



UNESP - UNIVERSIDADE ESTADUAL PAULISTA
FACULDADE DE ODONTOLOGIA DE ARARAQUARA

Karina Eiras Dela Coleta Pizzol

**ALTERAÇÕES DO TECIDO MOLE,
ESPAÇO FARÍNGEO E
ESTABILIDADE APÓS AVANÇO
MAXILO-MANDIBULAR COM ROTAÇÃO
ANTI-HORÁRIA E PRÓTESE TOTAL
DE ATM**

Araraquara
2008

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FARÍNGEO E ESTABILIDADE APÓS AVANÇO
MAXILO-MANDIBULAR COM ROTAÇÃO ANTI-
HORÁRIA E PRÓTESE TOTAL DE ATM

Tese apresentada ao Programa de Pós-graduação em Ciências Odontológicas - Área de Ortodontia, da Faculdade de Odontologia de Araraquara, Universidade Estadual Paulista, para obtenção do título de Doutor em Ortodontia.

Orientador: **Prof. Dr. João Roberto Gonçalves**

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Karina Eiras Dela Coleta Pizzol

**Alterações do tecido mole, espaço
faríngeo e estabilidade após avanço
maxilo-mandibular com rotação anti-
horária e prótese total de ATM**

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Tese para obtenção do grau de Doutor

**Presidente e Orientador: Prof. Dr. João Roberto
Gonçalves**

2º Examinador: Prof. Dr. Ary dos Santos-Pinto

3º Examinador: Prof. Dr. Roberto Henrique Barbeiro

4º Examinador: Prof. Dr. Darceny Zanetta Barbosa

5º Examinador: Profa. Dra. Terumi Okada

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Dados Curriculares

Karina Eiras Dela Coleta Pizzol

Nascimento: 09/02/76- Torrinha_S.P.

Filiação: Roberto Dela Coleta

Laura Helena Eiras Dela Coleta

1995/1998: Curso de Graduação

Faculdade de Odontologia de
Araraquara "Júlio de Mesquita
Filho"(UNESP)

1999/2002: Curso de Pós-Graduação em
Ortodontia, nível Mestrado, no
Centro de Pesquisas Odontológicas
São Leopoldo Mandic

2005/2008: Curso de Pós-Graduação em
Ortodontia, nível Doutorado, na
Faculdade de Odontologia
Araraquara (UNESP)

Dedicatória

A Deus,

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"Minhas imperfeições e fracassos são como uma bênção de Deus, assim como meus sucessos e meus talentos, e eu coloco ambos a seus pés."

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cumplicidade em todos os dias de nossas vidas.

"Se um dia tiver que escolher entre o mundo e o amor...

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*Se escolher o mundo ficará sem o amor, mas se
escolher o amor, com ele conquistará o mundo."*

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mesmo tempo, infinitamente delicado. "*

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esperar nada em troca e perceber que a vida pode ser
tão simples e bela quanto um olhar ou um sorriso.

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nós."*

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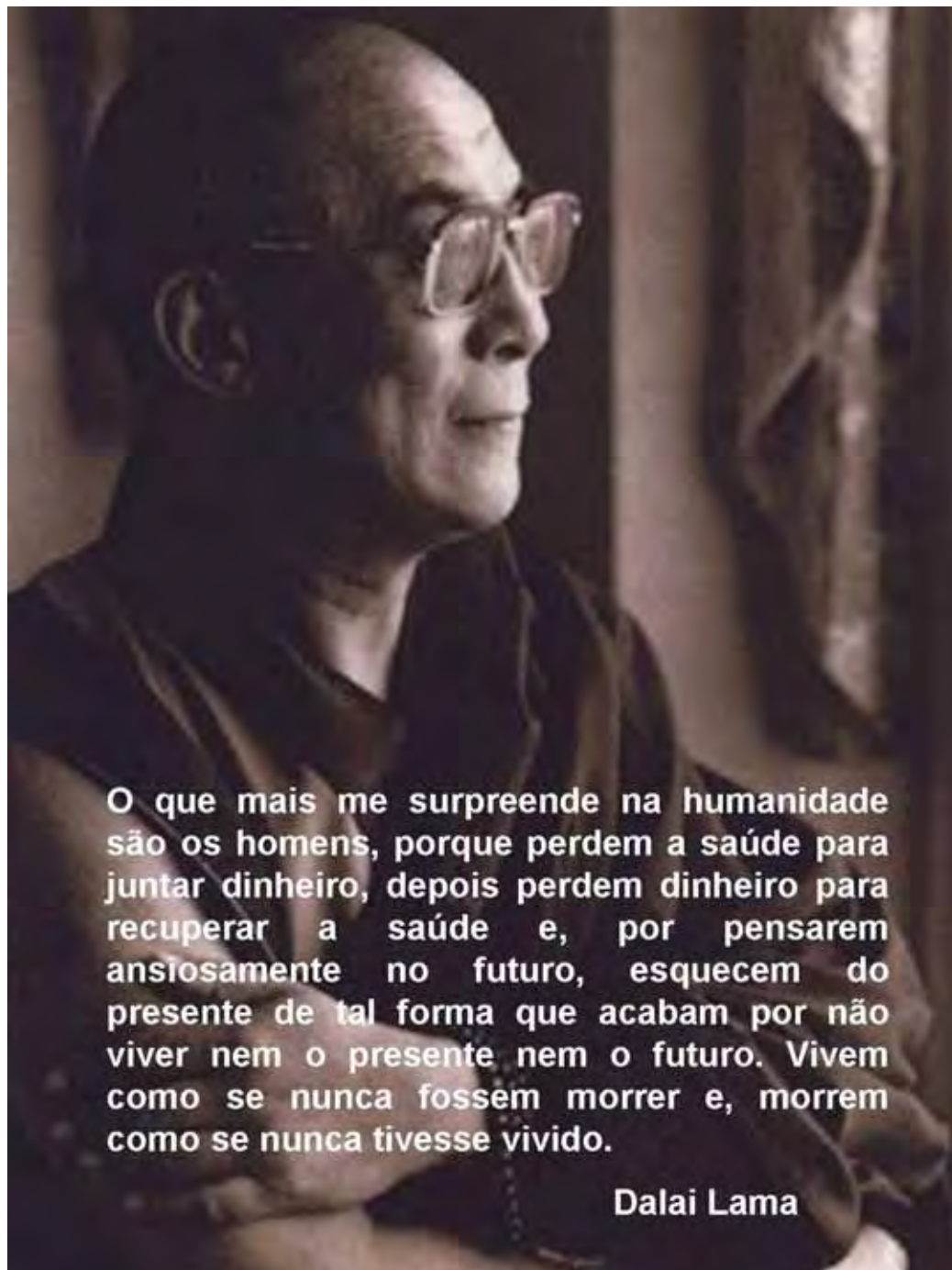
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Pizzol KEDC. Alterações do tecido mole, espaço faríngeo e estabilidade após avanço maxilo-mandibular com rotação anti-horária e prótese total de ATM [tese doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2008

Resumo

Este estudo avaliou a resposta do tecido mole, do espaço faríngeo e a estabilidade após avanço maxilo-mandibular com rotação anti-horária e reconstrução da ATM com próteses totais articulares do tipo TMJ Concepts system®. As mudanças cirúrgicas e pós-cirúrgicas foram analisadas utilizando-se telerradiografias laterais. Com o movimento cirúrgico, houve redução do ângulo do plano oclusal ($14,9 \pm 8,0^\circ$) e aumento do espaço aéreo faríngeo - PASnar (4,9mm). A região anterior da maxila moveu-se para a frente e para cima enquanto a porção posterior, para a frente e para baixo. A mandíbula avançou, e sofreu rotação no sentido anti-horário. No período pós-cirúrgico, a maxila apresentou alterações mínimas no plano horizontal, enquanto todas as medidas mandibulares permaneceram estáveis. A postura da cabeça (OPT/NS) mostrou flexão imediatamente após a cirurgia e extensão em longo prazo, enquanto a curvatura cervical (OPT/CVT) não apresentou mudanças. Os resultados cirúrgicos mostraram ainda aumento das distâncias entre a terceira vértebra cervical (C3) e o mento e desta com

o hióide, permanecendo estáveis durante o período de observação. A distância entre o osso hióide e o plano mandibular reduziu durante e após a cirurgia. Já a resposta do tecido mole evidenciou diferentes razões entre tecido duro/mole nos pacientes com e sem genioplastia. As mudanças horizontais na morfologia do lábio superior após avanço, impacção da maxila, sutura em VY e sutura da base alar mostraram maior movimento do que as mudanças observadas em tecido duro. O avanço maxilo-mandibular com rotação anti-horária do plano oclusal associado a próteses totais de ATM (TMJ Concepts system®) mostrou-se estável durante o período de observação. O espaço aéreo faríngeo aumentou significativamente, tendo sido influenciado pela posição da cabeça após a cirurgia. A resposta dos tecidos moles ante os movimentos esqueléticos realizados mostrou-se previsível.

Palavras-chave: Cirurgia; prótese articular; avaliação

Pizzol KEDC. Stability, soft tissue response and oropharyngeal airway space changes after maxillo-mandibular advancement and counter-clockwise rotation with total joint TMJ prostheses [tese doutorado]. Araraquara: Faculdade de Odontologia da UNESP; 2008

Abstract

This study evaluated stability, soft tissue response and oropharyngeal airway space changes after maxillo-mandibular advancement and counter-clockwise rotation with TMJ reconstruction using TMJ Concepts system® total joint prostheses. Lateral cephalograms were analyzed to estimate surgical and post surgical changes. During surgery, the occlusal plane angle decreased $14.9 \pm 8.0^\circ$ and the retroglossal airway space (PASnar) increased 4.9mm. The anterior region of maxilla moved forward and upward while the posterior nasal spine moved downward and forward. The mandible changed forward and rotated in a counter-clockwise direction. At long-term follow-up evaluation the maxilla showed minor horizontal changes, while all mandibular measurements remained stable. Head posture (OPT/NS) showed flexure immediately after surgery and extension long-term post surgery, while cervical curvature (OPT/CVT) had no significant changes. Surgery increased the distances between the third cervical vertebrae (C3) and menton, and C3 and hyoid, remaining stable afterwards. The distance from the hyoid to the mandibular plane decreased during surgery and in the longest

follow-up. Soft tissue response indicated different hard/soft tissue ratios between patients with or without genioplasties. Horizontal changes in upper lip morphology after maxillary advancement/impaction, VY closure, and alar base cinch sutures showed greater movement, than observed in hard tissue. TMJ Concepts total joint prostheses associated with maxillo-mandibular advancement and counter-clockwise rotation showed to be stable during the follow-up observation period. Immediate increase in oropharyngeal airway dimension, was influenced by post-surgical changes in head posture but remained stable over the follow-up period. Soft tissue changes showed a known predictable response.

Keywords: Surgery; joint prosthesis; evaluation



Introdução

1 Introdução

Certas patologias associadas à articulação temporo-mandibular podem gerar alterações clínicas envolvendo oclusão, músculos, respiração e estética facial¹⁸. Sintomas comuns da disfunção temporo-mandibular incluem sons/estalidos na ATM, dores, limitação de movimentos mandibulares, mudanças na oclusão, dificuldade mastigatória entre outros. Embora a grande maioria dessas disfunções articulares possa ser tratada com terapias não invasivas, existe um grupo restrito de pacientes com degenerações articulares irreversíveis que requerem reparo ou reconstrução cirúrgica, tradicionalmente realizada com tecido autógeno. Entretanto, quando esses enxertos autógenos são associados a avanços mandibulares de grande amplitude, observam-se resultados pouco previsíveis com freqüente reabsorção e recidiva. Algumas condições articulares específicas podem predispor a comportamento semelhante. Exemplos destas condições são: 1) ATMs previamente operadas (duas ou mais cirurgias anteriores); 2) colocação prévia de implantes aloplásticos de ATM contendo *Proplast/Teflon*, *Silastic*, acrílico ou cimentos ósseos; 3) patologias inflamatórias, infecciosas ou reabsorções condilares em adultos; 4) doenças auto-imunes ou dos ligamentos; 5) fibrose ou

anquilose; 6) ausência de ATM decorrente de patologia, trauma ou deformidade congênita e 7) tumores envolvendo a região da fossa e/ou cêndilo e ramo mandibular³³. Nesse caso, as próteses totais de ATM produzidas pelo processo de prototipagem são a melhor opção. Por meio da tecnologia CAD/CAM (computer assisted design/computer assisted manufacture) é possível obter detalhes anatômicos que permitem uma adaptação precisa para cada caso em particular.

As patologias de ATM podem afetar pacientes de qualquer idade e de ambos os gêneros. Quando essas condições (ex: artrite reumatóide, lúpus, doenças auto-imunes do tecido conjuntivo, reabsorção condilar idiopática entre outros) ocorrem em pacientes jovens, podem ocasionar alterações no crescimento maxilo-mandibular, deformidades dentofaciais, além de distúrbios respiratórios. Em pacientes adultos, processos degenerativos da ATM podem também alterar a morfologia crânio-facial com restrição importante do espaço aéreo faríngeo, exigindo reconstrução articular associada à cirurgia ortognática com finalidade de otimizar os resultados estéticos e funcionais^{5,25}.

Quando a cirurgia ortognática é realizada em associação à colocação de próteses articulares, é possível obter-se resultados mais estáveis³¹ para a correção da deformidade facial do que quando essa cirurgia é realizada sem levar em consideração o estado das ATMs^{20,26}. Entretanto, a estabilidade dos resultados não se restringe somente aos

fatores relacionados ao movimento cirúrgico ou à intervenção ou não nas ATMs, mas também a fatores que contribuem para o sucesso ou falha das próteses articulares como: hipersensibilidade ao metal³², micromovimento da prótese, perda de componentes da prótese, fratura ou corrosão do material^{2,4,10}, biocompatibilidade²⁻⁴, contaminação por bactéria^{11,12} e desenvolvimento de osso heterotópico ao redor da prótese³⁰.

Não existem trabalhos na literatura que se propõem avaliar a estabilidade do movimento ortodôntico-cirúrgico, bem como as mudanças respiratórias e de tecido mole, quando próteses totais articulares são colocadas concomitantemente ao ato cirúrgico. A grande maioria das pesquisas restringe-se a relatos da colocação isolada de próteses articulares sem correção da má oclusão esquelética associada ou propõe-se a avaliar a sintomatologia e os índices de qualidade de vida após o emprego dessa técnica.



Proposição

2 Proposição

2.1 Proposição geral

O objetivo deste estudo foi avaliar a estabilidade do avanço maxilo-mandibular com rotação anti-horária do plano oclusal, associado à prótese total de ATM (TMJ Concepts system®) sobre o comportamento esquelético, do tecido mole e do espaço aéreo faríngeo.

2.2 Proposições específicas

Este estudo tem como propósitos:

1. Avaliar a estabilidade do avanço com rotação anti-horária maxilo-mandibular associada à colocação de prótese total de ATM (TMJ Concepts system®);
2. Avaliar as mudanças e estabilidade no espaço aéreo faríngeo promovidas pela técnica cirúrgica;
3. Determinar se existe correlação entre a quantidade de movimento cirúrgico e as mudanças no tecido mole e determinar sua razão de correspondência;
4. Avaliar a influência da genioplastia nas mudanças do tecido mole.



Capítulos

Esta tese de Doutorado foi redigida em capítulos correspondentes a artigos de periódicos para publicação.

Capítulo 1 Maxillo-Mandibular Counter-Clockwise Rotation and Mandibular Advancement with TMJ Concepts® Total Joint Prostheses: Part I - Skeletal and Dental Stability

Karina E. Dela Coleta, Larry M. Wolford, João Roberto Gonçalves, Ary dos Santos Pinto, Lécio Pitombeira Pinto, Daniel Serra Cassano

Artigo submetido à publicação no periódico *International Journal of Oral Maxillofacial Surgery*.

Capítulo 2 Maxillo-Mandibular Counter-Clockwise Rotation and Mandibular Advancement with TMJ Concepts® Total Joint Prostheses: Part II – Airway Changes and Stability

Karina E. Dela Coleta, Larry M. Wolford, João Roberto Gonçalves, Ary dos Santos Pinto, Daniel Serra Cassano, Daniela A. Godoy Gonçalves

Artigo submetido à publicação no periódico *International Journal of Oral Maxillofacial Surgery*.

Capítulo 3 Maxillo-Mandibular Counter-Clockwise Rotation and Mandibular Advancement with TMJ Concepts® Total Joint Prostheses Part IV - Soft Tissue Response

Karina E. Dela Coleta, Larry M. Wolford, João Roberto Gonçalves, Ary dos Santos Pinto, Daniel Serra Cassano, Daniela A. Godoy Gonçalves

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Maxillo-Mandibular Counter-Clockwise Rotation and Mandibular

Advancement with TMJ Concepts® Total Joint Prostheses:

Part I - Skeletal and Dental Stability

¹Karina E. Dela Coleta,

²Larry M. Wolford,

¹Joao Roberto Gonçalves,

¹Ary dos Santos Pinto,

³Lécio Pitombeira Pinto,

²Daniel Serra Cassano,

¹Pediatric Dentistry Department - Araraquara Dental School, Sao Paulo State University, Brazil

²Department of Oral and Maxillofacial Surgery, Texas A&M University Health Science Center, Baylor College of Dentistry, Baylor University Medical Center, Dallas, TX, USA

³Department of Restorative Dentistry, Pharmacology, Dental and Nursing School, Federal University of Ceará, Fortaleza, Brazil

Address correspondence and reprint requests to:

Larry M. Wolford, DMD:

3409 Worth St, Suite 400

Dallas, TX 75246

Phone: 214-828-9115

Phone: 214-828-1714

E-mail: lwolford@swbell.net

Abstract

The purpose of this study was to evaluate skeletal and dental stability in patients that had TMJ reconstruction and mandibular counter-clockwise advancement using TMJ Concepts total joint prostheses (TMJ Concepts Inc. Ventura, CA) with maxillary osteotomies being performed at the same operation. Forty-seven females (14 to 57 years old) met the criteria for inclusion with an average post surgical follow-up of 40.6 months (range 12 to 143 months). Lateral cephalograms were analyzed to estimate surgical and post surgical changes. During surgery, the occlusal plane angle decreased $14.9 \pm 8.0^\circ$. The maxilla moved forward at ANS $1.3 \pm 2.4\text{mm}$, point A $2.5 \pm 2.2\text{mm}$, and upper incisor tip (U1T) $5.6 \pm 3.0\text{mm}$ and upward at ANS $-0.6 \pm 1.9\text{mm}$, point A $-1 \pm 1.9\text{mm}$, and U1T $-1.3 \pm 1.9\text{mm}$. The posterior nasal spine moved downward and forward $5.5 \pm 4.2\text{ mm}$ and $2.9 \pm 3.1\text{ mm}$ respectively. The mandible advanced $7.9 \pm 3.5\text{ mm}$ at the lower incisor tips, $12.4 \pm 5.4\text{ mm}$ at point B, $17.3 \pm 7.0\text{ mm}$ at menton, $18.4 \pm 8.5\text{ mm}$ at pogonion, and $11.0 \pm 5.3\text{ mm}$ at gonion. Vertically the lower incisors moved upward $-2.9 \pm 4.0\text{ mm}$, B point and Pog remained unchanged but Me moved downward $2.6 \pm 3.9\text{ mm}$ and Go $18.4 \pm 9.2\text{ mm}$. At longest follow-up post surgery, the maxilla showed minor horizontal changes while all mandibular measurements remained stable. TMJ reconstruction and mandibular advancement with TMJ Concepts total joint prosthesis in conjunction with maxillary osteotomies for counter-clockwise rotation of the maxillo-mandibular complex was a stable procedure for these patients at the longest follow-up.

Key words: Orthognathic Surgery; TMJ prostheses; Stability

Introduction

Temporomandibular joint (TMJ) pathology can create clinical problems including masticatory musculature, jaws, occlusion, and other associated structures resulting in pain and jaw dysfunction. Although many cases of TMJ dysfunction and symptoms can usually be managed with non-surgical therapies, there remains a group of patients with irreversible TMJ damage, requiring surgical repair or reconstruction; traditionally with autogenous tissues. However, certain specific TMJ conditions and pathology can have adverse outcomes using autogenous grafts, producing a significant failure rate with their use^{7,23}. These conditions include: 1) multiply operated TMJs (2 or more previous operations); 2) previous TMJ alloplastic implants containing Proplast/Teflon (PT, Vitek Inc., Houston, TX), Silastic (Dow Corning Inc, Midland, MO), acrylic, bone cements, metal-on-metal articulations or failed prostheses; 3) inflammatory, infective, reactive, or resorptive TMJ pathologies; 4) connective tissue and autoimmune diseases; 5) fibrous and bony ankylosis; 6) absence of TMJ structures due to pathology, trauma, or congenital deformity; and 7) tumors involving the fossa and/or condyle and mandibular ramus region²⁸. In these cases a custom-made total joint prostheses may be the best option. Using CAD/CAM (computer assisted design/computer assisted manufacture) technology, prostheses are designed and manufactured to fit the specific anatomical requirements for each patient.

TMJ pathology can affect patients of any age and both genders but, when these conditions occur in young patients, maxillo-mandibular growth alterations commonly occur resulting in dentofacial deformities and associated malocclusions. In adults, TMJ pathology (i.e., rheumatoid arthritis, psoriatic arthritis, reactive arthritis, condylar fractures, etc) can also cause dentofacial deformities. Degenerative pathological

processes of the condyles may require TMJ reconstruction and orthognathic surgery to achieve optimal functional and esthetic results.

Consideration should be given for surgical correction of co-existing TMJ pathology as part of the orthognathic surgical correction plan. Wolford et al.²⁷, routinely perform concomitant TMJ and orthognathic surgery for correction of patients with co-existing dentofacial deformities and TMJ internal derangement, with a high success rate. There have been variable success rates reported for TMJ prostheses, ranging from 60% to 100%¹⁶. There are risks and complications that can occur with the use of TMJ total joint prostheses. A common problem in patients with previous PT and Silastic implants as well as bone cements, acrylic, or metal-on-metal articulations, is the recurrent development of foreign body giant-cell reaction (FBGCR) and reactive bone that can cause limited jaw function as well as pain, fibrous and/or bony ankylosis. When reconstructing these patients with the TMJ Concepts total joint prostheses, packing autologous fat grafts around the articulating area of the prostheses has been shown to decrease the FBGCR and minimize the occurrence of excessive joint fibrosis and heterotopic calcification, consequently providing improved range of motion in prosthetic TMJ reconstruction and decreased pain²⁵.

There are many known factors which influence the success or failure of the total joint prostheses. The challenge is to minimize these factors such as metal hypersensitivity²⁶, prosthesis micro movement, loosening of the prosthetic components, material wear, break-down, and corrosion⁷, biocompatible and functionally compatible materials², FBGCR^{7,11}, prosthesis failure^{11,19}, bacterial contamination, and development of heterotopic/reactive bone around the prostheses²⁵.

It is considered a surgical success at long-term follow-up when the total joint prostheses provide TMJ and occlusal stability, improve function, decrease pain, and a long functional lifetime. Previous studies^{9-13,23,24,28,29} have showed that TMJ reconstruction with total joint prostheses resulted in a significant decrease in pain, and improvement in jaw function, diet and maximal interincisal opening. The present study has the specific purpose of evaluating skeletal and dental stability of TMJ reconstruction and mandibular advancement in a counter-clockwise direction using TMJ total joint prostheses with maxillary osteotomies being performed at the same operation.

Patients and Methods

This retrospective study evaluated records of 50 consecutive patients from a single private practice, from 1990 through 2003, who underwent TMJ reconstruction and counter-clockwise rotation of the maxillo-mandibular complex. Criteria for study inclusion were: 1. End-stage bilateral or unilateral TMJ reconstruction and mandibular advancement using custom-made TMJ total joint prostheses (TMJ Concepts system®), and maxillary osteotomies for counter-clockwise rotation of the maxillo-mandibular complex and occlusal plane angle; 2. All surgical procedures performed by one surgeon (L.M.W.) at Baylor University Medical Center, Dallas, TX, USA; 3. Use of maxillary and mandibular rigid fixation; 4. Females at least 14 years of age and males at least 17 years of age; 5. Absence of post surgical trauma; and 6. Minimum of 12-month post surgery follow-up. Patients were rejected based on the following criteria: 1. Craniofacial syndromes; and 2. Records (radiographs) inadequate or poor quality. There were 49 patients (47 females, 2 males) meeting the criteria, with one female

patient excluded because of less than 12 month follow-up. The two males were excluded from the study to make a homogeneous sample of 47 females (Table 1).

The custom-made total joint prostheses used in this study, were originally developed in 1989 by Techmedica Inc., Camarillo, CA, USA, and since 1997, have been manufactured by TMJ Concepts, Inc., Ventura, CA, USA. These prostheses are CAD/CAM devices (computer assisted design/computer assisted manufacture), designed to fit the specific anatomical requirements for each patient.

Forty-three patients had bilateral TMJ reconstruction and 4 patients had a unilateral prosthesis with a sagittal split osteotomy on the contra-lateral side. All patients had Le Fort I maxillary osteotomies, most with segmentation. All patients had coronoidectomies on the prosthesis side(s) at the reconstruction surgery or at a previous surgery. Mean patient age at the time of surgery was 34.5 years (range, 14 years to 57 years). Presurgical (T1) records were taken 1 day (range, 1 to 6 days) before surgery; immediate post surgical (T2) records were taken 5 days (range, 2 to 16 days) after surgery; and longest follow-up (T3) records were taken at a mean of 40.6 months (range, 12 to 143 months) after surgery.

Imaging evaluation

Two examiners were calibrated by repetition of the process until the method was considered adequate by a third examiner. Standardized lateral cephalometric radiographs (Quint Sectograph; American Dental Co, Hawthorne, CA) were randomly traced by one and digitized twice by other of the investigators approximately 1 week

apart. Average values between the 2 replicates were used to decrease landmark technical errors.

There were 16 landmarks identified by one examiner and digitized using DFPlus software (Dentofacial Software Inc, Toronto, Canada). The following landmarks were used to compute 25 measurements (Tab 2, Fig 1): Nasion, Sella, Point A, Anterior nasal spine, Posterior nasal spine, Point B, Pogonion, Menton, Gonion, and dental points. S-N minus 7° was used as the horizontal reference plane (HRP) and a line perpendicular through sella as the vertical reference plane (VRP). Horizontal and vertical changes for each landmark were evaluated. Surgical changes were computed as the differences between T2 and T1 values and post surgical changes between T3 and T2 values.

Null hypothesis

Mandibular advancement with counter-clockwise rotation of the occlusal plane with total joint TMJ prostheses is an unstable procedure.

Statistical method

All data were transferred to SPSS (release 9.0; SPSS Chicago, IL) for statistical analysis. The skewness and kurtosis statistics showed normal distributions for all variables. Paired *t* tests were performed to evaluate the surgical (T2-T1) and post surgical changes (T3-T2). A significance level of $p < .05$ was applied. The reliability of tracing, landmark identification, and analytical measurements had an intraclass correlation coefficient greater than 0.94.

Patients who received bilateral TMJ prostheses (n=43) and unilateral (n=4) were compared as separate groups. Because there were no statistically significant differences between those groups in post surgical changes, all the patients were analyzed as a single group. Patients were also divided into two groups with group 1 having 12 to 24 months post surgical follow-up (n = 18) and group 2 having 25 to 143 months follow-up (n = 29). There were no statistically significant differences in any of the parameters evaluated between the two groups. Therefore, all 47 patients were analyzed as a single group.

Surgical Technique

Seven patients required a preliminary surgical stage to remove previously placed, failed total joint prostheses that contained metal (i.e. Vitek total joint prostheses, Vitek Inc., Houston, TX; Christensen total joint prostheses, TMJ Implants Inc., Golden, CO) , so that an accurate CT scan could be taken. Metal in the TMJ and/or ramus can interfere with the CT scan imaging data, and significantly distort the 3-dimensional (3-D) plastic model on which the custom-made total joint prostheses are made. CT scans were taken on all patients extending from supero-posterior to the TMJ to anterior to the chin, maxilla and nasal bones. The 3-D plastic model was then created using stereolithography technology (Figure 3 A). A surgical prediction tracing was developed from a presurgical lateral cephalometric radiograph to determine the desired final position of the maxilla and mandible. The 3-D model was mounted on an anatomical articulator and precise model surgery performed to reposition the mandible to the desired post surgical position relative to the maxilla that remained in its original position on the model. Once the mandibular position was achieved, the mandible was secured to the maxilla by placing quick-cure acrylic inter-occlusally to lock-in the

position of the mandible. The condyles were cut off and if indicated, bony recontouring of the fosse and lateral aspect of the rami was completed. Any recontouring on the 3-D model had to be accurately duplicated on the patient at the time of surgery.

The custom-made total joint prostheses were then manufactured using CAD/CAM technology on the 3-D model to fit the patient's specific anatomical requirements (Figure 3 B). Immediately prior to surgery, the mandibular movements done on the 3-D model were accurately duplicated on anatomically mounted dental models, and an intermediate splint constructed to aid in repositioning the mandible. The maxillary model was then repositioned and sectioned if necessary to achieve the best occlusal relationship. A final splint was constructed when indicated.

At surgery, an endaural or preauricular approach was used to perform the condylectomy, joint debridement, coronoidectomy to release the temporalis muscle, and if indicated, accurate bony recontouring of the fossa as dictated by the recontouring done on the 3-D model. Through a submandibular approach, the medial pterygoid and masseter muscles were reflected off the mandibular ramus and lateral recontouring completed as indicated from the 3-D model. The mandible was then mobilized and repositioned using the intermediate splint and inter-maxillary fixation applied. The fossa component was inserted through the endaural / preauricular incision and stabilized to the zygomatic arch with 3 to 4, 2 mm diameter bone screws. The mandibular prosthetic component was inserted through the submandibular incision and stabilized to the ramus with 8 to 12, 2 mm diameter bone screws. Following stabilization of the prostheses, most patients had fat grafts (usually harvested from the

abdomen) packed around the articulating area of the prostheses to help prevent fibrosis and heterotopic/reactive bone formation post surgery. The incisions were closed.

Multiple maxillary osteotomies were then performed to establish the best possible functional and esthetic result, since presurgery the maxilla was usually AP retruded as well as had anterior vertical maxillary excess and/or posterior vertical maxillary deficiency with a high occlusal plane angulation. The maxilla was stabilized with bone plates and porous block hydroxyapatite grafts (PBHA, Interpore 200, Interpore Inc., Irvine, CA).

When indicated, genioplasty, turbinectomies, nasoseptoplasty, rhinoplasty, etc., were performed at the same surgery. Many of these patients, particularly those with significant retrognathia, had moderate to severe presurgical sleep apnea symptoms because of the decreased oropharyngeal airway. The suprahyoid muscles were not deliberately detached from the genial tubercles in any of the cases. Alloplastic materials such as PBHA or HTR (Hard Tissue Replacement, Walter Lorenz Inc, Jacksonville, FL) were used for augmentation genioplasties although some patients had osseous genioplasties.

Post surgery, no maxillo-mandibular fixation was used in any cases, but light interarch elastics were routinely applied to help support the mandible, since the muscles of mastication were reflected from the mandible and were initially non-functional. Post operative elastics were generally discontinued following adequate functional return of the pterygomasseteric musculature (usually 2 to 4 weeks post surgery), unless required for finishing orthodontic mechanics. Passive physical therapy was used on all patients

beginning approximately 6 to 8 weeks post surgery. Patients were instructed to open and close their jaws and begin shifting their jaws from side to side 4 to 5 sessions per day for 10 to 15 minutes each session. Patients were maintained on a puree to soft diet for 4 months post surgery to allow the maxilla to complete the initial bone healing phase. Patients were then encouraged to begin working up to a normal diet. Orthodontic appliances were usually maintained for at least 6 months post surgery and then removed at the discretion of the orthodontist.

Results

Surgical changes (T2-T1)

Initial values, surgical and longest follow-up changes are listed in Table 3. The mean surgical changes showed upward and forward movement of the maxillary anterior region (Fig 2). The horizontal movement of anterior nasal spine (ANS) was 1.3 mm (range -7.3 to 7.1mm), and point A was 2.5 mm (range -6.0 to 6.8 mm). In the horizontal direction, positive values mean forward movement, negative values mean posterior movement. The vertical movement (positive values mean downward movement, negative values mean upward movement) of the ANS was -0.6 mm (range -4.0 to 3.4 mm) and point A was -1.0 mm (range -4.2 to 3.3 mm). Posterior nasal spine (PNS) was displaced downward 5.5 mm (range 1.8 to 14.3 mm) and forward 2.9 mm (range -3.9 to 10.9 mm). The upper incisor tip (U1T) moved forward 5.6mm (range -0.6 to 11.3 mm) and vertically -1.3 mm (range -5.7 to 2.6 mm).

All the anterior mandibular measurements were advanced in a horizontal direction with lower incisor tip (L1T) 7.9 mm (range 0.9 to 14.3 mm), point B 12.4 mm (range 1.7 to 22.5 mm), Pogonion (Pog) 18.4 mm (range 2.1 to 42.1 mm), and Menton

(Me) 17.3 mm (range 2.6 to 32.8 mm). In the vertical direction, L1T showed a superior movement of -2.9 mm (range -16.5 to 2.3 mm), while B point and Pog showed no movement. However, Me showed an inferior movement of 2.6 mm (range -6.7 to 12.5 mm). Gonion (Go) moved downward 18.4 mm (range -1.5 to 43.4 mm) and forward 11.0 mm (range 2.8 to 25.6 mm). The occlusal plane angle (OPA) relative to HRP decreased a mean -14.9° (range -37.0 to -2.3°) and SNPog angle increased 9.1° (range 1.0 to 20.1°).

There was a surgical increase in the SNA angle of 2.3° (range -6.5 to 6.4°) and SNB of 6.9° (range 1.0 to 12.8°). The ANB angle decreased -4.6° (range -10.5 to 2.2°) because of the greater increase of the SNB value compared to SNA. Overjet (OJ) decreased -2.2 mm (range -7.4 to 1.8 mm). Overbite (OB) increased 1.6 mm (range -14.7 to 3.9 mm).

Post surgical stability (T3-T2)

Point A and posterior nasal spine (PNS), in their horizontal direction only, showed a change backwards of -0.4 mm (range -2.8 to 5.0 mm) and -0.8 mm (range -8.4 to 3.9 mm) respectively, that were considered statistically significant ($p < 0.05$). The remaining maxillary landmarks remained stable. All the anterior mandible measurements (L1T, B, Pog, Me) showed no statistically significant change at long-term follow-up ($p < 0.05$). Neither OPA nor SNPog angles had significant changes long term post surgery. Therefore, all horizontal and vertical mandibular measurements remained stable during the follow-up period (Table 3). There was a mean decrease in the ANB angle of -0.4° (range -2.6 to 5.4°), while SNA, SNB and overjet (OJ) showed

no statistically significant change (T3-T2). Overbite (OB) increased 0.7 mm (range -0.7 to 2.1 mm).

Case 1: (CT patient #41) This 28 year old female presented 4 years post trauma that involved multiple mandibular fractures including bilateral subcondylar fractures, comminution of the right condyle, symphysis fracture with loss of a central incisor, as well as fracture of the anterior maxilla resulting in the loss of 7 teeth from the left lateral incisor through the right 2nd bicuspid. The missing teeth were previously replaced with 5 osseo-integrated dental implants and a prosthesis. She had one previous surgery on her right TMJ with no improvement. Her diagnoses included: 1) Right TMJ severe arthritis, 2) Anterior open bite, 3) Transverse facial asymmetry, and 4) Retruded maxilla and mandible (Fig 4 A and B; 5 A-C; 6 A). She had severe right TMJ pain, headaches, myofascial pain, and difficulty eating and chewing.

Following orthodontic preparation, surgery was performed (Figure 6 B) in one operation including: 1) Right TMJ reconstruction and mandibular counter-clockwise advancement (right ramus was lengthened and advanced 26 mm) with a custom made TMJ total joint prosthesis (TMJ Concepts system®), 2) Right coronoidectomy, 3) Left mandibular ramus sagittal split osteotomy, and 4) Multiple maxillary osteotomies to down graft the posterior aspect, advance it, and transversely level the occlusal plane. The A-P occlusal plane was decreased 16 degrees. The patient's longest follow-up at completion of the study was 79 months post surgery showing good stability (Figures 4 C and D; 5 D-F), with elimination of TMJ pain, headaches, and myofascial pain; improved jaw function, occlusion, and facial esthetics. The patient recently returned for a follow-up evaluation at 18 years post surgery (Figures 4 E and F, 5 G-I, 6 C). She

remains pain free with good jaw stability (Figure 6 D), esthetics, and function with an incisal opening of 42 mm.

Case 2: (TW, patient # 47) This 25 year old female was referred after failed previous bilateral TMJ surgery, maxillary osteotomies, and genioplasty (Fig. 7 A and B; 8 A-C; 9 A). She reported problems with other joints and a rheumatology evaluation diagnosed a non-specific CTAD. MRI showed severe condylar resorption and a reactive pannus surrounding the TMJ articular discs. Her surgical diagnoses included: 1) Severe bilateral condylar resorption, 2) Maxillary A-P and posterior vertical hypoplasia, 3) Severe A-P mandibular hypoplasia, 4) Class II occlusion with severe apertognathia (7 mm), 5) Decreased oropharyngeal airway (A-P dimension of 2 mm, where normal is 11 ± 2 mm) causing severe sleep apnea, 6) Severe masticatory dysfunction, and 7) Severe TMJ and myofascial pain.

The surgical procedures performed (Figure 9 B) included: 1) Bilateral TMJ reconstruction and mandibular advancement in a counter-clockwise direction utilizing the TMJ Concepts/Techmedica custom-made total joint prostheses with the rami lengthened 17 mm and the chin (pogonion) advanced 24 mm, 2) Bilateral coronoidectomies, 3) Multiple maxillary osteotomies with the maxillary incisor tips advanced 7 mm and the posterior maxilla inferiorly positioned 5 mm stabilized with bone plates and PBHA grafts, and 4) Osseous chin augmentation (Figure 9 B). The mandibular occlusal plane was surgically decreased 19 degrees. At 6 years post surgery, the patient maintained a stable facial balance and occlusion (Figure 7 C and D, 8 D-F, 9 C and D). Incisal opening improved from 24 mm presurgery to 42 mm post

surgery. Pain levels decreased from 9 at T1 to 1 at T3. The sleep apnea was resolved, and the patient could eat relatively normally.

Discussion

TMJ reconstruction with total joint prostheses is indicated in specific TMJ conditions and pathology with irreversible joint damage. Some of those progressive TMJ disease conditions (i.e., rheumatoid arthritis, psoriatic arthritis, reactive arthritis, idiopathic condylar resorption, etc.) are predominantly found in females and can result in malocclusion, facial disfigurement, TMJ dysfunction, and pain^{7,9-13,23,29}.

The demographic data from our study revealed that the need for maxillo-mandibular surgery with total joint TMJ prostheses reconstruction involves a relatively younger patient population (many under the age of 40 years including teenagers), which means that the longevity of the prosthesis is an important variable. Longevity and stability of any implanted joint prosthesis is based on the proper indication for its use, correct placement and maintenance of the prosthesis, the properties and biocompatibility of the materials used, recipient's biological acceptance of the device, the implant's stability in situ, and the ability of the recipient to understand the limitations involved with having a prostheses in place. TMJ Concepts custom-made total joint prosthesis system was designed with these factors in mind⁹.

Previous studies have shown that TMJ reconstruction with this specific total joint prosthesis system resulted in a significant improvement in pain, function, diet and increase in maximum interincisal opening^{9-13,23,28,29}. There are only a few studies currently available in the literature concerning stability of maxillo-mandibular surgery

associated with total joint prostheses^{23,29}. This present study evaluated this aspect of TMJ prostheses using the TMJ Concepts custom-made total joint prostheses.

In this study, surgical changes showed upward and forward movement of the anterior region of the maxilla, while the posterior region was displaced downward and forward; thus the palatal plane angle also rotated in a counter-clockwise direction. The amount and direction of the surgical movement of the maxilla was directly related to the mandibular movement.

The post surgical stability of upward maxillary repositioning by Le Fort I osteotomy, was shown to be relatively stable by many authors^{3,17,18}. According to the literature the stability of the surgical movement of the maxilla (in the vertical and horizontal planes) was stable with counter-clockwise rotation of the maxillo-mandibular complex in the presence of healthy TMJs^{4,22}. In our study, point A showed a post surgical mean change of -0.4mm in the horizontal plane, and although clinically insignificant, it was statistically significant. This alteration can be explained in part by post surgical bone remodeling or by post surgical orthodontic movement. Point A is considered a dento-alveolar point, being subject to alteration of incisor position. With retraction of maxillary incisors, Point A can move posteriorly, and soft tissue tension created by maxillary advancement can also cause remodeling of point A. The posterior nasal spine (PNS) showed a clinically minimal post surgical mean horizontal movement of -0.8 mm, but statistically significant. This change can be associated with bone remodeling also. Most of the cases studied received three pieces maxillary segmentation with a midline split in the palate that could affect the posterior nasal spine anatomy with consequential bony remodeling.

In reference to the counter-clockwise rotation and advancement of the mandible, all of the anterior points of the mandible remained stable in the post surgical long-term follow-up period. The mean mandibular advancement at the incisor tips was 7.9 mm, Point B 12.4 mm, and pogonion substantially greater with 18.4 mm as a result of the counter-clockwise rotation of the maxillo-mandibular complex. The counter-clockwise rotation resulted in pogonion advancing 6.0 mm more than point B and 10.5 mm more than the lower incisor tips. This demonstrates the advantage of counter-clockwise rotation in advancing the mandible and chin in the high occlusal plane angle facial type patient. Decrease in the occlusal plane and mandibular plane angles were directly correlated with the anterior movement of the mandible. Our clinical results, confirm Wolford et al.²² previous supportive research and philosophy that maxillo-mandibular counter-clockwise rotation, in high occlusal plane facial types, may improve function and esthetics with a stable occlusion^{4,22}.

In the vertical plane, the counter-clockwise rotation of the mandible resulted in an upward movement of L1T and no movement at B point and Pog. The mean Menton surgical movement was in a downward direction as a result on geometrically up-righting the anterior aspect of the mandible (L1T to Me) causing Menton to rotate downward and forward compared to the lower incisor tips. Gonion showed a major downward surgical movement, due to reorientation of the mandibular ramus in that direction.

The long-term post surgical mandibular stability in this study was found to be comparable to the results of Chemello et al.⁴, with counter-clockwise rotation of the

maxillo-mandibular complex and occlusal plane in patients with healthy TMJs. These results are significantly better than those found by other authors such as Moore et al.¹⁴; Arnett & Tamborello¹, in which mandibular surgical advancement (without counter-clockwise rotation) was performed on patients without regard to the presence or absence of TMJ pathology, nor was any appropriate TMJ surgical intervention provided for any of the patients with TMJ pathology in those studies. This allowed post surgical relapse related to condylar remodeling and resorption to occur in some of their patients.

One of the biggest changes with the surgery in our study occurred in the occlusal plane angle. According to Ricketts¹⁵, the normal occlusal plane angle is 8 ± 4 degrees and is defined as: A line tangent to the lower bicuspid cusp tips through the second molar buccal groove and the angle formed with the Frankfort horizontal plane. In our study, the T1 occlusal plane angle was a mean of 25.1° and was surgically decreased at T2 to a mean of 10.2° with a mean change of 14.9° . The alteration of this angle is significantly influential on the horizontal and vertical menton position. With a decrease in the occlusal plane angulation, there is an increase of the horizontal projection of Menton compared to the lower incisor tips. Counter-clockwise rotation of maxillo-mandibular complex with mandibular advancement has inherent risks to the healthy as well as the TMJ with untreated pathology. The mandibular lever arm is lengthened so the soft tissues including skin, muscles, periosteum, etc., are stretched increasing the load to the TMJs. This can create or exacerbate TMJ problems.

Post surgical increased loading of the joints occurs until the TMJs, soft tissues, muscles, skeletal structures, and occlusion reach a state of equilibrium and adaptation to the new position, which could take several months. Although advancement of the

maxillo-mandibular complex in a counter-clockwise direction may further increase the loading of the TMJ by stretching the associated soft tissues, it is a very stable procedure in the presence of healthy TMJs^{4,6,22,27}. According to Wolford et al.^{6,30,31}, patients with co-existing TMJ dysfunction undergoing mandibular advancement without surgical correction of the TMJ pathology, are likely to have significantly increased signs and symptoms of TMJ dysfunction and pain.

Several studies have noted that at some period after surgery, the condyles tend to move posteriorly and superiorly in the fossa following mandibular advancement^{20,21}. Van Sickels et al.²⁰ noted this phenomenon with both wire osteosynthesis and rigid fixation from 8 weeks to 2 years after surgery. This posterior movement may be an adaptive response to mandibular advancement and change in the fulcrum arm length of the mandible, related to TMJ disc position change pre and post surgery, and/or soft tissue tension related to the advancement.

In our study, the joints were replaced by TMJ total joint prostheses (TMJ Concepts system), making it possible to get highly predictable functional, esthetic and stable results, since the TMJ prostheses are not affected by muscle adaptation, disc position, or physiological loading of the joints.

The Techmedica custom-made total joint prostheses (now manufactured by TMJ Concepts) were previously evaluated by Henry & Wolford⁷, to determine the outcomes in patients with a history of Proplast-Teflon (PT) TMJ implants. Twenty-six patients (43 joints) were evaluated, with a follow-up from 4 to 24 months. The prosthesis provided an 86% success rate relative to stability and function, with a level

of residual pain rated as good in 46%, fair 38%, and poor in 16% of the patients. The residual pain for the most part was related to the multiply operated patients, pre surgical irreversible pain, and continued foreign body giant cell reaction from failed previous TMJ alloplastic implants and prostheses containing PT.

The main problems associated with TMJ total joint reconstruction is related to wear at the articular surfaces, foreign body reaction, mobility of the implant with displacement, and implant fracture, caused by the use of inappropriate alloplastic materials⁵. Wolford & Karras²⁵ conducted a comparative study on patients who had Techmedica total joint prostheses placed. A total of 22 patients had fat grafts placed and were compared with 37 patients without fat grafts. Statistically significant improvement was found for MIO and excursive movements in the fat-grafted joints compared with the non-grafted joints. In addition, 35% of the non-grafted joints required additional surgery for the removal of heterotopic/reactive bone or severe fibrosis, whereas none of the fat-grafted joints required secondary joint surgery.

Because TMJ patients are often relatively young (mean age in this study was 35 years), a total TMJ prosthesis must have a very long lifetime and once the prosthesis is implanted, there is no way to go back to the previous anatomy¹⁹. Our follow-up period ranged from 12 to 143 months, with a median of 40.6 months. Only 10 patients had been followed for five years or more. It will be important to continue to monitor groups of patients such as ours over the coming years, particularly the younger patients. Speculand et al.¹⁶ stated that it is not possible to determine the lifetime of this type of TMJ prostheses. Wolford²⁴, demonstrated that custom-made total joint prostheses, constructed with materials used as the gold standard for orthopedic joint devices, work

very well for TMJ reconstruction. Total joint prostheses with use of appropriate materials are the only predictable alternative for many patients. During the past 19 years that these prostheses have been available, the senior author (LMW) has placed over 540 prostheses and has not replaced any because of wearing out. The longevity of the prostheses remains unknown.

The current study demonstrates that the TMJ Concepts total joint prostheses work well with good stability at longest follow-up (12 to 143 months), and is a viable technique for TMJ reconstruction, with mandibular advancement and counter-clockwise rotation of the maxillo-mandibular complex and occlusal plane, when indicated for patients with irreversible end-stage TMJ pathology and co-existing dentofacial deformity.

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Legends

Table 1. Demographics of the 47 female patients included in the study.

Table 2. Cephalometric landmarks used for analysis.

Table 3. Initial values, surgical and post surgical changes.

Figure 1. Reference landmarks and lines measured on a lateral cephalogram. The horizontal reference plane (HRP) was constructed at 7° to the SN plane through sella (S). The vertical reference plane (VRP) was constructed perpendicular to HRP through sella (S).

Figure 2. Superimposition of pre and post surgical lateral cephalograms demonstrate the surgical changes achieved.

Figure 3: A, A 3-D stereolithography model of the patient's jaws and jaw joints was constructed from CT scan data. The mandible was repositioned on the model. The red marks indicate areas of bony recontouring to facilitate the fit of the prosthesis. **B,** Custom-fitted total joint prostheses are constructed to fit the specific anatomical requirements for each patient.

Figure 4: Case 1 (CT, patient # 41) **A, B,** This 28 year old female is seen 4 years post trauma with multiple mandibular fractures and loss of 8 maxillary teeth. She presents with right TMJ severe arthritis and pain. The mandible and maxilla are significantly retruded with a high occlusal plane angle and transverse asymmetry. **C, D,** the patient is

seen 79 months post surgery following right TMJ reconstruction and mandibular advancement with custom-made TMJ total joint prostheses, left mandibular ramus sagittal split for advancement, and maxillary osteotomies. **E, F**, The patient was recently evaluated at 18 years post surgery showing the maintenance of good facial balance.

Figure 5: Case 1 – **A-C**, the presurgical occlusion demonstrates anterior open bite and the replacement of 7 teeth (left lateral incisor through the right 2nd bicuspid) with osseointegrated implants and prosthesis. **D-F**, the occlusion remained stable 79 months post surgery. **G-I**, at 18 years post surgery, she maintained a stable occlusion.

Figure 6: Case 1 – **A**, the pretreatment cephalometric analysis shows a retruded maxilla and mandible, anterior open bite, steep occlusal and mandibular plane angles, vertical facial asymmetry, and significant degenerative changes in the right condyle. **B**, the STO (prediction tracing) demonstrates the TMJ and orthognathic procedures required to achieve a good functional and esthetic result including right TMJ reconstruction and mandibular advancement with custom made TMJ total joint prostheses, left mandibular ramus sagittal osteotomy, right coronoidectomy, and maxillary osteotomies for counter-clockwise rotation and transverse leveling of the maxillo-mandibular complex. **C**, Cephalometric analysis at 18 years post surgery demonstrates good facial balance. **D**, Superimposition of the immediate post surgery (red lines) and 18 year follow-up (black lines) cephalometric tracings demonstrate the treatment stability achieved for this patient.

Figure 7: Case 2 – **A, B**, this 25 year old female presented with severe TMJ arthritis, significantly retruded maxilla and mandible, high occlusal plane angle, severe pain, and severe sleep apnea. **C, D**, the patient is seen 6 years post surgery following bilateral TMJ reconstruction and mandibular advancement with custom-made TMJ total joint prostheses (TMJ Concepts system®), bilateral coronoidectomies, simultaneous maxillary osteotomies, and genioplasty demonstrating a good stable, functional and esthetic outcome. She had a significant decrease in pain and elimination of the sleep apnea.

Figure 8: Case 2 – **A-C**, the presurgical occlusion demonstrated an anterior open bite (7 mm) and Class II end-on cuspid relationship. **D-F**, the occlusion remained stable 6 years post surgery.

Figure 9: Case 2 – **A**, the pretreatment cephalometric analysis shows a retruded maxilla and mandible, anterior open bite, steep occlusal and mandibular plane angles, and severely decreased oropharyngeal airway. **B**, the STO (prediction tracing) demonstrates the TMJ and orthognathic procedures required to achieve a good functional and esthetic result including bilateral TMJ reconstruction and mandibular advancement with custom-made TMJ total joint prostheses (TMJ Concepts system®), bilateral coronoidectomies, maxillary osteotomies for counter-clockwise rotation of the maxillo-mandibular complex and occlusal plane angle, and osseous genioplasty. **C**, Cephalometric analysis at 6 years post surgery demonstrates good facial balance. **D**, Superimposition of the immediate presurgery (red lines) and 6 year post surgery follow-up (black lines) cephalometric tracings demonstrate the treatment changes achieved for this patient, including the significant increase in the oropharyngeal airway.

TABLE 1. PATIENT DEMOGRAPHICS (n=47)

n	Name	Gender	Age (years)	TMJ Diagnoses	Previous TMJ Surg		Follow-up (months)
					Right	Left	
1	PA	F	29	(B) A, (B) FA, (B) SI, (B) FBGCR	3	3	16
2	JA	F	34	(B) A, (B) PTI, (B) FBGCR	1	2	25
3	JB	F	50	(B) A, (B) PTI, (B) FBGCR	3	3	61
4	GB	F	38	(B) A	0	0	46
5	SB	F	21	(B) A	0	0	37
6	SBU	F	52	(B) A	0	0	26
7	JD	F	38	(B) A	0	0	37
8	CE	F	14	(B) A	0	0	13
9	DE	F	42	(B) A	0	0	32
10	MF	F	36	(B) A	1	1	48
11	JF	F	42	(B) A	0	0	12
12	KG	F	39	(B) A	0	0	14
13	CG	F	27	(B) A, (B) FA, (B) PTI, (B) FBGCR	3	3	32
14	EG	F	43	(B) PsA	1	1	22
15	CGa	F	44	(L) A	0	0	51
16	PG	F	32	(B) BA, (B) SI, (B) FBGCR	2	2	12
17	SG	F	45	(B) A, (B) FA, (B) F Vittek TJP, (B) FBGCR	6	3	14
18	KH	F	42	(B) BA, (B) PTI, (B) FRG, (B) FBGCR	4	5	46
19	VH	F	37	(B) A	0	0	22
20	KHo	F	20	(B) ICR	0	0	12
21	KHa	F	36	(B) A, (B) PTI, (B) SI, (B) FBGCR	3	3	35
22	CH	F	57	(B) A	0	0	14
23	SJ	F	18	(B) ICR	0	0	19
24	SL	F	17	(B) JRA	0	0	25
25	EL	F	42	(B) F Christ TJP, (B) FBGCR	1	1	14
26	NL	F	46	(B) A	3	3	14
27	LL	F	26	(L) A, (L) PTI, (L) FBGCR	0	1	62
28	EM	F	44	(L) A	0	4	53
29	LM	F	21	(B) ICR	0	0	13
30	MM	F	34	(B) A, (B) PTI, (B) FBGCR	2	2	24
31	CM	F	22	(B) ICR	2	2	51
32	RN	F	28	(B) A	0	4	35
33	BO	F	43	(B) A, (B) PTI, (B) FBGCR	1	1	49
34	DP	F	30	(B) A, (B) PTI, (B) F Vittek TJP, (B) FBGCR	6	6	108
35	BP	F	41	(B) PTI, (B) SI, (B) F Christ TJP, (B) FBGCR	8	8	16
36	LR	F	21	(B) A	2	2	43
37	DS	F	37	(B) A, (B) PTI, (B) FBGCR	2	2	91
38	LS	F	41	(B) A	0	0	99
39	KS	F	15	(B) JRA	0	0	86
40	ES	F	35	(B) F Vittek TJP, (B) FBGCR	3	3	56
41	CT	F	28	(R) A, (R) SbCoFx	0	0	79
42	GT	F	21	(B) ICR	2	1	18
43	CTu	F	51	(B) F Vittek TJP, (B) FBGCR	2	2	35
44	KV	F	37	(B) SI, (B) F Vittek TJP, (B) FBGCR	5	4	143
45	CW	F	36	(B) PTI, (B) FRG, (B) BA	4	4	51
46	CWe	F	46	(B) A	1	0	24
47	TW	F	25	(B) RA	1	1	72

Abbreviations
(B) - Bilateral
(L) - Left side
(R) - Right side
A - Arthritis
RA - Rheumatoid Arthritis
JRA - Juvenal Rheumatoid Arthritis
PsA - Psoriatic Arthritis
ICR - Idiopathic Condylar Resorption
PTI - Proplast/Teflon Implant
SI - Silastic Implant
FRG - Failed Rib Graft
BA - Bony Ankylosis
FA - Fibrous Ankylosis
SbCoFx - Sub-condylar Fracture
F Vittek TJP - Failed Vittek-Kent Total Joint Prosthesis
F Christ TJP - Failed Christensen Total Joint Prosthesis
FBGCR - Foreign Body Giant Cell Reaction

TABLE2. CEPHALOMETRIC LANDMARKS

S	Sella	Midpoint of fossa hypophysealis
N	Nasion	Anterior point at fronto-nasal suture
ANS	Ant. nasal spine	A point posterior to the tip of the median, sharp bony process of the maxilla, on its superior surface, where the maxilla process first enlarge to a 5 mm width
PNS	Post. nasal spine	Most posterior point of the hard palate
A	Point A	The most posterior point in the concavity between ANS and the maxillary alveolar process
B	Point B	The most posterior point in the concavity between the chin and mandibular alveolar process
Pog	Pogonion	The point on the symphysis tangent to the facial plane
Me	Menton	Most inferior point of the bony chin
Go	Gonion	A mid-plane point at the gonial angle located by bisecting the posterior and inferior borders of the mandible
U6T		Upper molar mesial cusp tip
L6T		Lower molar distal cusp tip
L5T		Lower premolar cusp tip
U1T		Upper incisor tip
U1A		Upper incisor apex
L1T		Lower incisor tip
L1A		Lower incisor apex

TABLE3. INITIAL VALUES (T1), SURGICAL CHANGES (T2-T1) AND POST SURGICAL CHANGES (T3-T2) (n=47)

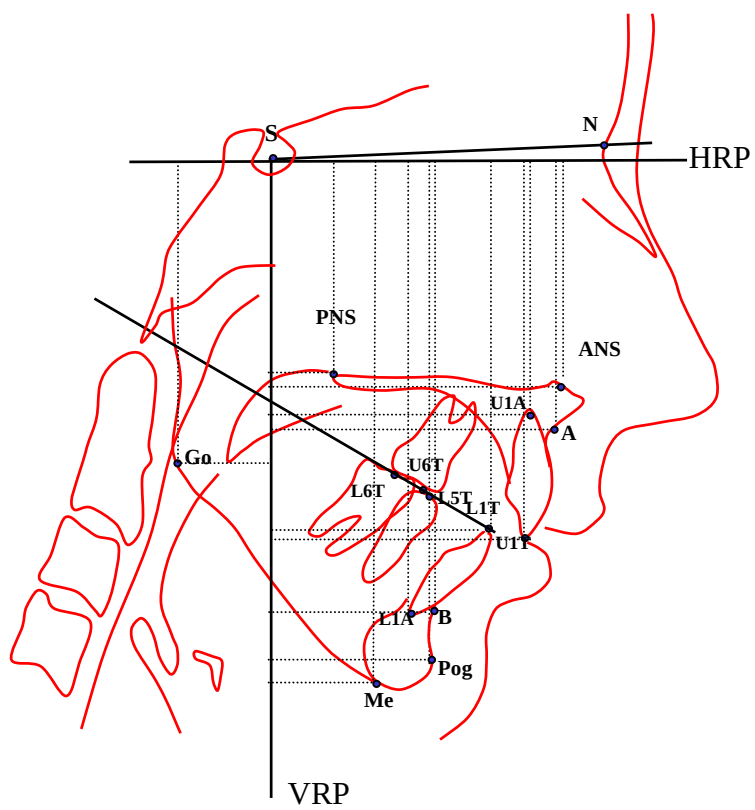
Variable	T1		T2-T1			T3-T2		
	Mean	SD	Mean	SD	P	Mean	SD	P
Horizontal (mm)								
ANS	65.7	4.7	1.3	2.4	**	-0.4	1.6	
PNS	19.6	4.3	2.9	3.1	**	-0.8	2.6	*
A	67.5	4.8	2.5	2.2	**	-0.4	1.3	*
B	52.0	8.3	12.4	5.4	**	0.0	1.8	
Pog	50.5	10.7	18.4	8.5	**	-0.1	2.1	
Me	39.4	11.3	17.3	7.0	**	0.0	2.3	
Go	-8.4	6.1	11.0	5.3	**	0.0	1.9	
U1T	68.7	6.3	5.6	3.0	**	-0.4	1.7	
L1T	63.3	6.6	7.9	3.5	**	-0.3	1.4	
OJ	5.4	2.7	-2.2	2.5	**	-0.1	1.2	
Vertical (mm)								
ANS	42.7	3.3	-0.6	1.9	*	0.4	1.5	
PNS	42.9	2.7	5.5	4.2	**	-0.6	2.0	
A	49.7	4.2	-1.0	1.9	**	0.4	1.6	
B	90.7	5.7	-0.1	3.5		-0.4	2.0	
Pog	104.5	6.9	-0.1	3.8		-0.3	2.1	
Me	108.3	6.6	2.6	3.9	**	-0.4	1.8	
Go	63.1	8.8	18.4	9.2	**	-0.4	2.2	
U1T	74.7	4.8	-1.3	1.9	**	0.3	1.7	
L1T	74.6	5.2	-2.9	4.0	**	-0.4	1.8	
OB	0.1	4.1	1.6	-3.7	**	0.7	1.6	**
Angle (deg)								
SNA	79.8	4.0	2.3	2.3	**	-0.4	1.4	
SNB	72.4	4.1	6.9	2.9	**	0.0	1.0	
ANB	7.4	3.3	-4.6	2.9	**	-0.4	1.4	*
SNPog	73.0	4.8	9.1	4.2	**	0.0	1.1	
OPA	25.1	8.2	-14.9	8.0	**	0.6	3.3	

Horizontal vector: Positive values = forward movement; negative values = posterior movement.

Vertical vector: Positive values = downward movement; negative values = upward movement.

* $p < .05$

** $p < .01$

**FIGURE 1**

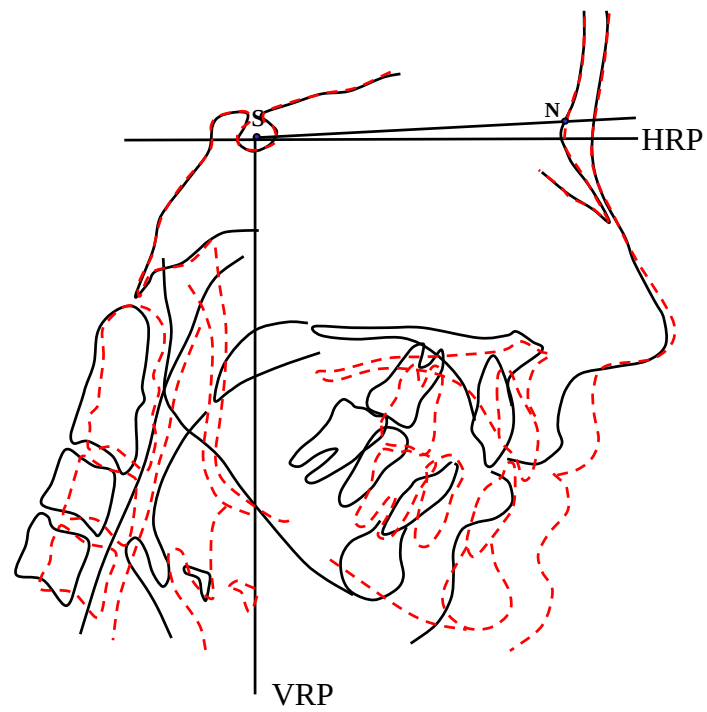
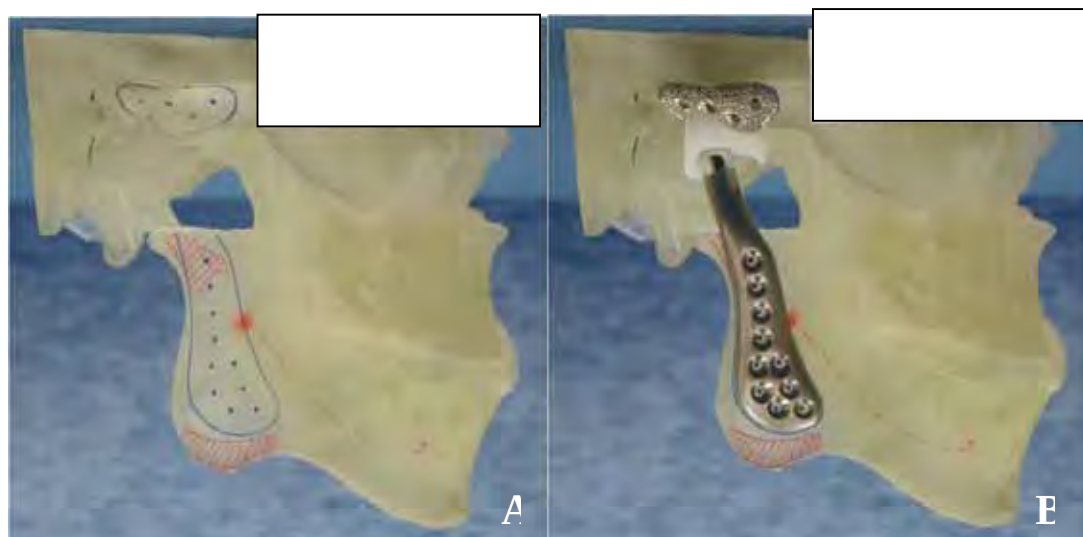
**FIGURE 2****FIGURE 3**



FIGURE 4



FIGURE 5

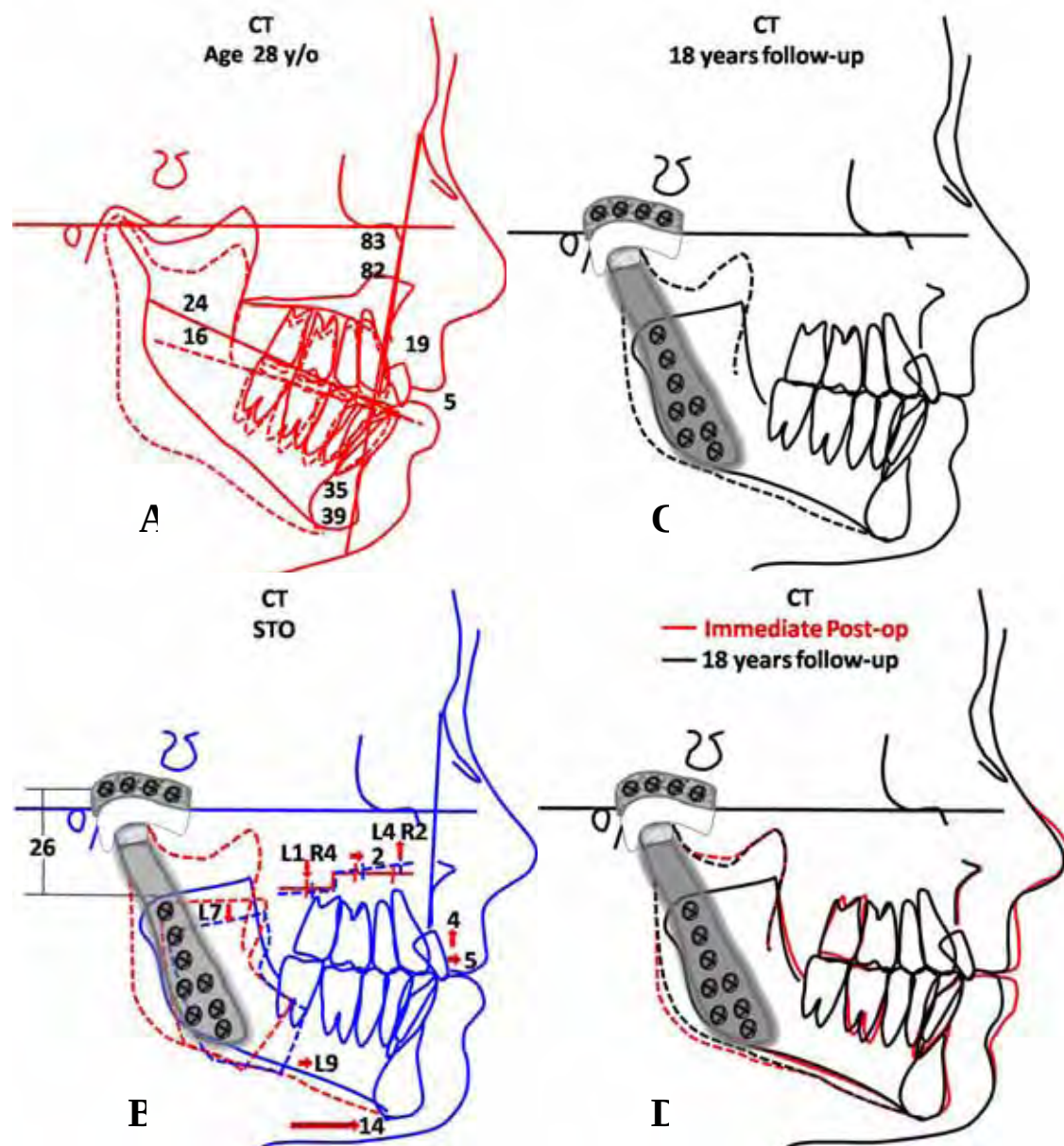
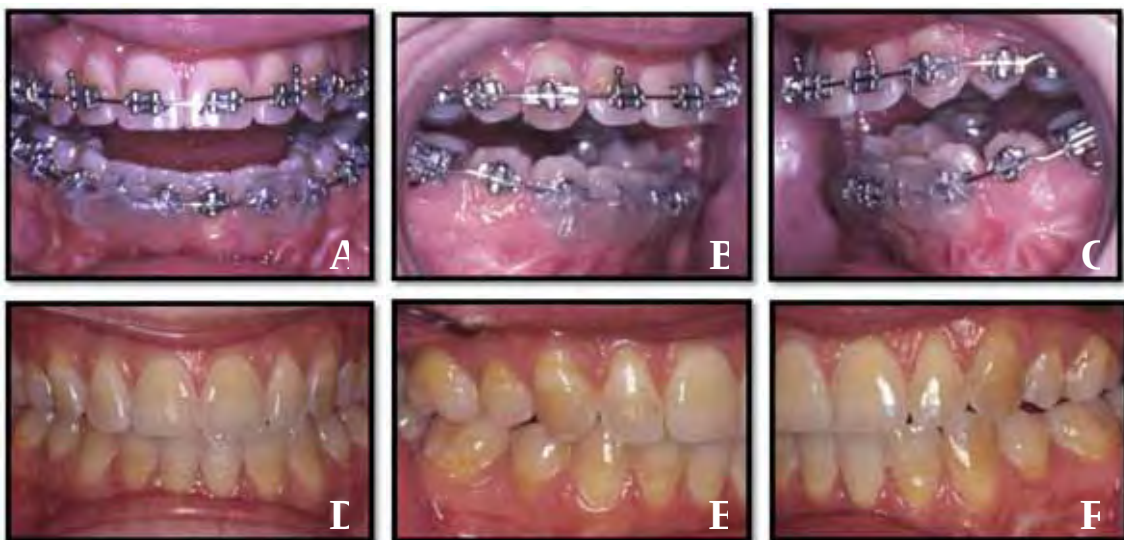


FIGURE 6

**FIGURE 7****FIGURE 8**

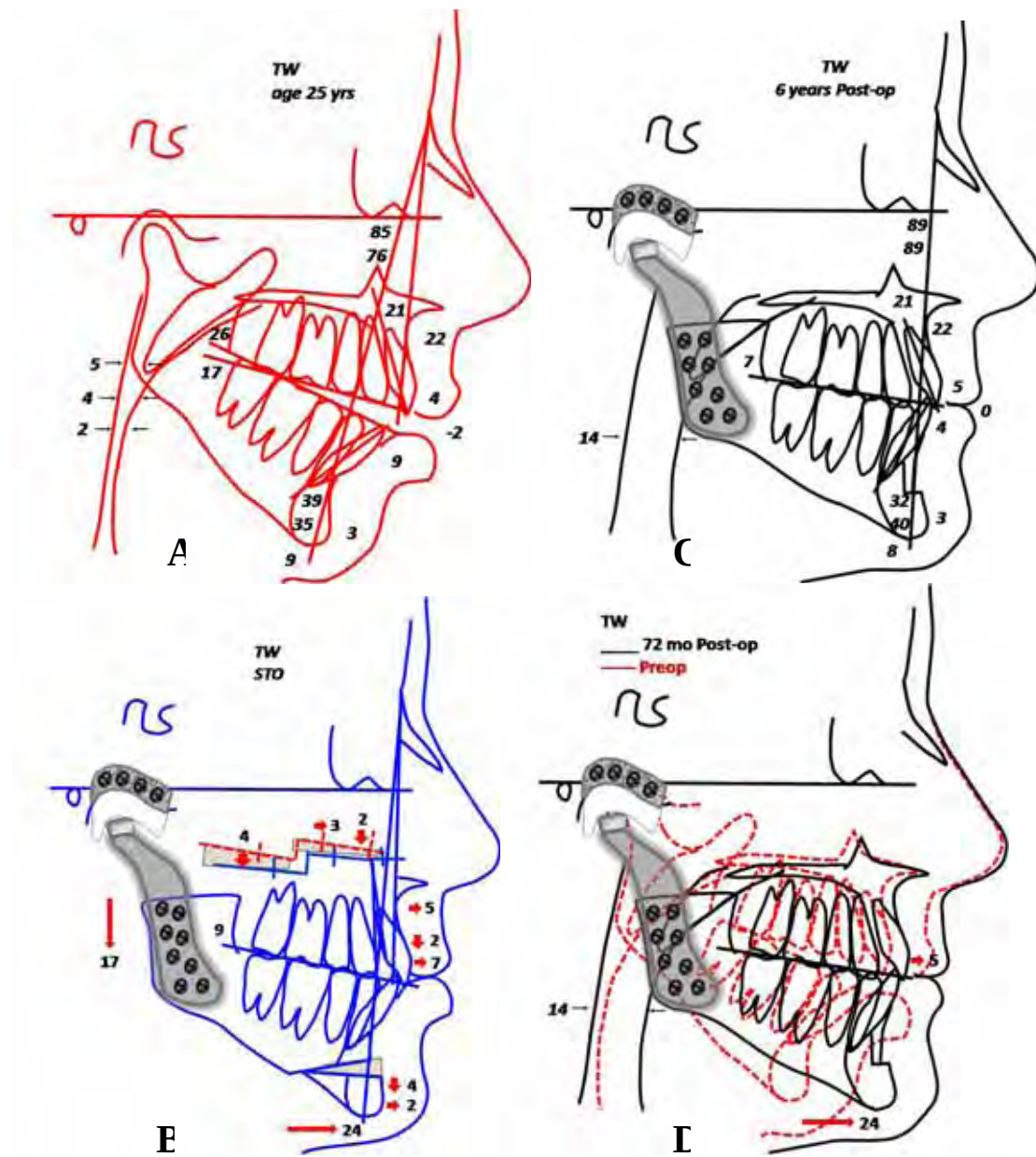


FIGURE 9

Maxillo-Mandibular Counter-Clockwise Rotation and Mandibular

Advancement with TMJ Concepts® Total Joint Prostheses:

Part II – Airway Changes and Stability

¹Karina E. Dela Coleta,

²Larry M. Wolford,

¹João R. Gonçalves,

¹Ary dos Santos Pinto,

²Daniel Serra Cassano,

³Daniela A. Godoy Gonçalves,

¹Pediatric Dentistry Department - Araraquara Dental School, Sao Paulo State University, Brazil

²Department of Oral and Maxillofacial Surgery, Texas A&M University Health Care Center, Baylor College of Dentistry, and Baylor University Medical Center. Dallas, TX.

³Department of Prosthodontics - Araraquara Dental School, Sao Paulo State University, Brazil

Address correspondence and reprint requests to:

Larry M. Wolford, DMD:

3409 Worth St, Suite 400

Dallas, TX 75246

Phone: 214-828-9115

Phone: 214-828-1714

E-mail: lwolford@swbell.net

Abstract

The purpose of this study was to evaluate the anatomical changes and stability of the oropharyngeal airway and head posture following TMJ reconstruction and mandibular advancement with TMJ Concepts custom-made total joint prostheses and maxillary osteotomies with counter-clockwise rotation of the maxillo-mandibular complex. Forty-seven females (14 to 57 years old) were included in the study with an average post surgical follow-up was 40.6 months (range 12 to 143 months). The patients' lateral cephalograms were traced, and analyzed to determine surgical (T2-T1) and post surgical changes (T3-T2) of the oropharyngeal airway, hyoid bone, and head posture. The skeletal and dental changes for this same patient population were presented in Part I of this series of studies. The results of this study showed that surgery increased the narrowest retroglossal airway space (PASnar) 4.9 mm (range -3.5 to 15.7 mm). Head posture (OPT/NS) showed flexure immediately after surgery ($-5.6 \pm 6.7^\circ$) and extension long-term post surgery ($1.8 \pm 6.7^\circ$), while cervical curvature (OPT/CVT) had no significant change. Surgery increased the distances between the third cervical vertebrae and menton (C3-Me) 11.7 ± 9.1 mm and the third cervical vertebrae and hyoid (Hy-C3) 3.2 ± 3.9 mm, and remained stable. The distance from the hyoid to the mandibular plane (MP-Hy) decreased during surgery (-3.8 ± 5.8 mm) and after surgery (-2.5 ± 5.2 mm). Maxillo-mandibular advancement with counter-clockwise rotation and TMJ reconstruction with total joint prostheses produced immediate increase in oropharyngeal airway dimension, which was influenced by long-term changes in head posture but remained stable over the follow-up period.

Key words: Airway Changes; Stability; Orthognathic surgery; TMJ prostheses

Introduction

Important relationships exist between the pharyngeal structures and the development of the face and occlusion. The oropharyngeal airway can influence the growth of craniofacial structures, by creating postural changes capable of affecting the relationship of teeth as well as the direction of jaw growth which may develop in a downward and backward direction¹⁷. On the other hand, skeletal features in patients with high occlusal plane angle facial morphologies (HOP) may be related to the etiology of a narrower dimension of the airway¹⁰.

HOP patients commonly exhibit increased anterior lower face height, retruded mandible and maxilla, Class II malocclusion, high occlusal plane angle and a decreased oropharyngeal airway¹⁶. Also, those patients frequently have TMJ problems with some cases resulting in progressing condylar resorption. This can decrease ramus height and increase mandibular retrusion and respiratory disturbances due to upper airway obstruction¹⁴.

Correction of these deformities in adolescents and adults to achieve optimal functional and esthetic results requires orthognathic surgery, with counter-clockwise rotation of the maxillo-mandibular complex and decrease of the occlusal plane angle²⁵. In cases of TMJ irreversible damage, it may be necessary to reconstruct the TMJ and advance the mandible using a total joint prosthesis²⁶.

According to Mehra et al.¹³ maxillo-mandibular advancement surgery (mandibular advancement of 7.5 mm) with counter-clockwise rotation increased the oropharyngeal airway spaces 3.5 mm in the retropalatal region and 5.7 mm in the

retroglossal region, representing a 76% increase in the retroglossal oropharyngeal airway dimension relative to the amount of mandibular advancement. Other studies have reported airway increases ranging from 42% to 51%^{5,12}.

However, the oropharyngeal airway is not the only structure improved with the mandibular advancement and/or counter-clockwise rotation. Previous studies^{1,7,9,11,22,24} have shown that there are also changes in hyoid bone position due to mandibular advancement. Post surgical hyoid bone position may reflect the stretching of the suprahyoid musculature and occupy an important role in the maintenance of the oropharyngeal airway space. Potential muscle tension increase is thought, by some authors, to be related to skeletal relapse^{1,22-24}. Schendel and Epker²² reported that the hyoid bone tends to return almost to its original presurgical position after a certain post surgical period following mandibular advancement with inter-maxillary fixation. LaBanc and Epker¹¹ reported immediate post surgical movement of the hyoid bone in an anterior direction, but, at the same time, they emphasized the “highly variable” nature of the post surgical position of the hyoid. Most studies describe changes in hyoid bone position and pharyngeal airway size 1 to 2 years post surgery^{1,7,9,11,23,24}.

Mandibular advancement surgery has been previously shown to increase oropharyngeal airway space⁵, however data on this procedure associated to TMJ total joint reconstruction and large mandibular advancements is not available. Although stability using total joint prostheses has been established, changes in airway space and its stability must be studied.

To help resolve the issue concerning post surgical stability and to better understand counter-clockwise rotation of the occlusal plane and the affect on the oropharyngeal airway, the present study tests the following null hypotheses:

- 1) There is no increase in the oropharyngeal airway space with TMJ total joint reconstruction, maxillo-mandibular advancement surgery and counter-clockwise rotation of the occlusal plane.
- 2) The oropharyngeal airway space does not remain stable over the post surgical period.

Patients and methods

This retrospective study evaluated treatment records from a single private practice, from 1990 through 2003, of patients with end-stage TMJ pathology, retruded maxilla and mandible, and high occlusal plane angle. All patients were operated by one of the authors (LMW) at Baylor University Medical Center, Dallas, TX, USA. Patients were selected according to the inclusion and exclusion criteria as presented in Part I². The patient sample was the same as Part I² and included 47 female patients, who underwent TMJ reconstruction and mandibular advancement with total joint prostheses and simultaneous maxillary osteotomies with counter-clockwise rotation of the maxillo-mandibular complex and occlusal plane. The study demographics are presented in Table 1, Part I² of this series of studies. There were 43 patients treated with bilateral TMJ total joint prostheses and 4 patients had unilateral prosthesis and sagittal split osteotomy on the contralateral side. The occlusal plane angle was decreased in all subjects by posterior down grafting the maxilla and/or anterior maxillary upward positioning with counter-clockwise rotation of the maxillo-mandibular complex. Mean patient age at the time of surgery was 34.5 years (range 14

to 57 years). The surgical technique and post operative management are presented in Part I² of this series. All osteotomies were rigidly stabilized using bone plates and screws without using post surgical maxillo-mandibular fixation, but light force vertical elastics were used on most patients for a minimum of 2 to 4 weeks to control the occlusion and provide vertical support to the mandible until the muscles of mastication reattached to the mandible and regained function.

The custom-made total joint prostheses used in this study, were originally developed in 1989 by Techmedica Inc., Camarillo, CA, USA, and since 1997, have been manufactured by TMJ Concepts, Inc., Ventura, CA, USA. These prostheses are CAD/CAM devices (computer assisted design/computer assisted manufacture), designed to fit the specific anatomical requirements for each patient.

Imaging evaluation

For all patients, lateral cephalometric radiographs were taken using a standard radiographic technique (centric relation with Frankfort horizontal parallel to the floor) at the following intervals: T1- immediately before surgery (range 1 to 6 days), T2- immediate post surgery (range 2 to 16 days), and T3- long-term follow-up (range 12 to 143 months). The radiographs were randomly traced by 1 of the examiners and digitized twice by another examiner approximately 1 week apart. There were 16 landmarks (Table 1) identified and digitized by using DFPlus software (Dentofacial Software Inc, Toronto, Canada). The landmarks were used to compute 28 measurements describing airway dimensions, head position, cervical curvature, hyoid position, and maxillo-mandibular relationships. S-N minus 7° was used as the horizontal reference plane (HRP), and a perpendicular line to HRP through sella was

used as the vertical reference plane (VRP). The horizontal and vertical changes for each landmark were evaluated (Fig 1). Surgical change (T2-T1) and long-term stability (T3-T2) were calculated and statistically analyzed.

Error of measurement

To determine the consistency of the method, the two examiners were previously calibrated by repetition of the process until the method was considered adequate by a third examiner. Each lateral cephalogram was traced twice to evaluate for errors in landmark localization (“random error”) during tracing and each lateral cephalometric radiograph got a median of the measurements. The intra-examiner consistency (ICC) was calculated for reliability of tracing, landmark identification, and analytical measurements showing a correlation coefficient always greater than 0.94.

Statistical method

All data were transferred to SPSS (release 9.0; SPSS Chicago, IL) for statistical analysis. The skewness and kurtosis statistics showed normal distributions for all variables. Unilateral and bilateral TMJ prostheses were compared. Because there were no statistically significant differences between these groups in post surgical changes, all the patients were analyzed as a single group. Paired *t* tests were performed to evaluate the surgical (T2-T1) and post surgical changes (T3-T2). A significance level of $p < .05$ was applied. Pearson product-moment correlations were used to determine the relationships between changes of specific anatomical measurements and oropharyngeal airway space changes. Correlations were also used to assess the association between surgical and post surgical changes in the oropharyngeal airway space.

Results

Surgical changes (T2-T1)

The surgical changes and stability of results for the maxilla, mandible, and occlusal plane were previously presented in Part I² of this series of papers.

The oropharyngeal surgical change was in the same direction, but with less increase than the horizontal advancement observed with the mandible. Narrowest retroglottal airway space (PASnar) showed a dimensional increase of 4.9 mm (range - 3.5 to 15.7 mm).

Head posture and hyoid position also changed from the surgery. Immediately post surgery, the head posture (OPT/NS) showed a significant ($p < .01$) flexure (-5.6 ± 6.7 degrees), while cervical curvature (OPT/CVT) had no significant change. C3, Hy and BT points showed a forward movement (5.9 ± 7.4 mm, 8.5 ± 5.8 mm and 7.9 ± 4.8 mm respectively). In the vertical plane Hy and BT were displaced in a downward direction (2.1 ± 6.0 mm, 8.3 ± 7.0 mm), while C3 showed upward change (-0.5 ± 1.5 mm). The distances between the third cervical vertebra and menton (C3-Me) and the third cervical vertebra and hyoid (Hy-C3) increased 11.7 ± 9.1 mm and 3.2 ± 3.9 mm, respectively. The distance from the hyoid to the mandibular plane (MP-Hy) decreased (-3.8 ± 5.8 mm).

Post surgical stability (T3-T2)

The post surgical changes and stability of results for the maxilla, mandible, and occlusal plane were previously presented in Part I² of this series of papers.

The narrowest retroglossal airway space (PASnar) remained stable post surgery, although BT point showed a postero-superior movement. The hyoid moved superiorly, thereby decreasing its distance from the mandibular plane (-2.5 ± 5.2 mm). However, there was no significant change in the distance between the hyoid and the third cervical vertebra (Hy-C3) and in the distance between the third cervical vertebra and menton (C3-Me). Head posture (OPT/NS) showed 1.8 ± 6.7 degrees of extension while cervical curvature (OPT/CVT) had no change.

Correlations

The correlations showed that surgical increase in oropharyngeal airway space was associated with a variety of other changes (Table 3). All the mandibular horizontal measurements (B, Pog, Me, Go) showed positive correlation with the oropharyngeal measurement (PASnar). The further the mandible was advanced, the greater the dimensional increase of PASnar. This correlation was also found at A point in the horizontal direction, showing the influence of the maxillary position on the airway space. In vertical direction, only Go showed positive correlation with the increase of oropharyngeal airway space. Similarly, patients with greater increases in the distances between C3 and menton (C3-Me) and between C3 and hyoid (Hy-C3) showed greater increases in PASnar immediately post surgery. This correlation was also true relative to the tongue (BT) in the horizontal direction.

The head position was correlated with the oropharyngeal airway space. Patients with greater head extension (OPT/NS) showed greater increases of PASnar. Although the oropharyngeal airway space showed a positive correlation with a variety

of other changes, the occlusal and the mandibular plane angles, and C3-horizontal showed a negative correlation with the increase of PASnar.

Positive correlations were identified for the mandibular and head position measurements with Me horizontal and C3-Me as well as Me horizontal and Hy-C3 (Table 4). However, there were negative correlations between the occlusal plane angle (OPA) and C3-Me, OPA and HY-C3 as well as Me vertical and MP-Hy. The greater the mandibular counter-clockwise rotation (decrease OPA and MPA), the greater the increase of the distances between C3-Me and Hy-C3.

Long-term post surgery (Table 3), the strongest correlations were found between changes in oropharyngeal dimension and head position (OPT/NS), mandibular position (C3-Me), hyoid position (Hy horizontal and Hy-C3) and C3 position (C3 horizontal and vertical). Patients who extended their heads (OPT/NS) more over the post surgical period showed greater increase in PASnar dimension. The oropharyngeal airway measurement showed greater increase for patients who increased the distances between C3 and Me and between C3 and Hy in the follow-up period. The long-term post surgical changes in Me related with the head and hyoid positions, showed a positive correlation between Hy-C3 and Me in the horizontal direction, and between OPT/NS and Me-vertical. Therefore, the greater extension of head position and C3 change resulted in greater anterior and superior movement of menton post surgery.

Discussion

The high occlusal plane facial type (HOP) patient, also called long face syndrome, dolicocephalic or hyperdivergent, has known morphological characteristics

including maxillo-mandibular clockwise growth pattern, decreased oropharyngeal airway space, and TMJ problems^{10,13,25,26}. The comprehensive treatment for those patients includes maxillo-mandibular counter-clockwise rotation that will improve function and facial balance as well as permanently increase the oropharyngeal airway space. Patients with end-stage TMJ pathology such as connective tissue autoimmune diseases, idiopathic condylar resorption, ankylosis, severe trauma, more than two failed TMJ surgeries, and so on, may benefit from TMJ reconstruction (using TMJ Concepts total joint prostheses), simultaneously with maxillo-mandibular counter-clockwise rotation, in order to provide the best stability, improve function and esthetics, as well as decrease TMJ associated pain and other symptoms.

There are a variety of ways to evaluate the oropharyngeal airway space changes associated with maxillo-mandibular orthognathic surgery including lateral cephalometry, computed tomography, polysomnography, and nasopharyngoscopy^{12,20}. In our study, the PAS was measured on lateral cephalometric films that were taken with patients in a sitting position. This technique has the advantage of being expedient and convenient, since it is a conventional document required for orthognathic surgery during planning and follow-up evaluation. Riley et al.²⁰ found a good correlation between the posterior airway space and the pharyngeal space measured by cephalometric radiography and computed tomography.

According to Fitzpatrick et al.⁶, the upper airway dimensions are also influenced by the patient's position, either sitting or supine. This positional influence of upper airway dimensions can be related to the effects of gravity on upper airway structures and to the lung volume dependency of upper airway patency. In our sample

all lateral cephalometric films were obtained in the same sitting position, so this variable had a small impact on the method used to determine the surgical (T2-T1) and post surgical (T3-T2) changes. Landmark definition and digitalization were tested and found to have high intra-class correlation coefficient (greater than 0.94). This minimized bias and increased the dependability of the study.

The methodology applied in our research used only one measurement to evaluate the narrowest retroglossal airway (PAS), differing from other studies^{4,8,13,14} where 2 or more measurements were used to show airway changes due to the surgery. This fact can be justified by the impossible task of identifying some landmarks after surgery (T2 and T3), since the mandibular component of the TMJ total joint prostheses overlapped and obscured the mandibular ramus and portions of the oropharyngeal soft tissue structures.

The surgical skeletal and dental changes (T2-T1) and longest follow-up stability results (T3-T2) are presented in Part I² of this series of papers. The counter-clockwise rotation of the maxillo-mandibular complex advanced the mandible an average of 12.4 mm at B point, 18.4 mm at Pogonion, and 17.3 mm at Menton. Mandibular advancement measured at menton was substantially greater than the incisor edge as a result of the counter-clockwise rotation, which demonstrates the advantage of this movement in high occlusal plane angle facial type patients. All surgical movements (T2-T1) remained stable during the follow-up period (T3-T2), except for minimal horizontal changes that occurred at point A and PNS.

The counter-clockwise rotation and advancement of the maxillo-mandibular complex significantly increases the size of the oral cavity volume, providing increased space for the tongue and soft palate to be postured forward. The maintenance of the suprahyoid musculature attachment to the anterior aspect of the mandible provides an anterior tension to the tongue and hyoid bone pulling them forward and, thus, significantly increases the posterior pharyngeal airway space (PASnar). Those clinical results further confirm Wolford et al.²⁵ position that counter-clockwise rotation of the maxillo-mandibular complex, is the surgical modality of choice to establish the best function, facial esthetics, skeletal and occlusal stability, as well as an increase in the oropharyngeal airway in HOP facial types.

Associated with the anterior mandibular advancement, C3 showed an antero-superior movement, although to a lesser degree, and remained stable post surgery. The distances from C3 to menton (C3-Me) and to hyoid (Hy-C3) showed an increase at surgery due to the greater anterior movement of Me and Hy than C3. The length of C3-Me depends on the length of the mandibular body as well as the change in cranio-cervical angulation¹⁵.

Since the hyoid bone serves as anchorage for the tongue muscles, its position also partly determines the position of the tongue³. Eggensperger et al.⁴ showed that with a mandibular advancement of 4.3 mm at menton, the hyoid advanced 1.6 mm; 37% of the mandibular advancement. At longest follow-up, the position of the hyoid was more posterior (-0.3 mm) than it was presurgery. Our results showed a forward and downward movement of Hy and BT with the surgery (T2-T1), emphasizing that the hyoid anterior movement represented 49% of the total mandibular advancement

(measured at Me). The hyoid surgical movements in the horizontal (8.5mm) and vertical (2.1mm) directions were larger than amounts previously reported^{1,4,7}, probably related to the greater amount of mandibular advancement in our study. However, the vertical hyoid movement differed from other studies^{7,9} that showed a superior movement of the hyoid bone. The downward movement of the hyoid in the immediate post surgical period is from the downward and forward rotation of menton and greater mandibular advancement related to muscle and ligament stretch as well as greater submandibular edema induced by the extra-oral surgical approach necessary for placement of the TMJ total joint prostheses.

The surgical advancement moved the hyoid bone closer to the mandibular body (MP-Hy= -3.8 mm) due to the tensile forces of the attached musculature and the downward rotation of the ramus and inferior border of the mandible, and continued to reduce at the long-term follow-up (T3-T2), although to a lesser degree (-2.5mm). In the horizontal direction changes were not significant, although 20% relapse occurred related to the total surgical movement. Goncalves et al.⁸ showed a 10% hyoid horizontal relapse, but their mandibular advancement was 13.1 mm at Me compared to this present study of 17.3 mm. In their study, there was a greater upward surgical movement of the hyoid bone than the downward movement observed in our study, showing their final values similar to results observed by others authors^{1,4,7-9}. This fact contributes to the hypothesis that the immediate post surgical edema temporary displaces the hyoid downward.

Although some authors^{1,23,24} consider that the hyoid bone movement and increased muscle tension are associated with the post surgical mandibular relapse, our

results of good post surgical skeletal stability², indicates that the tendency for the hyoid bone to return toward its original position was not related to skeletal relapse.

The narrowest retroglossal airway space (PASnar) showed significant dimensional increase immediate post surgery (4.9 mm) that remained stable during the follow-up period. This value was greater than reported by Goncalves et al⁸. (4.4 mm) however it was less than Mehra et al.¹³ (5.7 mm) that showed a 76% increase in the retroglossal oropharyngeal airway dimension relative to the amount of mandibular advancement. Other studies have reported airway increases ranging from 42% to 51%^{5,12}. In our sample, the increase of PASnar was 28% of the mandibular advancement. Although the PASnar increase was significant ($p < .01$), the increased dimension was proportionally lower than the mandibular advancement of 17.3 mm at Me. This disproportional amount of increase may be related to 2 basic factors: First, Reiche-Fischel and Wolford¹⁹ evaluated the changes in the oropharyngeal airway in 72 patients with mandibular advancement and demonstrated that there is a greater percentage of change (increase) of the oropharyngeal airway dimension for the first 10 mm of mandibular advancement (66%). Beyond 10 mm, the airway continued to increase in dimension, but proportionally less relative to the amount of mandibular advancement (for 10 to 15 mm of mandibular advancement the airway increased 56% , and for >15 mm advancement the airway increased 41%) . Second, our study showed a head flexion, changing OPT/NS immediately after surgery. The amount of increase in the PAS following head movement may depend on how the subject flexed or extended the head. It was found that the airway became wider when the extension occurred at the uppermost part of the cervical spine (OPT/NS)¹⁵. In the present study, change in OPT/NS showed a strong correlation with the size of the oropharyngeal airway,

however, OPT/CVT in the lower part of the cervical spine showed no change or only a weak correlation to the size of the PAS. Considering that the normal value for PAS based on lateral cephalometric radiograph is $11 \pm 2 \text{ mm}^{21}$, our results showed an immediate post surgical PASnar average value of 12.2 mm that stabilized at 11.1 mm at the longest follow-up period, demonstrating a final PAS measurement within normal limits.

Head posture affects the pre and post surgery PAS dimension. Muto et al.¹⁵ observed a positive correlation between airway space and head posture of 0.807 (PAS-OPT/NS). The present study showed a significant positive correlation between airway increase and head posture of 0.456 with surgical changes and of 0.603 during the follow-up period.

This cranio-cervical adaptation (OPT/NS) is influenced by the post surgical supra-hyoid muscle tension, the direction and distance of surgical movement (mandibular advancement or setback) and the changes in PAS. There is a strong tendency toward head flexion after most orthognathic surgical procedures. It was previously reported¹⁸ that patients with high occlusal plane facial morphology treated by maxillary intrusion (no counter-clockwise rotation of the maxillo-mandibular complex) had a somewhat extended head posture presurgically. Their head flexion post surgery brought them toward the center of the normal range, but only temporarily. According to the authors, patients who undergo mandibular advancement are in the middle of the normal range for head posture prior to treatment, but they have about the same amount of transient flexion. In our study, patients flexed their heads after surgery (average, 5.6°) and extended it 1.8° during the long term follow-up. Previous studies

have reported 0.65° to 3.4° of head flexure following advancement surgery^{7,18,22}. The amount of head flexion observed in our study may be due to the immediate surgical counter-clockwise rotation of the maxillo-mandibular complex, promoting a greater amount of mandibular advancement with subsequent increased tension of the supra and infra-hyoid musculature. The slight extension of the head post surgery (T3-T2) was probably a result of the supra- and infra-hyoid musculature adapting to the surgical changes.

PASnar showed a significant negative correlation (- 0.726) between the surgical movement (T2-T1) and the post surgical changes (T3-T2). The farther the PASnar was changed surgically, the greater the chance of instability of this area. Considering that OPT/NS didn't show significant movement after surgery, we can't attribute this negative correlation to the post surgical head extension.

The correlation of maxillo-mandibular bone movement with PASnar showed a positive correlation with A point, B point, Pog and Me points in a horizontal direction, and Go in the horizontal and vertical directions. The further the maxillo-mandibular complex was advanced and Go was moved inferiorly, the greater the increase of PAS. Although those correlations were statistically significant, the values were low probably due to the lack of standardized head posture resulting in an increase of the variability of OPT/NS at different times (T2- OPT/NS= 105.6 ± 7.1 degrees; T3-OPT/NS= 107.4 ± 8.1 degrees). Also, immediately post surgery, the tongue (BT) advancement showed a positive correlation with the PASnar.

Occlusal and mandibular plane angle changes showed a negative correlation with PASnar. Those angulations were reduced relative to the HRP line by the mandibular counter-clockwise rotation, increasing the airway space. This same negative correlation was observed at the third vertebra (C3) position in vertical and horizontal directions during the follow-up period.

C3-Me and Hy-C3, measurements showed a positive correlation with PASnar in the immediate and long-term evaluations. The anterior movement of Me was positively correlated to increases in C3-Me which was directly correlated to the PASnar measurement. These correlations were stronger than observed by Goncalves et al.⁸ The data indicated that oropharyngeal airway improvement due to the counter-clockwise rotation of the maxillo-mandibular complex would be significantly greater if the patients had maintained the same head position during the 3 different times of evaluation. The lack of head and neck positional during radiographic acquisition, was directly related to the variability observed for OPT/NS and OPT/CVT at T1, T2, T3 and to the lesser increase than expected for the oropharyngeal airway dimension.

Changes in head and neck posture immediately post surgery constrained the immediate oropharyngeal airway improvement. Muto et al.¹⁵ showed that a change of 10° in OPT/NS produced about 4 mm of change in the PAS. They also showed that the distance between C3 to Me was related to the oropharyngeal airway improvement, which was also observed in the present study. However, it is important to emphasize that although the majority of measurements showed a statistically significant correlation with PASnar, they were low (mostly less than 0.5). This could be related in part to the influence of head posture in the airway dimension.

The results of this study show that: (1) maxillo-mandibular advancement surgery with counter-clockwise occlusal plane rotation improved the oropharyngeal airway dimensions; (2) changes of C3, Hy and BT distances to mandibular advancement were correlated with oropharyngeal airway changes; (3) head position influenced the amount of increase in oropharyngeal airway dimensions that occurred after maxillo-mandibular advancement surgery, (4) the oropharyngeal airway space remained stable over the post surgical follow-up period; (5) total joint prostheses provide stability of maxillo-mandibular counter-clockwise rotation and consequently of the narrowest retroglossal airway space (PASnar).

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Legends

Figure 1. Landmarks, distances and planes used to define linear and angular measurements. HRP means horizontal reference plane and VRP means vertical reference plane. Linear measurements: PASnar; narrowest retroglossal airway space (the narrowest distance between the base of the tongue and the posterior pharyngeal wall, measured by a perpendicular line from the posterior pharyngeal wall). C3-Me; distance from C3 to Me. MP-Hy; distance from Hy to mandibular plane measured by a perpendicular line from MP to Hy. Hy-C3; distance from hyoid to C3. Angular measurements: OPT/NS; angle of odontoid process/head posture. OPT/CVT; cervical curvature. OPA; angle of occlusion plane to N-S line. MPA; angle of mandibular plane to N-S line.

Figure 2. Superimposition of pre and post surgical lateral cephalograms demonstrating surgical changes.

Table 1. Cephalometric landmarks.

Table 2. Initial values, surgical changes and post surgical stability.

Table 3. Pearson correlation coefficients between surgical and post surgical landmarks and oropharyngeal airway changes.

Table 4. Pearson correlation coefficients between surgical and post surgical changes.

Table 1. Cephalometric landmarks

S	Sella	Midpoint of fossa hypophysealis
N	Nasion	Anterior point at frontonasal suture
ANS	Ant. nasal spine	A point posterior to the tip of the median, sharp bony process of the maxilla, on its superior surface, where the maxilla process first enlarge to a 5 mm width
PNS	Post. nasal spine	Most posterior point of the hard palate
A	Point A	The most posterior point in the concavity between ANS and the maxillary alveolar process
B	Point B	The most posterior point in the concavity between the chin and mandibular alveolar process
Pog	Pogonion	The point on the body symphysis tangent to the facial plane
Me	Menton	Most inferior point of the bony chin
Go	Gonion	A mid-plane point at the gonial angle located by bisecting the posterior and inferior borders of the mandible
LPW	Lower pharyngeal wall	Intersection of the posterior pharyngeal wall to the narrowest space of the retroglossal region
Hy	Hyoid	Most antero-superior point of hyoid
BT	Base of tongue	Most posterior point of the base of the tongue
Cv2ig	Odontoid process	Tangent point at the superior, posterior extremity of the odontoid process of the second cervical vertebra
Cv2ip	Second vertebra	Most inferior-posterior point on the body of the second cervical vertebra
Cv4ip	Fourth vertebra	Most inferior-posterior point on the body of the fourth cervical vertebra
C3	Third vertebra	Most antero-inferior point on the body of the third cervical vertebra

Table 2. Initial values (T1), surgical (T2-T1), and post surgical (T3-T2) changes (n= (n=47))

	T1		T2-T1					T3-T2				
Variable	Mean	SD	Mean	SD	Min	Max	P	Mean	SD	Min	Max	P
Angle (deg)												
OPA	25.1	8.2	-14.9	8.0	-37.0	-2.4	**	0.6	3.3	-4.5	10.9	
MPA	50.4	8.0	-15.0	7.7	-35.3	-0.6	**	0.0	2.2	-5.1	5.9	
OPT/NS	111.1	8.7	-5.6	6.7	-21.2	5.2	**	1.8	6.7	-11.9	16.8	
OPT/CVT	17.3	1.5	0.0	0.7	-1.8	1.4		0.2	0.9	-1.6	2.1	
Horizontal (mm)												
ANS	65.7	4.7	1.3	2.4	-7.4	7.1	**	-0.4	1.6	-4.1	5.2	
PNS	19.6	4.3	2.9	3.1	-3.9	10.9	**	-0.8	2.6	-8.4	3.9	*
A	67.5	4.8	2.5	2.2	-6.0	6.8	**	-0.4	1.3	-2.8	5.0	*
B	52.0	8.3	12.4	5.4	1.7	22.5	**	0.0	1.8	-4.9	4.2	
Pog	50.5	10.7	18.4	8.5	2.2	42.1	**	-0.1	2.1	-4.9	5.3	
Me	39.4	11.3	17.3	7.0	2.7	32.8	**	0.0	2.3	-5.3	5.4	
Go	-8.4	6.1	11.0	5.3	2.9	25.6	**	0.0	1.9	-5.9	4.9	
C3	-26.8	10.6	5.9	7.4	-7.7	24.7	**	-1.7	7.3	-19.9	15.2	
Hy	3.3	10.3	8.5	5.8	-7.6	23.2	**	-1.7	5.9	-18.8	13.3	
BT	-10.5	7.5	7.9	4.8	-5.6	16.3	**	-2.1	4.2	-14.5	8.1	**
PASnar	7.3	3.8	4.9	4.1	-3.5	15.7	**	-1.1	4.1	-12.7	6.8	
C3-Me	67.3	9.6	11.7	9.1	-15.3	36.9	**	1.7	7.4	-15.8	17.6	
Hy-C3	31.7	4.6	3.2	3.9	-8.2	14.6	**	-1.0	4.1	-11.5	9.5	
Vertical (mm)												
ANS	42.7	3.3	-0.6	1.9	-4.0	3.4	*	0.4	1.5	-4.4	7.0	
PNS	42.9	2.7	5.5	4.2	-1.8	14.3	**	-0.6	2.0	-5.0	6.8	
A	49.7	4.2	-1.0	1.9	-4.2	3.3	**	0.4	1.6	-4.4	7.0	
B	90.7	5.7	-0.1	3.5	-8.5	5.8		-0.4	2.0	-4.7	3.8	
Pog	104.5	6.9	-0.1	3.8	-10.9	8.9		-0.3	2.1	-5.3	4.1	
Me	108.3	6.6	2.6	3.9	-6.7	12.6	**	-0.4	1.8	-4.8	3.8	
Go	63.1	8.8	18.4	9.2	-1.5	43.4	**	-0.4	2.2	-6.8	6.2	
C3	99.4	5.5	-0.5	1.5	-4.1	4.9	*	0.5	2.3	-6.7	8.0	
Hy	106.5	8.5	2.1	6.0	-12.3	14.1	*	-4.1	5.7	-19.0	9.9	**
BT	84.8	8.3	8.3	7.0	-8.7	27.1	**	-3.4	5.1	-14.3	9.8	**
MP-Hy	23.2	5.9	-3.8	5.8	-18.4	9.8	**	-2.5	5.2	-14.5	10.0	**

Horizontal vector: Positive values = forward movement; negative values = posterior movement.

Vertical vector: Positive values = downward movement; negative values = upward movement.

* $p < .05$

** $p < .01$

Table 3. Pearson correlation coefficients between surgical and post surgical landmarks and oropharyngeal airway changes

Variable (T1-T2)/(T2-T3)	Surgical Changes		Post surgical Changes	
	PASnar		PASnar	
Angle (deg)				
OPA	-0.396	**	-0.038	
MPA	-0.377	**	-0.221	
OPT/NS	0.456	**	0.603	**
OPT/CVT	-0.028		-0.133	
Horizontal (mm)				
ANS	0.284		-0.081	
PNS	0.114		-0.051	
A	0.352	*	-0.004	
B	0.420	**	0.243	
Pog	0.344	*	0.274	
Me	0.409	**	0.277	
Go	0.385	**	0.033	
C3	-0.475	**	-0.657	**
Hy	-0.125		-0.394	**
BT	0.394	**	0.60	
C3-Me	0.697	**	0.707	**
Hy-C3	0.650	**	0.603	**
Vertical (mm)				
ANS	-0.154		-0.091	
PNS	0.271		0.110	
A	-0.177		-0.095	
B	-0.046		0.058	
Pog	-0.115		0.065	
Me	0.079		0.083	
Go	0.426	**	0.182	
C3	0.140		0.540	**
Hy	0.021		-0.068	
BT	-0.111		-0.170	
MP-Hy	0.058		0.251	

* $p < .05$ ** $p < .01$ **Table 4.** Pearson correlation coefficients between surgical and post surgical

Variable (T1-T2)/(T2-T3)	Surgical Changes			Post surgical Changes		
	Me-HT	Me-VT	OPA	Me-HT	Me-VT	OPA
C3-Me	0.623 **	0.105	- 0.633 **	0.260	0.151	- 0.118
MP-Hy	- 0.198	- 0.319 *	0.061	0.140	0.132	- 0.189
Hy-C3	0.338 *	- 0.025	- 0.445 **	0.354 *	- 0.061	- 0.151
OPT/NS	- 0.229	- 0.188	0.030	- 0.075	0.332 *	0.065
OPT/CVT	- 0.024	0.001	0.147	- 0.210	0.180	- 0.010

* $p < .05$ ** $p < .01$

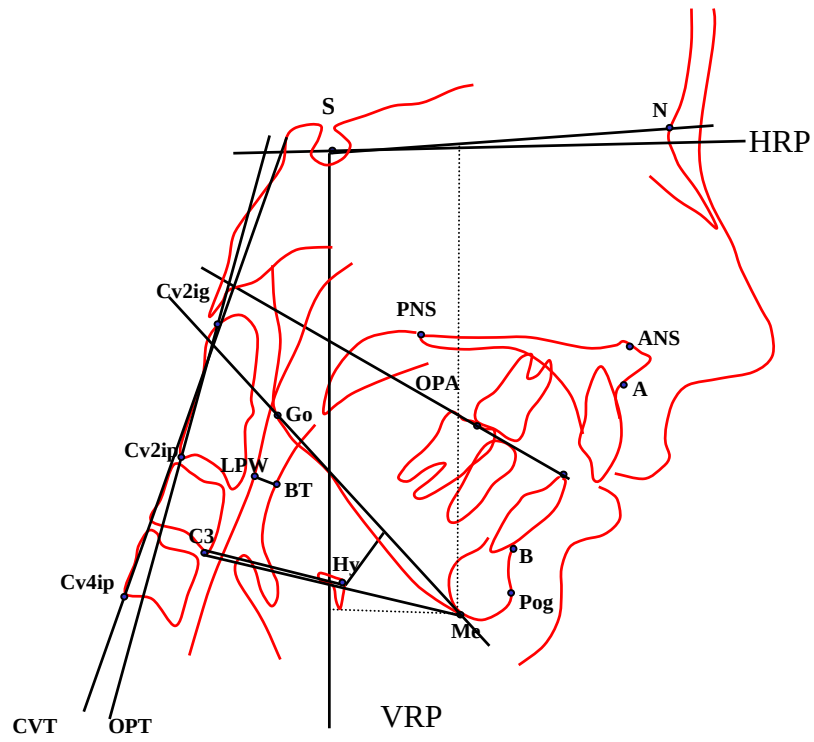


FIGURE 1

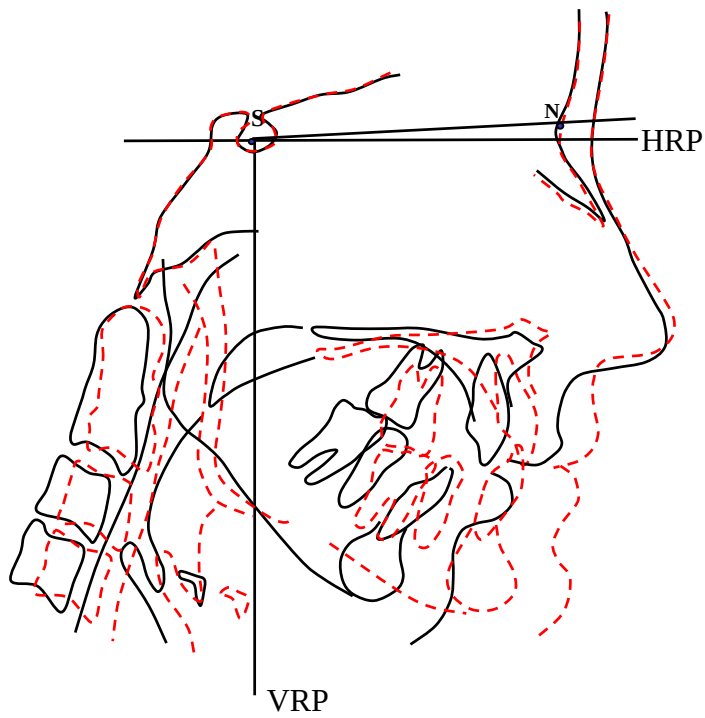


FIGURE 2

Maxillo-Mandibular Counter-Clockwise Rotation and Mandibular

Advancement with TMJ Concepts[®] Total Joint Prostheses:

Part IV - Soft Tissue Response

¹Karina E. Dela Coleta,

²Larry M. Wolford,

¹João R. Gonçalves,

¹Ary dos Santos Pinto,

²Daniel Serra Cassano,

³Daniela A. Godoy Gonçalves,

¹Department of Pediatric Dentistry - Araraquara Dental School, Sao Paulo State University, Brazil

²Department of Oral and Maxillofacial Surgery, Baylor College of Dentistry, Texas A&M University System.

³Department of Prosthodontics - Araraquara Dental School, Sao Paulo State University, Brazil

Address correspondence and reprint requests to:

Larry M. Wolford, DMD:

3409 Worth St, Suite 400

Dallas, TX 75246

Phone: 214-828-9115

Phone: 214-828-1714

E-mail: lwolford@swbell.net

Abstract

The purpose of this study was to evaluate soft tissue response to maxillo-mandibular counter-clockwise rotation, with TMJ reconstruction and mandibular advancement using TMJ Concepts system® total joint prostheses, and maxillary osteotomies in forty-four females (14 to 57 years of age). Eighteen patients had genioplasties with either Porous Block Hydroxyapatite or HTR implants. Lateral cephalograms were taken 1 week before surgery and at least 12 months (mean 40.8 months) post surgery to evaluate soft to hard tissue changes. Two groups were analyzed: Group 1, no genioplasty (n = 26) and Group 2, with genioplasty (n = 18). Surgically, the maxilla moved forward and upward by counter-clockwise mandibular rotation with greater horizontal movement in Group 2. Vertically, both groups showed diversity of maxillo-mandibular mean movement. Hard and soft tissue ratios were different between groups. Group 1 showed a consistent 1 : 0.97 ratio of hard to soft tissue advancement at Pogonion and 1 : 1.01 ratio (range 1 : 0.99 to 1 : 1.61) at B point and LMf. Group 2 results were less consistent, with ratios between 1 : 0.84 and 1 : 1.02. Horizontal changes in upper lip morphology after maxillary advancement/impaction, VY closure, and alar base cinch sutures showed almost greater movement in both groups, than observed in hard tissue. When comparing the percentage movement of soft tissue to underlying bone, the upper lip moved anteriorly at subnasale 145% (Group 1) and 180% (Group 2), and at labrale superius 100% (Group 1) and 107% (Group 2). There was a slight upper lip lengthening of 0.4 and 0.5 mm. Counter-clockwise rotation of the maxilla-mandibular complex using TMJ Concepts total joint prostheses resulted in similar soft tissue response as previously reported for traditional maxillo-mandibular advancement without counter-clockwise rotation of the occlusal plane. The association of chin implants, in the present sample, showed higher variability of soft tissue response.

Key words: Soft tissue; Orthognathic surgery; TMJ prostheses

Introduction

Dentofacial deformities are the result of variations in skeletal and dental alveolar morphology that affect function as well as facial appearance and balance. Orthognathic surgery for these patients can successfully improve these aspects. The key to achieving improved function and facial esthetics is to carefully and systematically analyze functional and facial balance, establish esthetic priorities, and then coordinate and implement correction through the use of cephalometric planning and occlusal studies¹.

Since the improvement of facial appearance is often an important motivating factor in seeking treatment¹⁶, the ability to predict the outcome of treatment is essential. The predictability of treatment depends on the relationship between the hard and soft tissues²⁶. Orthognathic surgery moves the skeletal elements in a planned and controlled manner, but the soft tissue drape is not as precisely controlled during surgery^{11,17}. There are a number of techniques available for the planning of orthognathic treatment and these have become increasingly sophisticated over the years. Cephalometric prediction tracings and computer imaging software^{19,21,27} are examples.

According to Dolce et al.⁸ the percentage change of soft tissue points for a given hard tissue advancement depends on both treatment method and time. Bone movement in orthognathic surgery gives rise to changes in the positions of the adjacent soft tissues, with such change varying according to the location, direction, and degree of movement. The behavior of the soft tissues, especially the labial tissues, can be influenced by aspects such as lip thickness, length, and taper, surgical change in palatal plane, and soft tissue manipulation techniques (ie, VY closure and alar base cinch suture)^{3,22}. The balance of

the soft tissue contours of the nose and chin must also be evaluated^{3,4}. Although the soft tissue horizontal response can be relatively accurately determined, the vertical plane isn't as precise. To obtain the final soft tissue results, a minimum of 6-12 months follow-up is required¹¹.

In planning cases for double jaw surgery, the vertical and horizontal predicted surgical positioning of the maxilla will affect the amount of mandibular repositioning and the need for mandibular osteotomies and/or adjunctive genioplasty. The simultaneous repositioning of the maxilla, mandible, and chin can dramatically alter the facial soft tissue contour and proportions to afford the clinician much greater latitude in treatment outcomes².

Although the addition of other adjunctive surgical procedures such as genioplasty, rhinoplasty, cheek augmentation, etc., to the clockwise or counter-clockwise rotation of the maxillo-mandibular complex can improve esthetic results, they may make it more difficult to determine with certainty the changes in the soft tissue profile²⁶. In studies that examined the hard to soft tissue response with bilateral mandibular ramus sagittal split osteotomy (no genioplasty), most authors reported a ratio of 1:1 for pogonion^{9,17,20}. A similar ratio is generally accepted for B-point. However, Ewing & Ross⁹ concluded that when an advancement genioplasty is included in the surgical movement, the soft tissue of the chin tends to move downward and proportionally less than the hard tissue movement in the horizontal direction, making the soft tissues thinner in this area. The soft tissue response shows considerable individual variation, contributing to inaccuracy of soft tissue outcome predictions¹⁰.

The TMJs are the foundation for orthognathic surgery. A better facial profile is usually expected by patients who seek orthognathic surgery, but, if the TMJs are not healthy, the outcome results and stability may not be predictable relative to the hard and soft tissue changes. There are a great variety of options to treat TMJ problems depending on the type and severity of its pathology. From non-surgical management to the total prosthetic replacement, it is necessary that appropriate TMJ treatment is provided in order to get the best and most stable results.

Patients with non-salvageable temporomandibular joints may have articular degenerative processes that promote a retrusive, high occlusal plane (HOP) profile, and Class II occlusion with or without open bite, requiring TMJ reconstructive surgery with TMJ total joint prostheses and orthognathic surgery. The lack of predictability of some soft tissue areas as well as the low number of studies involving technique variations like the use of TMJ total joint prostheses with double jaw surgery and counter-clockwise rotation of the maxillo-mandibular complex, initiated the present study. In addition, there are no studies involving large mandibular advancements (> 15 mm).

The objectives of this study were:

- (1) Determine reliable correlations, if any, of soft tissue changes to bony movements due to surgery;
- (2) Evaluate the influence of genioplasty in soft tissue response.

Material and methods

The same female patient population (n = 47) used in Parts I, II, and III of this series of papers was used in this study^{6,7,23}. All patients were operated by one of the

authors (LMW) at Baylor University Medical Center, Dallas, TX, USA. Patients were selected according to the inclusion and exclusion criteria as presented in Part I⁶. However, 3 patients had lateral cephalograms where the soft tissue profile could not be identified. Therefore, longitudinal records were available for 44 of the 47 female patients. All patients had TMJ reconstruction and mandibular advancement using total joint prostheses with simultaneous maxillary osteotomies and counter-clockwise rotation of the occlusal plane⁶. Eighteen patients had an augmentation genioplasty in the same operation with Porous Block Hydroxyapatite (PBHA, Interpore 200, Interpore Inc, Irvine, CA) or Hard Tissue Replacement (HTR) polymer implant, (Walter Lorenz CO, Jacksonville, FL). Mean patient age at surgery was 35 years (range, 14 to 57 years). All maxillary osteotomies were rigidly stabilized using bone plates and screws, synthetic bone grafting when indicated, and no maxillo-mandibular fixation. Details of the surgical techniques are presented in Part I⁶. An alar cinch suture and VY vestibular closure were performed in all cases in the study¹². Post surgery, light force elastics were used on most patients for 2 to 4 weeks to control the occlusion.

The sample was divided into 2 groups based on the presence or absence of a genioplasty: Group 1, no genioplasty (n = 26); Group 2, with genioplasty (n = 18). Patients were offered a genioplasty if the surgeon recommended it for improved esthetic outcome. Most genioplasties were performed for horizontal augmentation of the chin with minimal vertical change. Correlation coefficients were calculated between hard tissue advancement and corresponding soft tissue movement.

The custom-made total joint prostheses used in this study, were originally developed in 1989 by Techmedica Inc., Camarillo, CA, USA, and since 1997, have been

manufactured by TMJ Concepts, Inc., Ventura, CA, USA. These prostheses are CAD/CAM devices (computer assisted design/computer assisted manufacture), designed to fit the specific anatomical requirements for each patient.

Imaging evaluation

Lateral cephalometric radiographs were taken using a standard radiographic technique (centric relation, Frankfort horizontal plane parallel to the floor and lips relaxed). Radiographs had to be of good quality with all hard and soft tissue landmarks clearly identifiable. Three patients were disqualified from an initial sample of 47 cases, because of poor quality records where soft tissue profile could not be determined. Radiographs were taken at the following intervals: T1- immediately before surgery (range 1 to 6 days), and T2- long-term follow-up with an average 40.8 months (range, 12 to 143 months) post surgery. Each patient's lateral cephalograms were traced, digitized twice, and averaged to estimate hard and soft tissue surgical changes in the 2 groups analyzed: Group 1, no genioplasty (n = 26), and Group 2, with genioplasty (n = 18). The landmarks used for measurements are presented in Fig. 1, Table 1. The landmarks were digitized by using Dentofacial Planner Plus version 2.02 (Dentofacial Software Inc, Toronto, Canada) and analyzed to describe hard and soft tissues surgical movements as well as the correlation between them. Stable reference lines were established from S-N minus 7° for the horizontal reference plane (HRP) and a perpendicular line to HRP through sella for the vertical reference plane (VRP). Hard and soft tissue changes due to surgical movement were evaluated in relation to these reference lines (Fig. 1).

Method error

To determine the consistency of the method, two examiners were previously calibrated by repetition of the process until the method was considered adequate by a third examiner. Random errors in landmark localization were decreased by tracing twice each lateral cephalogram and using the medium values of each measurement. The intra-examiner consistency (ICC) was calculated for reliability of tracing, landmark identification, and analytical measurement showing a correlation coefficient always greater than 0.94.

Statistical method

All data were transferred to SPSS (release 9.0; SPSS Chicago, IL) for statistical analysis. The skewness and kurtosis statistics showed normal distributions for all variables. Differences were compared between patients in Groups 1 and 2. Because there were statistically significant differences between those groups in post surgical changes, the patients were analyzed in two distinct groups: Group 1 - no genioplasty and Group 2 - with genioplasty. Paired *t* tests were performed to evaluate the surgical changes (T2-T1). A significance level of $p < .05$ was applied. To compare the results with existing studies, linear regression analyses were performed that evaluated the relationships between hard tissue variables and their soft tissue counterparts. Pearson product-moment correlations were also used to assess the association between the soft and hard tissues.

Results

Group 1 (no genioplasty, n = 26)

The maxilla advanced 1.1 ± 2.3 mm at anterior nasal spine (ANS), 2.2 ± 2.3 mm at A point and 2.0 ± 2.9 mm at posterior nasal spine (PNS), while vertically, just PNS showed statistically significant downward movement (5.0 ± 4.0 mm). The supra-dental

(Sd) and upper incisor tip (U1T) landmarks showed the greatest changes in the maxillary area (horizontal 3.8 ± 2.3 mm and 5.4 ± 3.0 mm; vertical -1.0 ± 1.9 mm and -0.8 ± 1.9 mm, respectively). For vertical movement, negative numbers indicate upward and positive numbers downward movement. For horizontal movement, positive numbers indicate forward movement and negative numbers indicate backward movement. Horizontal soft tissue changes were very similar in amount and direction to hard tissue surgical movements. However, it was observed that areas Sn and Sls showed greater advancement than their respective hard tissue points (ANS and A point). Upper lip soft tissue forward movements at Sn was 1.6 ± 1.8 mm, Sls 3.2 ± 1.9 mm, Ls 3.8 ± 2.2 mm, and Sts 5.0 ± 2.8 mm. Sn (-0.6 ± 1.0 mm) was the only upper lip landmark that showed significant vertical change (Table 2).

The mandibular hard tissue changed significantly in all horizontal measurements as observed in the following landmarks: L1T 6.9 ± 3.8 mm, Id 9.5 ± 4.4 mm, B point 11.4 ± 4.8 mm, Pog 14.7 ± 6.1 mm, Me 16.3 ± 7.0 mm, and Go 11.1 ± 5.2 mm. Vertically, the mandible showed no statistically significant movement at B point and Me, but an inferior change of 16.7 ± 8.9 mm at Go point and an upward movement at L1T (-3.7 ± 4.4 mm), Id (-2.8 ± 3.9 mm) and Pog (-1.5 ± 3.5 mm). Soft tissue moved forward and upward in all mandibular landmarks respectively (Sti 7.4 ± 3.4 mm and -3.5 ± 4.2 mm; Li 8.7 ± 3.8 mm and -5.1 ± 4.5 mm; LMf 11.6 ± 5.0 mm and -3.6 ± 4.0 mm; Pog' 14.4 ± 6.0 mm and -2.5 ± 3.8 mm; Gn' 15.8 ± 6.6 mm and -1.7 ± 3.4 mm) as recorded in Table 2.

In the middle third of the face, soft tissues advanced at point Pn (0.4 ± 1.0 mm) and at Cm showed forward (1.4 ± 1.6 mm) and upward (-0.8 ± 1.2 mm) movement. N' and Nd showed no change.

Maxillary and mandibular angular measurements (SNA, SNB, ANB and SNPog) confirmed linear movements as recorded in Table 4. Occlusal plane and mandibular plane angles decreased a mean of 13.8 ± 7.9 degrees and 14.0 ± 7.6 degrees respectively, during the maxillo-mandibular counter-clockwise rotation. Surgical changes associated with the mandibular counter-clockwise advancement are seen in Table 4 and Fig 2.

Group 2 (with genioplasty, n = 18)

In group 2, the maxilla showed significant movement at A point horizontally (1.5 ± 2.6 mm) and at PNS, in both directions (H 2.3 ± 3.5 mm and V 4.9 ± 3.3 mm). The supra-dental and upper incisor tip advanced 2.8 ± 2.6 mm and 5.0 ± 3.2 mm respectively, while in the vertical plane both points showed upward movement (-1.7 ± 2.4 mm and -1.7 ± 2.5 mm). The upper lip soft tissue changes showed progressive increased advancement at points: Sn 0.9 ± 1.5 mm, Sls 2.5 ± 2.2 mm, Ls 3.0 ± 2.6 mm, and Sts 3.5 ± 3.3 mm. Vertically, there was no significant movement (Table 3).

The mandibular hard tissue changes were significant in all horizontal measurements, being greater than observed in Group 1 (L1T 8.2 ± 3.1 mm, Id 11.0 ± 3.7 mm, B 13.9 ± 4.8 mm, Pog 22.6 ± 6.9 mm, Me 18.6 ± 5.4 mm, and Go 11.1 ± 5.1 mm). In the vertical plane, the mandible showed an inferior movement at Me of 3.3 ± 4.0 mm and

Go 19.8 ± 8.6 mm, while L1T and Id showed upward movement. Soft tissue moved forward in all mandibular points: Sti 7.4 ± 4.9 mm, Li 9.8 ± 5.1 mm, LMf 14.2 ± 5.7 mm, Pog' 19.0 ± 5.8 mm and Gn' 21.5 ± 6.7 mm, and upward at Sti -4.1 ± 3.4 mm; Li -5.8 ± 3.9 mm; LMf -3.1 ± 3.7 mm and Pog' -1.1 ± 5.0 mm recorded in Table 3. The middle third of the face did not show significant movement, except at Cm point (horizontal 1.2 ± 1.5 mm and vertical -0.8 ± 1.1 mm).

Maxillary and mandibular angular measurements (SNA, SNB, ANB and SNPog) confirm linear movements as recorded in Table 4. Occlusal plane and mandibular plane angles decreased a mean 14.9 ± 5.7 degrees and 16.5 ± 6.0 degrees respectively, being greater than observed in Group 1.

Correlation

1. Horizontal correlations. The high correlation of hard tissue landmarks and their soft tissue counterparts can be seen in Table 7. Many statistically significant and reliable correlations were found among hard and soft tissue landmarks in both groups. Anterior nasal spine had significant correlations (although not strong) with superior labial sulcus and subnasale in Groups 1 ($r=0.51$) and 2 ($r=0.69$); and with labrale superius, stomion superius, and inferius only in the Group 1 (Table 5). The ratios from ANS to Sn were 1:1.45 in Group 1 and 1:1.80 in Group 2. Soft tissue landmarks appeared to follow A point more closely than anterior nasal spine, with ratios from A to SlS of 1:1.45 (Group 1) and 1:1.66 (Group 2). A surgical movement of A point could predict long-term movement of superior labial sulcus with correlations of 0.76 (Group 1) and 0.68 (Group 2). That is, a 1.0 mm hard tissue movement would result in a 1.45 mm and a 1.66 mm soft tissue movement for each. The Sd landmark showed stronger correlations than observed in ANS

and A point with correlation (Sd-Ls) of 0.83 (Group 1) and 0.88 (Group 2). The mandibular hard tissue measurements (B point, Pog, and Id) showed high correlation with all inferior soft tissue points (Sti, Li, Mlf, Pog') in both groups. Also, there was a significant correlation of B point with Sn in Group 2. Ratios between hard and soft tissues after horizontal advancement were: B point:LMf 1 : 1.01 (Group 1) and 1 : 1.02 (Group 2); Pog:Pog' 1 : 0.97 (Group 1) and 1 : 0.84 (Group 2); Id:Li 1 : 0.91 (Group 1) and 1 : 0.89 (Group 2). Dental landmarks (U1T and L1T) correlated quite highly with the soft tissue measurements in both groups, demonstrating a close relationship between lower incisor tip and stomion inferius (Table 9). These changes can be seen in Figure 2 that shows the percentage of soft tissue movement in relation to hard tissue surgical change in the horizontal plane.

2. Vertical correlations. A number of reliable correlations for vertical movements could be found, but far less than for horizontal movements. Table 8 showed high correlation ($r > 0.75$) of hard tissue landmarks and their respective soft tissue reference points, only in the mandibular region. In Pearson product-moment correlations (Table 6), maxillary landmarks (A point, ANS and Sd) showed good correlation ($r > 0.6$) with few soft tissue landmarks, only in Group 2. None of the maxillary landmarks showed correlation greater than 0.6 in Group 1. Mandibular landmarks correlations were stronger than observed in the maxillary region, nevertheless the values were higher in Group 1. Dental landmarks (U1T and L1T) showed a different behavior. While the upper incisor tip showed few correlations, the inferior tooth (L1T) reveal good correlations with all mandibular soft tissue landmarks in both groups. Figure 3 shows the percentage of soft tissue movement in relation to hard tissue surgical change in the vertical plane.

Discussion

The prediction of the soft tissue response that will follow surgical hard tissue advancement appears to be a straight forward procedure in general. After surgery, patients show straighter facial profiles, more harmonious lip balance, and labial folds more defined. Those changes can be predicted in millimeters in most cases, however when some soft tissue manipulation techniques are added (ie alar base cinch suture, V-Y vestibular incision closure) or other surgical procedures are incorporate, such as a genioplasty, this generalization does not apply.

The influence of different surgical procedures on soft tissue results was considered in our study, since more than 40% of the patient sample required an augmentation genioplasty. So, the results were compared between the two groups (Group 1, no genioplasty and Group 2, with genioplasty) and were found to have statistically significant differences. This standardization of the sample optimized the reliability of soft tissue prediction.

Predicting the soft tissue profile from orthognathic surgery was first described in 1972 by McNeill et al¹⁸. Since then, studies have reported on soft tissue responses to hard tissue changes⁸. However, special considerations needed to be taken in reference to the follow-up period. Transient soft tissue changes that result from different stages of healing and resolution of edema were eliminated by requiring post surgery cephalograms be taken at least 12 months post surgery, although soft tissues overlying maxillary structures may take several years to reach their final equilibrium. An analysis of stability data revealed that most horizontal and vertical soft tissue change after Le Fort I surgery

stabilize in the first year after surgery¹³. Based on this fact our study used at least 12 months of follow-up with the purpose to obtain soft tissue equilibrium.

The final soft tissue profile of the lips is of particular importance because there is generally more emphasis on post surgical changes in the lips than on the nose or chin, when evaluating esthetics of life-sized lateral photographs⁵.

Powers²⁴ found that the upper lip and labiomental fold horizontally were very predictable, with only a few patients (3% and 8%, respectively) exhibiting clinically significant differences. The predictability of maxillary surgery is influenced by the ability of the surgeon to accurately position and provide adequate stability of the maxilla in its new location as well as the variability of the soft tissue response¹⁵.

Our study evaluated the relation of the maxilla and upper lip in the horizontal and vertical planes. The results showed a mean movement forward and upward of the anterior maxilla (ANS, A point, Sd and U1T) and downward movement of PNS in both groups, although some of these changes was not statistically significant. This counter-clockwise rotation of the palatal plane and occlusal plane promoted increased advancement in a graduated fashion from the upper to the lower part of the maxilla, allowing greater projection of the upper incisor while the anterior nasal spine was only slightly advanced. Vertically, the upper incisor showed greater upward movement than the maxilla superior area (ANS and A point), which may be a favorable movement in high-angle cases to reduce the upper incisor exposure. However, it was observed that the upper incisor tip (U1T) showed equal or less upward movement than the supra-dental

landmark, probably by the post surgical orthodontic treatment that can influence the incisor vertical position.

The soft tissue response of the upper lip was similar to the maxilla, but with different intensity. While the maxillary hard tissue advanced an average 1.1 to 5.4 mm in Group 1 and 0.5 to 5.0 mm in Group 2, the respective soft tissue landmarks showed a forward mean movement of 1.6 to 5.0 mm (Group 1) and 0.9 to 3.5 mm (Group 2). The landmarks Ls and Sts showed the greatest mean anterior change, while Sn and SlS showed slightly lower amounts of mean anterior movement. In the vertical plane, the soft tissue showed upward movement, but in a decreased scale from the uppermost (Sn) to lowermost (Sts) landmarks. Thus, the stomion superius showed minimal vertical change, maintaining the lip length.

The use of the alar base cinch suture and VY vestibular incision closure techniques directly affected upper lip results. The alar base suture prevents flaring of the alar base of the nose and thickens the lip while the VY closure helps minimize shortening of the upper lip and maintains lip thickness¹². These techniques¹⁴ improve the surgeon's ability to control the post surgery morphologic features and esthetics of the upper lip⁴.

Comparing hard and soft tissues changes, we observed that the uppermost points of the lip showed greater advancement than their hard tissue counterparts. The same fact did not occur at the lip vermilion. Most previous studies showed the higher region of the upper lip (Sn) presented less change than the inferior part of the lip (Sts) when the maxilla was advanced. Gregoret¹² reported Sn followed just 30% of hard tissue movement and Sts, 80%. Our results showed that the upper landmarks of the lip (Sn and

SlS) moved more than 100% of the osseous advancement in both groups, with 70-100% of soft to hard tissue advancement in the lower part (Sl and Sts), as observed in Figure 2. This result was expected considering that an alar base cinch suture and VY vestibular closure were performed in all cases of the study, promoting a greater projection of the subnasal area. The amount of hard tissue movement at ANS and A point was small with only 0.5 to 2.2 mm of advancement. Also, orthodontic brackets in place for the presurgical cephalogram were removed in most instances at longest follow-up. This could introduce soft tissue discrepancies affecting predictions and lip thickness.

Nary Filho et al.²² reported that it was possible to detect a tendency toward more posterior positioning of the upper lip with maxillary surgery, which can be compensated by the V-Y suture technique. Alterations in the vertical position of the soft tissues were not significant.

In our study, the Pearson product-moment analysis showed good correlation of maxillary hard and soft tissues horizontally (Table 5). Previous studies^{16,21} have reported slightly lower correlations between the two tissue movements, with the average correlation ratio being approximately 0.75, and ranged between 0.45 and 0.97. The average correlation for upper lip landmarks in the present study ranged between 0.51 to 0.90 and ratios from 0.92 - 1.45 (Group 1) and 0.70 - 1.80 (Group 2). Similar to our results, others have reported maxillary advancements that used specialized soft tissue reconstruction techniques, such as VY closure, demonstrating higher soft/hard tissue ratios that range from 0.78 to 1.00¹⁴. Vertically, this correlation was not strong although the behavior of both tissues showed movement in the same direction.

The significant correlations between hard and soft tissue response seen in the present study may be due to a variety of factors. Homogeneity of the sample, the accuracy of the surgical method, the technical skills of the surgeon and the standardized surgical technique of alar base cinch suture and VY closure, may explain the improvement in correlations.

In the mandibular area, our results showed an advancement of all landmarks associated with a counter-clockwise rotation and decrease of occlusal and mandibular plane angles. Our results showed that the amount of advancement was greater than previous studies^{9,25,26} with a mean movement of 11.4 mm at B point, 14.7 mm at Pog, 16.3 mm at Me, and 11.1 mm at Go (Group 1). In the Group 2, the amount of hard tissue advancement was slightly more at B point, Me and Go, but significantly greater at Pog (22.6 mm). The more pronounced mandibular advancement observed in our study is justified by the patients previous history of TMJ pathology or irreversible damages with condylar resorption, significant mandibular retrusion, and high occlusal plane angle that required greater movements to obtain optimal functional and esthetic results.

The mandibular dental landmarks (L1T, Id) showed less significant movement in both groups as compared to the lower areas of the mandible (Pog, Me). The anterior maxillary upward movement and posterior downward movement promoted a mandibular counter-clockwise rotation with greater horizontal projection in the inferior area of the mandible (Pog, Me). Therefore, it was possible to obtain a significant mandibular projection without as great of maxillary and dental advancement. Proffit & Phillips²⁵ considered that the soft tissues are relaxed and the lip pressure is decreased by the

surgical treatment when the mandible rotates upward and forward following maxillary intrusion.

The mandibular soft tissues in both groups, showed gradual increased advancement similar to the hard tissues. The lower lip landmarks movement was greater than their respective osseous counterpoints only at Sti (7.4 mm in Group 1) and at LMf (11.6 mm in Group 1; 14.2 mm in Group 2). Vertically, all soft tissue landmarks showed upward movement with Li elevating more than the inferior stomion (in both groups), probably related to the labial seal or thinning of the lower lip.

In studies that examined the hard to soft tissue response with bilateral sagittal split osteotomies, most reported a ratio of 1:1 at pogonion and B point^{9,18,21}. However, these studies demonstrated great variability in soft tissue response of the lower lip^{18,21}.

The soft tissue in Group 1 of our study showed similar changes to that obtained in other studies, with 97% at pogonion and 101% at B point. The lower lip predictably moved anteriorly in a graduated fashion from 91% at Li to 107% at Sti relative to the underlying hard tissue movement. The Pearson product-moment analysis showed high correlations of mandibular hard and soft tissues horizontally, but not so consistent vertically. In the present study, the horizontal average correlation for inferior soft tissue landmarks and their osseous counterparts ranged from 0.84 to 0.98 in Group 1. This data points out high levels of soft tissue predictability based on the skeletal hard tissue movements.

However, when a genioplasty is performed, the soft tissue response shows considerable individual variation and is also dependent on whether the procedure is performed alone or in combination with other surgery¹⁰. In our study, Group 2 soft tissue behavior was similar to Group 1 but to a lesser degree. The highest correlation of hard to soft tissue change was at Pog (0.93) horizontally, ranging from 0.81 to 0.93. Previous studies^{9,26} showed a lower correlation (0.34 - 0.49) between hard and soft tissue advancement at pogonion. Vertically, the mandible had less significant correlations than in the horizontal plane, although almost all were greater than 0.6 (Tables 6).

The ratios obtained for Group 2 was 1 : 1.02 (B : LMf) and 1 : 0.84 (Pog : Pog'), being greater than shown by other genioplasty studies that ranged from 1 : 0.6 to 1:1.^{9,11} Shaughnessy et al.²⁶, suggested that a ratio of 1 : 0.9 can be used to predict hard to soft tissue movements in osseous genioplasty, although attention has been paid to the importance of maintaining as much soft tissue attachment as possible to the repositioned bony segment to obtain predictable soft tissue changes. Similar results were found by Ewing & Ross⁹ although the average difference between hard and soft tissue movement was ± 2.6 mm.

In mandibular advancement with genioplasty the soft to hard tissue correlations are much less consistent¹ than observed in cases of advancement without genioplasty. The cases requiring genioplasty were often the more severe cases, and soft tissue drape in severe retrognathia is usually abnormal. Individual assessment is essential in such cases. Also, minor variations in the surgical management of tissues occur from patient to patient and differs from surgeon to surgeon, so that variation in results in the chin area are not surprising⁹.

According to Ewing & Ross⁹, genioplasty cases develop a thinning or unfurling of the lower lip at the vermilion border. This factor was also observed in our results where the lower anterior movement of stomion inferior compared to the hard tissue change, promoted a thinning of the lower lip in genioplasty cases. This relation was not seen in Group 1. The authors⁹ recommend that surgeons should evaluate their own genioplasty cases to establish the soft tissue response to their particular surgical technique.

The lower lip did not advance as much as the lower incisor. Instead tended to become thinner or fall back, with a change of 91% in Group 1 and 89% in Group 2 relative to the incisor movement. This is illustrated in Figures 2 and 4.

Our study results showed better soft tissue response to hard tissue movements in most areas compared to previous studies probably related to the maxillo-mandibular counter-clockwise rotation and advancement with TMJ reconstruction using total joint prostheses that permits greater mandibular advancement to optimizing facial profiles as well as soft tissue management techniques (ie alar base cinch suture, V-Y vestibular closure). Upper lip soft tissue horizontal response was greater than the hard tissue movement related to the relatively small amount of maxillary advancement and the use of the alar base cinch suture and the V-Y closure of the vestibular incision which tends to thicken the lip. There was less soft tissue horizontal movement of the lower lip and pogonion with genioplasty as compared to no genioplasty.

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Legends

Figure 1. Hard and soft tissue landmarks used in cephalometric analysis (definition in Table 1)

Figure 2. Percentage of soft tissue movement in relation to hard tissue surgical change in horizontal plane

Figure 3. Percentage of soft tissue movement in relation to hard tissue surgical change in vertical plane

Figure 4. Schematic representation of hard and soft tissue changes

Table 1. Cephalometric landmarks and some measurement definitions

Table 2. Group 1 (no genioplasty) horizontal and vertical movements (millimeters) of hard and soft tissue landmarks (T1-T2)

Table 3. Group 2 (genioplasty) horizontal and vertical movements (millimeters) of hard and soft tissue landmarks (T1-T2)

Table 4. . Group 1 (no genioplasty) and Group 2 (with genioplasty) angular movements (degrees) of hard tissue landmarks (T1-T2)

Table 5. Pearson product-moment correlations for horizontal landmark movement

Table 6. Pearson product-moment correlations for vertical landmark movement

Table 7. Linear regression for horizontal landmark movement

Table 8. Linear regression for vertical landmark movement

Table 9. Ratios between hard and soft tissues after horizontal advancement

Table 1. Cephalometric landmarks and some measurement definitions

Landmark		Explanation
Hard tissue landmark		
S	Sella	Center of the bony contour of sella turcica
N	Nasion	Most anterior point of the frontonasal suture on the midsagittal plane
ANS	Anterior nasal spine	A point posterior to the tip of the median, sharp bony process of the maxilla, on its superior surface, where the maxilla process first enlarge to a 5 mm width
PNS	Posterior nasal spine	Posterior tip of the sharp bony process of the palatine bones at the posterior-most aspect of the maxillary complex
A	Point A	Innermost point on contour of maxilla between anterior nasal spine and incisor
B	Point B	Innermost point on contour of mandible between incisor and bony chin
Pog	Pogonion	Most anterior point on osseous contour of chin
Me	Menton	Most inferior midline point on mandibular symphysis
Go	Gonion	A mid-plane point at the gonial angle located by bisecting the posterior and inferior borders of the mandible
Sd	Supra-dental	Point where maxillary dental alveolus contacts the labial surface of maxillary central incisor in the midsagittal plane
U1	Upper incisor tip	Midpoint of incisal edge of most prominent maxillary central incisor
L1	Lower incisor tip	Midpoint of incisal edge of most prominent mandibular central incisor
Id	Infra-dental	Point where mandibular dental alveolus contacts the labial surface of mandible central incisor in the midsagittal plane
Soft tissue landmark		
N'	Nasion soft tissue	The deepest point in the soft tissue concavity overlying the naso-frontal suture
Nd	Nasal dorsum	A landmark located approximately halfway from Nasion to Pronasale
Cm	Columella point	A landmark on the inferior surface of the nose, representing the anterior delimiter of the naso-labial angle
Pn	Pronasale	Most anterior and prominent point of nasal tip
Sn	Subnasale	Point at which columella (nasal septum) merges with upper lip in midsagittal plane
SlS	Superior labial sulcus	Point of greatest concavity in middle of upper lip between subnasale and labrale superius
Ls	Labrale superius	Most anterior point of upper lip
Sts	Stomion superius	Lowermost point on vermillion of upper lip
Sti	Stomion inferius	Uppermost point on vermillion of lower lip
Li	Labrale inferius	Most anterior point of lower lip
LMf	Labiomental fold	Point of greatest concavity in midline of lower lip between labrale inferius and soft tissue pogonion
Pog'	Soft-tissue Pogonion	Most prominent or anterior point on chin in midsagittal plane
Gn'	Soft-tissue Gnathion	Most antero-inferior point on the soft tissue chin

Table 2. Group 1 (no genioplasty, n = 26) horizontal and vertical movements (millimeters) of hard and soft tissue landmarks (T1-T2)

<i>Landmark</i>	<i>Horizontal</i>			<i>Vertical</i>		
	<i>Mean</i>	<i>SD</i>	<i>p</i>	<i>Mean</i>	<i>SD</i>	<i>p</i>
Hard tissue (mm)						
ANS	1.1	2.3	*	-0.3	1.5	
PNS	2.0	2.9	**	5.0	4.0	**
A	2.2	2.3	**	-0.6	1.6	
Sd	3.8	2.3	**	-1.0	1.9	*
U1	5.4	3.0	**	-0.8	1.9	*
L1	6.9	3.8	**	-3.7	4.4	**
Id	9.5	4.4	**	-2.8	3.9	**
B	11.4	4.8	**	-1.3	3.4	
Pog	14.7	6.1	**	-1.5	3.5	*
Me	16.3	7.0	**	1.0	3.3	
Go	11.1	5.2	**	16.7	8.9	**
Soft Tissue (mm)						
N'	0.3	1.0		0.0	0.1	
Nd	0.0	1.2		-0.2	1.0	
Pn	0.4	1.0	*	-0.6	1.7	
Cm	1.4	1.6	**	-0.8	1.2	**
Sn	1.6	1.8	**	-0.6	1.0	**
Sls	3.2	1.9	**	-0.3	1.3	
Ls	3.8	2.2	**	-0.6	1.8	
Sts	5.0	2.8	**	-0.1	1.5	
Sti	7.4	3.4	**	-3.5	4.2	**
Li	8.7	3.8	**	-5.1	4.5	**
LMf	11.6	5.0	**	-3.6	4.0	**
Pog'	14.4	6.0	**	-2.5	3.8	**
Gn'	15.8	6.6	**	-1.7	3.4	*

*p<.05

**p<.01

Table 3. Group 2 (with genioplasty, n = 18) horizontal and vertical movements (millimeters) of hard and soft tissue landmarks (T1-T2)

Landmark	Horizontal			Vertical		
	Mean	SD	p	Mean	SD	p
Hard tissue (mm)						
ANS	0.5	3.0		-0.6	2.4	
PNS	2.3	3.5	*	4.9	3.3	**
A	1.5	2.6	*	-0.9	2.3	
Sd	2.8	2.6	**	-1.7	2.4	**
U1	5.0	3.2	**	-1.7	2.5	*
L1	8.2	3.1	**	-2.9	3.3	**
Id	11.0	3.7	**	-1.8	3.4	*
B	13.9	4.8	**	0.4	3.4	
Pog	22.6	6.9	**	1.0	4.2	
Me	18.6	5.4	**	3.3	4.0	**
Go	11.1	5.1	**	19.8	8.6	**
Soft Tissue (mm)						
N'	0.2	0.9		0.0	0.2	
Nd	-0.1	0.5		-0.2	0.9	
Pn	0.2	0.8		-0.7	1.7	
Cm	1.2	1.5	**	-0.8	1.1	**
Sn	0.9	1.5	*	-0.3	1.0	
SlS	2.5	2.2	**	-0.1	1.3	
Ls	3.0	2.6	**	-0.1	2.0	
Sts	3.5	3.3	**	0.1	1.9	
Sti	7.4	4.9	**	-4.1	3.4	**
Li	9.8	5.1	**	-5.8	3.9	**
Mlf	14.2	5.7	**	-3.1	3.7	**
Pog'	19.0	5.8	**	-1.1	5.1	
Gn'	21.5	6.7	**	1.0	3.9	

* $p < .05$ ** $p < .01$ **4.** Group 1 (no genioplasty, n = 26) and Group 2 (with genioplasty, n = 18) angular movements (degrees) of hard tissue landmarks (T1-T2)

Landmark	Mean	SD	p
Group 1			
(deg) SNA	2.0	2.3	**
SNB	6.4	2.7	**
ANB	-4.4	2.9	**
SNPog	7.3	3.0	**
OPA	-13.8	7.9	**
MPA	-14.0	7.6	**
Group 2			
(deg) SNA	1.4	2.8	**
SNB	7.7	2.6	**
ANB	-6.3	3.1	**
SNPog	11.2	3.4	**
OPA	-14.9	5.7	**
MPA	-16.5	6.0	**

* $p < .05$ ** $p < .01$

Table 5. Pearson product-moment correlations for horizontal landmark movement

<i>Hard tissue landmarks</i>	<i>Genioplasty</i>	<i>Soft tissue landmarks</i>							
		Sn	Sls	Ls	Sts	Sti	Li	Mlf	Pog'
ANS	- no	0.51**	0.63**	0.60**	0.64**	0.34**	0.21	0.18	0.22
	- yes	0.69**	0.55*	0.36	0.28	0.33	0.32	0.22	0.32
A	- no	0.58**	0.76**	0.73**	0.71**	0.38	0.29	0.25	0.26
	- yes	0.72**	0.68**	0.52*	0.47*	0.42	0.39	0.26	0.29
Sd	- no	0.53**	0.83**	0.83**	0.78**	0.60**	0.57**	0.51**	0.49*
	- yes	0.65**	0.90**	0.88**	0.82**	0.62**	0.57*	0.40	0.33
U1	- no	0.58**	0.81**	0.85**	0.85**	0.72**	0.68**	0.62**	0.58**
	- yes	0.46	0.80**	0.86**	0.87**	0.61**	0.52*	0.38	0.26
L1	- no	0.27	0.56**	0.58**	0.56**	0.84**	0.87**	0.87**	0.85**
	- yes	0.57*	0.57*	0.54*	0.50*	0.81**	0.86**	0.90**	0.86**
Id	- no	0.91	0.45*	0.49*	0.44*	0.82**	0.86**	0.94**	0.95**
	- yes	0.55*	0.50*	0.44	0.41	0.81**	0.85**	0.91**	0.91**
B	- no	0.05	0.40*	0.43*	0.39*	0.80**	0.85**	0.94**	0.96**
	- yes	0.61**	0.56*	0.42	0.38	0.84**	0.87**	0.92**	0.92**
Pogs	- no	-0.06	0.31	0.34	0.29	0.73**	0.84**	0.95**	0.98**
	- yes	0.44	0.45	0.39	0.26	0.75**	0.76**	0.83**	0.93**

* $p < .05$ ** $p < .01$ **Table 6.** Pearson product-moment correlations for vertical landmark movement

<i>Hard tissue landmarks</i>	<i>Genioplasty</i>	<i>Soft tissue landmarks</i>							
		Sn	Sls	Ls	Sts	Sti	Li	Mlf	Pog'
ANS	- no	0.16	0.28	0.18	0.29	0.28	0.30	0.22	0.29
	- yes	0.51*	0.36	0.30	-0.05	0.62**	0.57*	0.55*	0.50*
A	- no	0.23	0.32	0.23	0.30	0.31	0.34	0.25	0.30
	- yes	0.50*	0.40	0.36	0.02	0.66**	0.61**	0.61**	0.54*
Sd	- no	0.36	0.49*	0.41*	0.51**	0.14	0.18	0.19	0.25
	- yes	0.63**	0.60**	0.60**	0.29	0.66**	0.51*	0.66**	0.48*
U1	- no	0.39*	0.49*	0.40*	0.52**	0.13	0.17	0.20	0.27
	- yes	0.59**	0.55*	0.55*	0.25	0.64**	0.51*	0.67**	0.50*
L1	- no	0.56**	0.50**	0.26	0.32	0.78**	0.80**	0.93**	0.72**
	- yes	0.10	0.25	0.20	0.03	0.63**	0.77**	0.70**	0.72**
Id	- no	0.57**	0.48*	0.24	0.32	0.75**	0.75**	0.93**	0.74**
	- yes	0.07	0.23	0.20	0.07	0.62**	0.77**	0.73**	0.75**
B	- no	0.60**	0.58**	0.36	0.44*	0.64**	0.68**	0.90**	0.74**
	- yes	0.08	0.25	0.25	0.23	0.47*	0.62**	0.74**	0.73**
Pogs	- no	0.57**	0.58**	0.37	0.46*	0.55**	0.60**	0.86**	0.68**
	- yes	0.08	0.22	0.18	0.12	0.45	0.61**	0.68**	0.74**

Table 7. Linear regression for horizontal landmark movement

<i>Dependent variable</i>	<i>Independent variable</i>	<i>Genioplasty</i>	<i>Coefficient</i>	<i>Intersection</i>	<i>F</i>	<i>p</i>	<i>r</i>
Sn	ANS	-no	0.41	1.17	8.26	0.008	0.51
		-yes	0.34	0.72	14.36	0.001	0.69
Sls	A	-no	0.63	1.76	32.74	0.000	0.76
		-yes	0.59	1.63	14.07	0.001	0.68
Ls	Sd	-no	0.80	0.75	50.98	0.000	0.82
		-yes	0.86	0.59	53.09	0.000	0.88
Sts	U1	-no	0.79	0.72	61.59	0.000	0.85
		-yes	0.91	- 0.97	44.43	0.000	0.86
Sti	L1	-no	0.76	2.17	57.22	0.000	0.84
		-yes	1.27	- 3.04	31.21	0.000	0.81
Li	Id	-no	0.75	1.55	70.37	0.000	0.86
		-yes	1.18	- 3.18	41.70	0.000	0.85
LMf	B	-no	0.97	0.51	195.18	0.000	0.94
		-yes	1.10	- 0.99	87.97	0.000	0.92
Pog'	Pog	-no	0.95	0.35	562.95	0.000	0.98
		-yes	0.77	1.52	104.04	0.000	0.93

Table 8. Linear regression for vertical landmark movement

<i>Dependent variable</i>	<i>Independent variable</i>	<i>Genioplasty</i>	<i>Coefficient</i>	<i>Intersection</i>	<i>F</i>	<i>p</i>	<i>r</i>
Sn	ANS	-no	0.11	- 0.56	0.63	0.433	0.16
		-yes	0.22	- 0.13	5.48	0.032	0.51
Sls	A	-no	0.27	- 0.11	2.75	0.110	0.32
		-yes	0.23	0.09	3.04	0.100	0.40
Ls	Sd	-no	0.38	- 0.21	4.80	0.038	0.60
		-yes	0.49	0.75	8.78	0.009	0.52
Sts	U1	-no	0.41	0.24	8.99	0.006	0.52
		-yes	0.19	0.43	1.08	0.313	0.25
Sti	L1	-no	0.75	- 0.76	36.29	0.000	0.78
		-yes	0.65	- 2.18	10.37	0.005	0.63
Li	Id	-no	0.87	- 2.63	31.64	0.000	0.75
		-yes	0.91	- 4.16	23.72	0.000	0.77
LMf	B	-no	1.06	- 2.22	104.65	0.000	0.90
		-yes	0.79	- 3.40	19.57	0.000	0.74
Pog'	Pog	-no	0.73	- 1.38	20.13	0.000	0.68
		-yes	0.90	- 2.00	18.79	0.000	0.73

Table 9. Ratios and percentage changes between hard and soft tissues after horizontal advancement

<i>Ratios</i>	<i>No genioplasty</i>	<i>Percentage Changes</i>	<i>Genioplasty</i>	<i>Percentage Changes</i>
ANS: Sn	1: 1.45	145	1:1.80	180
A: Sls	1:1.45	145	1:1.66	166
Sd: Ls	1:1	100	1:1.07	107
U1: Sts	1:0.92	92	1:0.70	70
L1: Sti	1:1.07	102	1:0.90	90
Id: Li	1:0.91	91	1:0.89	89
B: LMf	1:1.01	101	1:1.02	102
Pog: Pog'	1:0.97	97	1:0.84	84

4 Considerações Finais

A ciência evolui em meio a erros e acertos. Avanços consistentes e embasados cientificamente, só ocorrem mediante observação criteriosa e analítica dos fatos; sempre desprovida de tendenciosidades.

Historicamente, cirurgias de ATM evoluíram de maneira consistente, porém controvertida. Muito antes de Costen⁶ o advento do raio X no final do século XIX, ofereceu indícios para uma possível correlação entre diminuição do espaço intra-articular e dor facial. Essa constatação bastou para que uma série de condilectomias conservadoras ou radicais fosse realizada na tentativa de restabelecer o espaço diminuído. Claramente equivocada, essa técnica gerou inúmeros efeitos-colaterais sempre acompanhados de mordida aberta anterior e dor.

Com o surgimento da ressonância magnética, viabilizou-se um diagnóstico mais minucioso e preciso dos componentes internos da ATM, principalmente do disco articular e de seus ligamentos e inserções. Assim, abriu-se caminho à interpretação de que os problemas relacionados à ATM originavam-se de posições anômalas dos discos articulares, perfurações ou outras alterações morfológicas que, de maneira simplista, foram tratados com menissectomias,

reposicionamentos de disco, ou substituição dos discos morfológicamente alterados por implantes aloplásticos ou retalhos musculares pediculados. Novamente a instituição generalizada dessas técnicas não trouxe os resultados esperados para muitos pacientes. Embora os resultados iniciais fossem promissores, com índice de sucesso em torno de 91%²⁷, o acompanhamento em longo prazo mostrou que pacientes submetidos a implantes de Proplast/Teflon (PT, Vitek Inc., Houston, TX) na sua maioria, desenvolviam reação de células gigantes por corpo estranho que os levavam a quadros dramáticos, irreversíveis e de solução paliativa^{10,14,17,24}.

Paralelamente ao desenvolvimento das técnicas cirúrgicas para tratamento da ATM e suas conseqüências negativas, desenvolveu-se também técnicas conhecidas como de invasão mínima (artroscopia e artrocentese). O advento dessas técnicas derrubou a idéia de que um disco deslocado seria o causador da dor, uma vez que, com simples lavagem ou remoção de aderências da ATM ocorria melhora significativa dos sintomas^{1,13,15,16}. Desse modo, assumiu-se que as alterações morfológicas seriam na verdade, conseqüências dos eventos bioquímicos que antecederam essa alteração, e não sua causa como acreditavam os seguidores de terapias intervencionistas.

Outra contribuição importante que a artroscopia e a artrocentese trouxeram foi o desenvolvimento de pesquisas sobre os eventos biológicos moleculares que ocorriam na articulação doente. A

partir disso, observou-se uma sequência de eventos químicos que denunciavam a transição de um metabolismo anabólico (adaptativo) para um metabolismo catabólico (degenerativo) na articulação comprometida^{7,22}.

Embora a ATM tenha um grande potencial adaptativo devido à sua fibrocartilagem, essa adaptação depende da variabilidade biológica de cada indivíduo ante o agente agressor. Um exemplo disso são os pacientes que exercem apertamento ou outra parafunção, e pelo estímulo existente, podem sair de uma condição metabólica adaptativa para uma condição metabólica degenerativa. Somado ao processo degenerativo, é comum observar-se uma sintomatologia exacerbada nos pacientes portadores de DTM. Frequentemente acompanhados de dor crônica, os sintomas são normalmente desencadeados pelos sucessivos anos de processo patológico na ATM somado ao comprometimento emocional muitas vezes presente²³. Os portadores de dor crônica sofrem de sensibilização central pela estimulação continuada das vias aferentes associada a alterações no sistema inibitório descendente da dor^{19,21}. O resultado importante dessas alterações é que a dor não reflete simplesmente a presença, intensidade ou duração de um estímulo específico na periferia, mas também mudanças na função do Sistema Nervoso Central^{34,35}. Dessa forma, muitos pacientes sofredores de dor crônica não respondem de maneira previsível ao trauma cirúrgico, ainda que este venha a eliminar

o fator etiológico que iniciou o estímulo doloroso. Como uma entidade própria, a dor ou a falha dos mecanismos fisiológicos de sua inibição, perpetua-se ou agrava-se independentemente da intervenção realizada²⁸. Cirurgias em ATM ou outras cirurgias realizadas nesses pacientes participam, de maneira negativa, no sistema de retroalimentação de seus problemas físicos e emocionais. Portanto, o tratamento cirúrgico para portadores de dor crônica não é a melhor escolha³⁵.

Felizmente as cirurgias em ATM não são rotina em nosso meio, como acontece com a cirurgia ortognática convencional. Nos Estados Unidos da América do Norte essa situação é bem diferente. O sistema privativo de saúde desse país teve participação direta no estímulo às intervenções complexas, principalmente as de caráter cirúrgico. A expectativa de que a complexa, cara e ousada intervenção possa trazer a solução para seu sofrimento e a posterior frustração por não atingir os resultados esperados, leva pacientes a repetidas cirurgias em ATM. Pacientes pagantes dos caros planos existentes sentem-se indulgentes com intervenções dispendiosas na tentativa subconsciente de sentir que esses procedimentos fazem jus ao dinheiro empregado. Esta linha de pensamento é agravada quando intervenções cirúrgicas estão envolvidas. Intervenções cirúrgicas, no entendimento do paciente abalado emocionalmente pela DTM com dor crônica, têm um caráter de socorro extremo, externo e totalmente desvinculado da participação do

paciente ou mesmo de uma equipe multidisciplinar. É como se uma intervenção isolada fosse capaz de solucionar problemas que se desenvolveram ao longo de décadas e provavelmente por etiologias multifatoriais.

A evidenciação científica de que DTMs de origem articular são um evento multifatorial com respostas biológicas variáveis fez com que protocolos de tratamento generalizados e invasivos fossem questionados. Criou-se então um consensual preconceito sobre a execução de cirurgias nas ATMs pela comunidade científica baseado nos insucessos obtidos e na melhor compreensão dos mecanismos envolvidos na dor crônica da ATM, gerando uma rejeição às intervenções cirúrgicas nessa articulação como forma previsível de tratamento. Assim, de um extremo passou-se a outro. E novos equívocos se somam resultando em mais dificuldade em se estabelecer bons protocolos de tratamento.

Esse preconceito generalizado não estaria presente caso terapias intervencionistas fossem aplicadas diante de condições específicas, o que reduziria em muito, os altos índices de insucesso acumulados no passado. Existem várias situações clínicas bem definidas em que a intervenção cirúrgica na ATM assume indicação indiscutível. São elas, as anquiloses, as microsomias hemifaciais tipo III, as reabsorções condilares idiopáticas totais, as reabsorções de origem reumatóide ou auto-imune, os traumatismos com destruição

condilar, os tumores e os pacientes previamente submetidos a múltiplas cirurgias, em especial as de implantes de Proplast/Teflon. Pacientes portadores dessas condições sofrem com o preconceito citado.

A rejeição à intervenção cirúrgica das ATMs, faz com que inúmeros pacientes portadores de reabsorção condilar idiopática sejam submetidos a sucessivas cirurgias ortognáticas na expectativa de se obter a estabilidade não conseguida nas cirurgias anteriores devido à patologia da ATM⁹. Pacientes com dramática restrição do espaço aéreo buco ou nasofaríngeo devido a patologias diversas da ATM que afetaram o crescimento mandibular são condenados a uma vida de limitações já que seus côndilos mandibulares não suportariam a amplitude do avanço mandibular necessário para atender suas necessidades. A mesma situação ocorre quando processos auto-imunes acometem as ATMs em idade precoce. O comprometimento da articulação afeta o crescimento, gerando um padrão dolicofacial com severa retrusão mandibular onde a cirurgia ortognática isolada não é uma opção previsível²⁹. Essas condições estão presentes na amostra estudada nesta série de artigos. Graças à superação de preconceitos e a uma convicção obstinada, a técnica desenvolvida pelo Dr. Larry Wolford mudou para melhor a vida de muitos pacientes. O desenvolvimento de uma prótese individualizada por meio da tecnologia CAD/CAM e com materiais biocompatíveis viabilizou um alto índice de sucesso para esses casos. Embora ainda não se saiba ao certo a

longevidade dessa prótese, já é possível afirmar, com base nos resultados desta série de artigos, que o índice de estabilidade cirúrgica é extremamente satisfatório. Os 19 anos de experiência do Dr. Wolford com a prótese estudada, somados a mais de 540 substituições de ATM com sucesso, faz com que esse tipo de prótese customizada represente uma opção real para inúmeros pacientes carentes de soluções definitivas para seus problemas.

Não há como ignorar, que em alguns raros casos da amostra estudada, a melhora nas funções e na sintomatologia dolorosa foi limitada*. Mas são esses mesmos casos na qual há uma história de sucessivas e fracassadas tentativas de intervenção cirúrgica somada ao desenvolvimento de sensibilização central. Esses casos merecem estudos complementares. O que se observou na grande maioria dos casos, foi justamente o oposto. Os resultados mostraram que as próteses totais de ATM (TMJ Concepts system®) apresentam estabilidade em longo prazo (1 a 11,9 anos de acompanhamento), sendo uma técnica viável para casos de reconstrução de ATM na qual se faz necessário grandes avanços mandibulares com rotação anti-horária do plano oclusal. Pacientes com deformidades dentofaciais decorrentes de patologias da ATM são os grandes beneficiados pela técnica. Porém, esse não foi o único benefício observado. O aumento significativo do espaço aéreo bucofaríngeo incrementou a qualidade de vida a esses pacientes. Enquanto a cirurgia ortognática isolada em

*Pinto LP, Wolford LM, Buschang; Bernardi FH, Goncalves JR, Cassano DS. Maxillo-Mandibular Counter-Clockwise Rotation and Mandibular Advancement with TMJ Concepts® Total Joint Prostheses: Part III - Pain and Dysfunction Outcomes. IJOMS-D-07-00535R1

pacientes com ATMs saudáveis viabiliza, segundo Gonçalves⁸ (2006), um aumento médio de 4,4 mm nas dimensões faringeanas, a incorporação da cirurgia de substituição das ATMs em pacientes com comprometimento irreversível possibilitou resultados semelhantes (média de 4,9 mm). As mudanças em tecido mole comportaram-se de forma previsível diante da movimentação esquelética e otimizaram a estética facial que, de maneira nenhuma, poderia ser alcançada pelos métodos convencionais de cirurgia ortognática.

Assim, é preciso que se olhe para as cirurgias de ATM sem uma visão mercadológica e livre de preconceitos. A substituição das ATMs por prótese, embora rara, tem se mostrado uma ótima opção quando bem indicada, e algumas vezes, é a única opção de tratamento presente. Para que se reverta essa visão preestabelecida sobre as intervenções cirúrgicas faz-se necessário que estudos científicos imparciais, com metodologia meticulosa e amostra significativa, e com um longo período de acompanhamento sejam realizados, assim como este trabalho se propôs a fazer. As mudanças nesse conceito foram iniciadas, mas ainda há um grande caminho a ser percorrido principalmente em relação às indicações da técnica discutida no presente trabalho.



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* De acordo com o estilo Vancouver. Disponível em: http://www.nlm.nih.gov/bsd/uniform_requirements.html

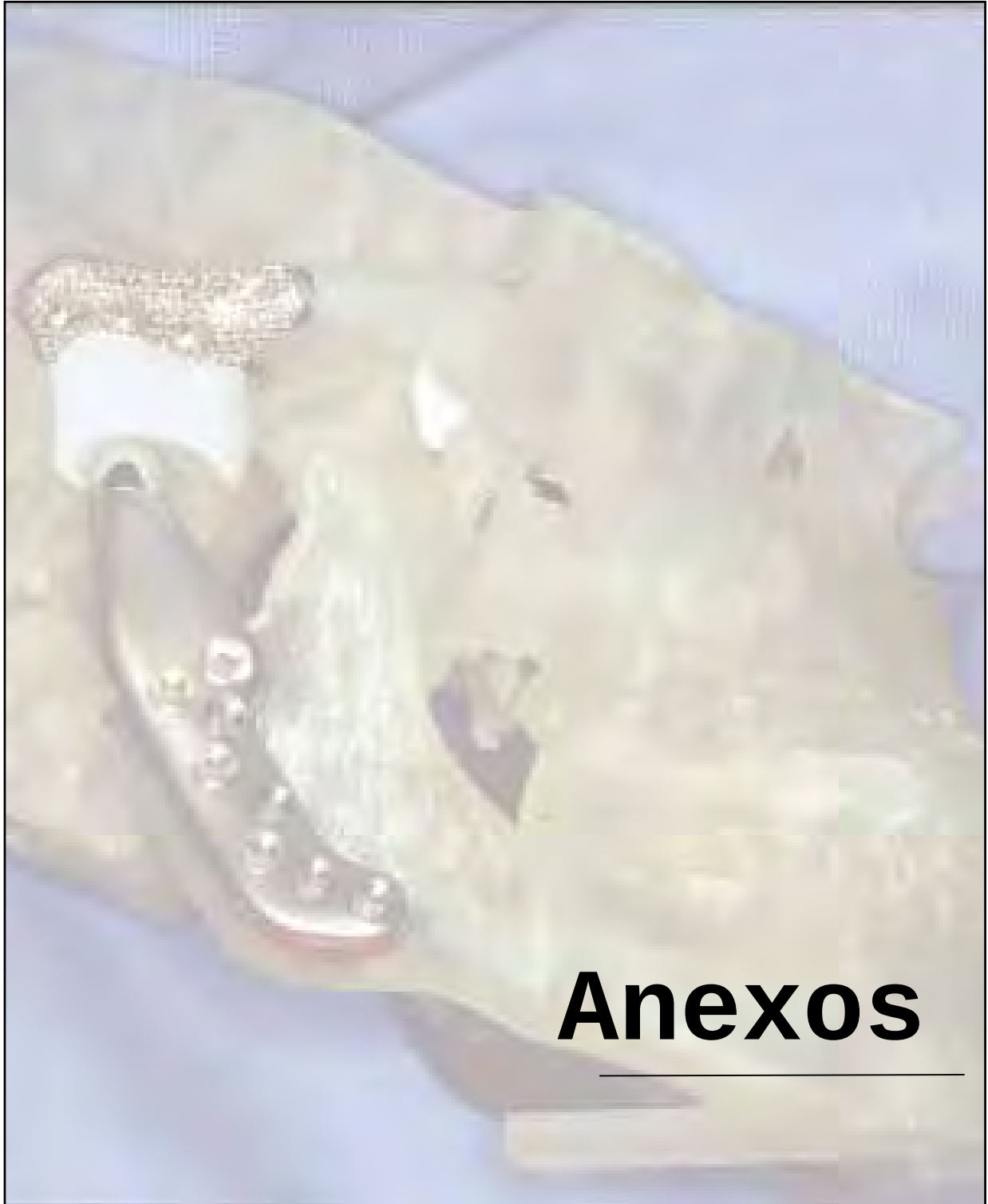
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Anexos

ANEXO 1

Tabela A1- Valores iniciais e mudanças cirúrgicas e pós-cirúrgicas

Variable	T1			T2-T1			P	T3-T2			P	
	Mean	SD	Mean	SD	Min	Max		Mean	SD	Min		Max
(deg)	SNA	79.8	4.0	2.3	2.3	-6.5	6.4	-0.4	1.4	-2.4	5.9	
	SNB	72.4	4.1	6.9	2.9	1.0	12.8	0.0	1.0	-3.1	2.2	
	ANB	7.4	3.3	-4.6	2.9	-10.5	2.2	-0.4	1.4	-2.6	5.4	*
	SNiPog	73.0	4.8	9.1	4.2	1.0	20.1	0.0	1.1	-2.8	2.5	
(mm)	OPA	25.1	8.2	-14.9	8.0	-37.0	-2.3	0.6	3.3	-4.5	10.9	
	MPA	50.4	8.0	-15.0	7.7	-35.3	-0.6	0.0	2.2	-5.1	5.9	
	OPT/NS	111.1	8.7	-5.6	6.7	-21.2	5.2	1.8	6.7	-11.9	16.8	
	OPT/CVT	17.3	1.5	0.0	0.7	-1.8	1.4	0.2	0.9	-1.6	2.1	
	ANS-horizontal	65.7	4.7	1.3	2.4	-7.3	7.1	-0.4	1.6	-4.0	5.2	
	ANS-vertical	42.7	3.3	-0.6	1.9	-4.0	3.4	0.4	1.5	-2.2	7.0	
	PNS-horizontal	19.6	4.3	2.9	3.1	-3.9	10.9	-0.8	2.6	-8.4	3.9	*
	PNS-vertical	42.9	2.7	5.5	4.2	-1.8	14.3	-0.6	2.0	-5.0	6.8	
	A-horizontal	67.5	4.8	2.5	2.2	-6.0	6.8	-0.4	1.3	-2.8	5.0	*
	A-vertical	49.7	4.2	-1.0	1.9	-4.2	3.3	0.4	1.6	-2.5	7.0	
	B-horizontal	52.0	8.3	12.4	5.4	1.7	22.5	0.0	1.8	-4.9	4.2	
	B-vertical	90.7	5.7	-0.1	3.5	-8.4	5.8	-0.4	2.0	-4.7	3.8	
	Pog- horizontal	50.5	10.7	18.4	8.5	2.1	42.1	-0.1	2.1	-4.9	5.3	
	Pog- vertical	104.5	6.9	-0.1	3.8	-10.9	8.8	-0.3	2.1	-5.3	4.0	
	Me- horizontal	39.4	11.3	17.3	7.0	2.6	32.8	0.0	2.3	-5.3	5.3	
	Me- vertical	108.3	6.6	2.6	3.9	-6.7	12.5	-0.4	1.8	-4.8	3.8	
	Go- horizontal	-8.4	6.1	11.0	5.3	2.8	25.6	0.0	1.9	-5.9	4.9	
	Go- vertical	63.1	8.8	18.4	9.2	-1.5	43.4	-0.4	2.2	-6.8	6.2	
	U1T-horizontal	68.7	6.3	5.6	3.0	-0.6	11.3	-0.4	1.7	-3.9	4.8	
	U1T-vertical	74.7	4.8	-1.3	1.9	-5.7	2.6	0.3	1.7	-3.8	5.7	
	L1T-horizontal	63.3	6.6	7.9	3.5	0.9	14.3	-0.3	1.4	-2.8	3.9	
	L1T-vertical	74.6	5.2	-2.9	4.0	-16.5	2.3	-0.4	1.8	-4.3	3.8	
	C3- horizontal	-26.8	10.6	5.9	7.4	-7.7	24.7	-1.7	7.3	-19.9	15.2	
	C3- vertical	99.4	5.5	-0.5	1.5	-4.1	4.9	0.5	2.3	-6.7	8.0	
	Hy- horizontal	3.3	10.3	8.5	5.8	-7.6	23.2	-1.7	5.9	-18.8	13.3	
	Hy- vertical	106.5	8.5	2.1	6.0	-12.3	14.1	-4.1	5.7	-19.0	9.9	**
BT- horizontal	-10.5	7.5	7.9	4.8	-5.6	16.3	-2.1	4.2	-14.5	8.1	**	
BT- vertical	84.8	8.3	8.3	7.0	-8.7	27.1	-3.4	5.1	-14.3	9.8	**	
PASnar	7.3	3.8	4.9	4.1	-3.5	15.7	-1.1	4.1	-12.7	6.8		
C3-Me	67.3	9.6	11.7	9.1	-15.3	36.9	1.7	7.4	-15.8	17.6		
Hy-C3	31.7	4.6	3.2	3.9	-8.2	14.6	-1.0	4.1	-11.5	9.5		
MP-Hy	23.2	5.9	-3.8	5.8	-18.4	9.8	-2.5	5.2	-14.5	10.0	**	
OJ	5.4	2.7	-2.2	2.5	-7.4	1.8	-0.1	1.2	-3.5	3.8		
OB	-0.1	4.1	-1.6	3.7	-14.7	3.9	-0.7	1.6	-7.5	2.1	**	

* $p < .05$

** $p < .01$

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Araraquara, 23 de setembro de 2008

Karina Eiras Dela Coleta Pizzol