interdisciplinary Concepts Corner

Editor's Note: The Journal will be highlighting certain programs offered that feature Roth Williams or related treatment ideas and concepts, emphasizing interdisciplinary cases. In this first Interdisciplinary Concepts Corner, we are featuring the FACEtx program, courtesy of RWISO members Dr. Straty Righellis and Dr. Doug Knight. We hope you enjoy this feature and your feedback is welcome.

Functional and Cosmetic Excellence: FACEtx

Functional and Cosmetic Excellence (FACE Tx™) is an approach to orthodontic treatment that establishes measurable treatment goals for six elements that form the basis of comprehensive, interdisciplinary, high-quality orthodontic care. These are:

- functional occlusion;
- TMJ health;
- facial balance;
- optimal dento-gingival esthetics (smile design);
- periodontal health and
- stability.

For each of these goals, the originators of the FACE Tx™ discipline have defined specific elements that create a framework for the systematic evaluation of the esthetic and functional needs of each patient and a method to assess treatment results. These treatment goals are supported by reputable studies published in well-respected, peer-reviewed journals. Sharing these goals and the means to achieve them with an interdisciplinary team—the orthodontist, the dentist and/or other specialist(s)—provides an orthodontist an opportunity to work with colleagues to create outstanding results.

Developing the skillsets required to manage and function within FACE Tx interdisciplinary treatment teams increases the complexity of cases one can treat. The collaborative interaction with experts in their respective fields (prosthodontists, periodontists, cosmetic and general dentists and surgeons), who ascribe to the same principles of tooth positioning and jaw function, creates a knowledge base to treat to predictable, on-time, optimal results while meeting and/or exceeding patients' expectations.

Worldwide Program of Instruction

FACE Tx offers one of the world's only postgraduate interdisciplinary continuing educational programs. Offered in numerous countries to university-trained orthodontists, it provides didactic instruction and hands-on experience. Through a series of 5 to 7 one-week sessions, a team of established educators and practitioners convey this unique curriculum.

The FACE Tx teaching staff builds on each participating clinician's knowledge base. The full-time faculty—Drs. Jorge Ayala (Santiago, Chile), Renato Cocconi (Parma, Italy), L. Douglas Knight (Kentucky, USA), Domingo Martin (San Sebastian, Spain), Jeffrey McClendon (New York, USA), Straty Righellis (California, USA), and Carl Roy (Virginia, USA)—all manage active private practices and have extensive educational and clinical experience. The teaching faculty combines considerable years of skills and knowledge to formulate the FACE Tx approach to diagnosis, treatment planning and execution.

Defining Functional Occlusion, Smile Esthetics and Facial Balance

A number of orthodontic disciplines specify functional occlusion as a primary treatment goal, but few articulate criteria for its measurement or, for that matter, incorporate gnathological measurement protocols. Dr. Domingo Martin defines functional occlusion by what it is as well as what it is not.

Functional occlusion is not a definition of tooth position but rather describes a dental and articular position. The criteria for an optimal occlusion is to have even and simultaneous contacts of all possible teeth when the mandibular condyles are in their most superoanterior position, resting against the posterior slopes of the articular eminences with the discs properly placed; that is, when the teeth and the joints are in harmony. The mutually protected occlusion is a centered condyle in the jaw joint, maxillary lingual cusps seated into corresponding mandibular fossae and at least 3 to 4 mm of incisal overbite.—Dr. Domingo Martin

While functional occlusion serves as the foundation for the FACE Tx approach, the discipline further differentiates itself by integrating facial balance with dento-gingival esthetics for a comprehensive approach to diagnosis, treatment planning and execution. Dr. Renato Cocconi and surgeon Dr. Micro Raffaini, have analyzed the standards for optimal facial balance and dento-gingival esthetics and have quantified the relationship of the inclination of the upper incisors with the alar base and the pedestal of the nose. These elements are important diagnostic findings for the development of specific treatment goals and metrics to assess the esthetic quality of treatment results. Dr. Jorge Ayala has quantified the range of optimal facial balancing elements of various ethnicities, which is essential to strengthening our ability to apply the highest standards of care across various cultures. From this data, he developed the first VTO- and STO- based orthodontic and orthognathic surgery treatment planning systems that incorporate soft tissue. From this research and these practicing orthodontists, along with the other clinicians in the group, comes a refreshing approach to lifelong learning that is not only didactic, but clinically realistic. It can be readily applied to one's day-to-day practice.

CASE NL

Straty Righellis, DDS
Oakland, CA

Case NL illustrates FACE principles that address goals for functional occlusion, facial balance and dental esthetics with the ultimate goal to provide dental stability, long-term health to the periodontium and TMJs.

The keys in this collaborative interdisciplinary case are an accurate periodontal diagnosis, careful orthodontic tooth position detailing, and a dentist who managed pontic shape to carefully to develop the interproximal papillae.

The case images presented focus on the relationships amongst the periodontist, orthodontist, and the prosthodontist. The orthodontic component was very simple as there were no TMD concerns. The key teaching point with this case is the inclusion of the periodontist for an accurate periodontal diagnosis prior to orthodontic care and a prosthodontist who could manage the pontic shape to create the papillae.

For full Case presentation, click here.
(Requires Adobe Acrobat.)

Dr. Righellis graduated from UCLA Dental School and received his orthodontic specialty certification from University of California, San Francisco. He maintains a private practice and serves as an associate clinical professor at the University of the Pacific and University of California, San Francisco. Dr. Righellis is a Diplomate of the American Board of Orthodontics, is on the editorial review board for the American Journal of Orthodontics *and lectures domestically and internationally on excellence in clinical orthodontics.*

CASE KT

L. Douglas Knight, DMD
Louisville, KY

The patient's motivation for treatment included a desire to:

- straighten the front teeth,
- move the chin forward, and
- close open bite.

Treatment options were to extract upper and lower first premolars, advance the lower jaw or intrude the maxillary posterior with skeletal anchorage.

We elected to utilize maxillary zygomatic skeletal anchor plates because we felt it was the least invasive and would yield the best result. There is also an overwhelming number of research articles that support the use of skeletal anchor plates for the treatment of anterior open bites.

Our biggest challenge to date has been to convince the patient to go back to the oral surgeon to have her plates removed. She insists that the plates do not bother her. She has now been out of orthodontic treatment for over two years.

The patient's chief concerns were achieved. The teeth were aligned and the open bite closed. The projection of pogonion increased due to the auto-rotation of the mandible, following intrusion of the maxillary posterior teeth. The case has remained stable for over 30 months.

For full Case presentation, click here.
(Requires Adobe Acrobat.)

Dr. Knight received his dental degree from the University of Kentucky and was awarded a certificate in orthodontics and dentofacial orthopedics from New York University. Dr. Knight completed a comprehensive two-year clinical program in occlusion and orthodontics at the Roth-Williams Center for Functional Occlusion. In private practice, Dr. Knight is a Diplomate of the American Board of Orthodontics, a fellow of the Academy of General Dentistry, an active member of the American Association of Orthodontists, and lectures domestically and internationally on new orthodontic techniques and interdisciplinary dentistry.

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