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Case report impact on orthognathic surgery for counterclockwise rotation and effect on airway, with or without temporomandibular joint total joint prostheses

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ABSTRACT

Purpose: Present case reports that have generated new treatment protocols improving treatment of patient outcomes with jaw deformities and airway compromises requiring counterclockwise rotation (CCWR) of the maxillo-mandibular complex (MMC) with or without a requirement for temporomandibular joint (TMJ) total joint prostheses (TJP). Presented are studies that verify the efficacy of these procedures.

Methods: Initial case presentations were identified in reference to CCWR of the MMC without and with TMJ total joint prostheses in cases of co-existing end-stage TMJ pathology. A non-systematic literature search was conducted to identify studies pertinent to subject matter.

Results: Two case reports are presented that have significantly affected our specialty: 1) CCWR of the MMC and effect on airway, and 2) TMJ TJP with concomitant maxillary osteotomies for CCWR of the MMC. Forty papers were identified meeting the filtered criteria. Twenty-nine papers were excluded as case reports, philosophy, technique, or small case series. Eleven studies met the inclusion criteria and are summarized according to the data included. These studies validate the efficacy and stability of CCWR of the MMC in the presence of healthy joints as well as patients with end-stage TMJ pathology using custom TMJ TJP in conjunction with orthognathic surgery.

Conclusions: Patients with healthy TMJs can be treated with CCWR of the MMC with predictable outcomes and stability. Patients with end-stage TMJ pathology can benefit from TMJ TJP and orthognathic surgery for CCWR of the MMC with good stability, improved function, decreased pain, improved airway, and quality of life.

1. Introduction

Occasionally, a case report will have a significant impact in treatment philosophy and surgical protocol improving the quality of patient care. This paper identifies two initial case reports that generated new treatment philosophies and techniques that have resulted in major advances in the treatment of patients with jaw deformities and airway compromises requiring counterclockwise rotation (CCWR) of the maxillo-mandibular complex (MMC) with or without a requirement for temporomandibular joint (TMJ) total joint prostheses (TJP). The health and stability of the TMJs are dependent on the structural integrity, position, and presence or absence of

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disease or injury affecting the articular disc, condyle, fossa, and associated soft tissues. The TMJ hard and soft tissue components may become degenerated, arthritic, and end-stage with any of these following TMJ pathologies; 1) articular disc dislocation (long duration), 2) adolescent internal condylar resorption (AICR), 3) reactive arthritis, 4) osteoarthritis, 5) ankylosis, 6) congenital deformation or absence of the TMJ, 7) trauma, 8) connective tissue and autoimmune diseases, 9) previously failed TMJ surgery, and 10) other end-stage TMJ pathologies.1-4 These TMJ conditions may be associated with dentofacial deformities, malocclusion, TMJ pain, headaches, myofascial pain, TMJ and jaw dysfunction, ear symptoms, nasal airway obstruction, and sleep apnea. Patients with these conditions may benefit from TMJ reconstruction with TJP, orthognathic surgery, and other adjunctive procedures [1–3].

This paper will present the initial case report of CCWR of the MMC) and the effect on the oropharyngeal airway (OPAW) as well as describe the initial case report of combined application of TJP and orthognathic surgery in a single operation for CCWR of the MMC. Studies that have verified the results of these initial reports will be summarized. In the author's 30+ year experience of using custom TMJ TJP, approximately 2/3rds of patients can benefit from concomitant maxillary orthognathic surgery for improvement in jaw and TMJ function, airway and breathing, decrease or eliminate pain, and improved facial balance. The aims of this paper are: 1) present the initial case report of CCWR of the MMC and the effect on the OPAW; and 2) identify the initial case report that influenced the application of TMJ TJP in conjunction with orthognathic surgery for correction of facial deformities with end-stage TMJ pathology; and 3) review the published studies that validate CCWR of the MMC and effect on the OPAW as well as the effectiveness and predictability of TMJ TJP with CCWR of the MMC.

2. Methods

This paper is not a systematic literature review, but a search was performed to identify studies related to CCWR of the MMC, and effect on the OPAW with or without concomitant TMJ TJP. Search engines used included PubMed, ScienceDirect, Scopus, and Google Search. MeSH filters included: Counterclockwise rotation of the maxilla and mandible AND airway changes AND TMJ total joint prostheses. Inclusion criteria were: 1) Patients treated with CCWR of the MMC and 2) TMJ TJP with CCWR of the MMC. Exclusion criteria were: 1) TMJ TJP and/or CCWR not performed, and 2) case reports, technical reports, or case series of 5 or less subjects. The articles were reviewed by both authors for inclusion. The context of this paper focuses on studies involving patients with CCWR of the MMC with or without end-stage TMJ pathology requiring TMJ TJP.

3. Results

Two case reports are presented that have significantly affected our specialty: 1) CCWR of the MMC and effect on OPAW, and 2) TMJ TJP with concomitant maxillary osteotomies for CCWR of the MMC. Forty papers were identified meeting the filtered criteria. Twenty-nine papers were excluded as case reports, philosophy, technique, or small case series. Eleven papers met the inclusion criteria and will be categorized and summarized according to the data included. A few other select papers are included to substantiate the treatment protocols.

3.1. Case report: CCWR of the MMC and the effect on the OPAW

Many patients diagnosed with sleep apnea may benefit from CCWR of the MMC if the jaws are retruded with compromised OPAW. Patients who also have TMJ pathology, may benefit from TMJ surgery at the same time or before the orthognathic surgery is performed to provide a stable, predictable outcome and decrease preexisting pain. Advancing the MMC with a CCWR, increases the OPAW significantly [4–7].

The philosophy of alteration of the occlusal plane with CCWR of the MMC was developed by Wolford in 1981, initially performed on a 14-year-old patient with cerebro-costo-mandibular syndrome. Her diagnosis included: 1) maxillary A-P and posterior vertical hypoplasia, 2) severe mandibular A-P and posterior vertical hypoplasia, 3) high occlusal plane angulation facial morphology, 4) Class II mal-occlusion, 5) A-P microgenia, 6) markedly decreased OPAW (<2 mm), and 7) severe sleep apnea (Fig. 1A–C, 2A). The TMJs were stable. At the age of 12 years-old, she had a mandibular advancement of 10 mm to place it in a Class I occlusion and a 14 mm alloplastic chin implant (Fig. 2B). However, because of the extremely high occlusal plane angle, the mandible advancement had minimal effect on the oropharyngeal airway and the severe sleep apnea persisted. This is where the counterclockwise rotation concept developed in an effort to improve her airway. She was then treated with the following procedures: 1) vertical lengthening of the mandibular rami 18 mm using bilateral intraoral inverted "L" osteotomies, with iliac crest bone grafting, 2) maxillary osteotomies, down-grafting the posterior maxilla 10 mm with iliac crest bone grafts (Figs. 2C), and 3) stabilization of down-grafted maxilla with bilateral threaded Steinman pins placed through the zygomatic buttress and attached to the 1st molar orthodontic brackets [8,9]. The maxilla was advanced 10 mm and Pogonion was advanced 18 mm. The total advancement of the mandible at Pogonion with the 2 orthognathic surgical procedures and alloplastic chin implant was 35 mm. Presurgery the oropharyngeal airway was <2 mm and at 4½ years follow-up was 10 mm. The surgery was done prior to availability of rigid fixation so the treaded Steinman pin fixation technique was used which proved to be a very stable procedure [8, 9]. The patient is seen 4 ½ years post-surgery (Fig. 1D–F, 2D). The results of this case initiated the CCRW of the MMC treatment approach for patients with jaw deformities involving retruded mandible, with or without sleep apnea. Wolford and Hilliard [8] in 1987 published this case and is the first known patient to have CCWR involving vertical lengthening of the ramus and posterior maxilla. Wolford et al. [10] in 1985, published the protocol for surgical planning of CCWR of the occlusal plane and MMC.

CCWR of the MMC can have a major impact on the OPAW. Kortebein and Wolford [11] in 1991 were the first to publish on the positive effects of CCWR of the MMC on OPAW. Other studies followed that validated the positive effects of CCWR of the MMC on the OPAW.[12–14] It is important that the TMJs are healthy and stable, or the indicated surgical treatment provided for a co-existing

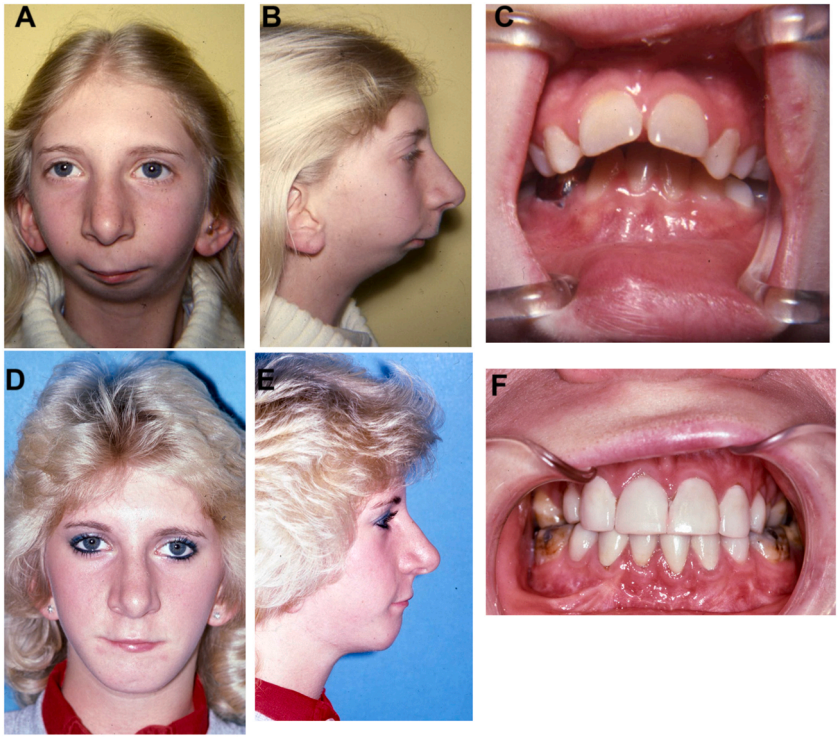

Fig. 1. (A–C) 12 year-old female with Cerebro-Costo-Mandibular syndrome with associated maxillary hypoplasia, severe mandibular hypoplasia, high occlusal plane facial morphology, Class II mal-occlusion, and OPAW of less than 2 mm. The patient was treated with bilateral mandibular ramus inverted "L" osteotomies and bone grafting lengthening the ramus 18 mm, maxillary advancement of 10 mm and posterior down-graft of 10 mm with bone grafting. The chin advanced 35 mm from its original position. (D–F) The patient is seen at 4 ½ years post-surgery showing excellent stability and improved functional and esthetic outcomes.

TMJ pathology to ensure a stable and predictable outcome with orthognathic surgery. If the TMJs are not healthy, CCWR of the MMC may lead to condylar resorption with resulting relapse, mal-occlusion, TMJ/jaw dysfunction, and pain [15–19].

3.2. Case report: Combined TMJ TJP and orthognathic surgery for CCWR of the MMC

Wolford et al. [18] in 1994, publish a study of 56 patients undergoing TMJ reconstruction using Techmedica patient-fitted TJP (Techmedica Inc., Camarillo, CA). Two case reports were presented in this study with TMJ reconstruction and mandibular advancement using Techmedica TJP and maxillary osteotomies for CCWR of the MMC to correct the severe facial deformity and eliminate obstructive sleep apnea. These are the first known published cases using this technology.

Case 1 was a 25-year-old female who had 3 previous bilateral TMJ failed surgeries including bilateral articular disc replacement using Proplast-Teflon TMJ interpositional implants (Vitek Inc. Houston, TX) and Silastic interpositional implants (Dow-Corning, Midland, MI). These implants created severe foreign-body giant-cell reaction causing: 1) significant TMJ destruction, 2) high occlusal plane angle facial morphology, 3) mandibular retrusion, 4) Class II malocclusion, 5) OPAW with an A-P dimension of 2 mm, and 6) severe sleep apnea. She was treated in 1990 with the following surgical procedures: 1) bilateral TMJ reconstruction and mandibular advancement with CCWR using Techmedica TJP; and 2) multiple maxillary osteotomies to advance in a CCWR, expand and down-graft the posterior maxilla. At. 22 months post-surgery, the MMC remained skeletally and occlusally stable with Pogonion advanced 22 mm, pain and sleep apnea eliminated, and significant improvement in facial balance and quality of life.

Case 2 was a 15-year-old female with juvenile idiopathic arthritis (JIA). Diagnosis included: 1) severe condylar resorption from JIA; 2) maxillary posterior vertical and transverse hypoplasia, anterior vertical hyperplasia; 3) severe mandibular hypoplasia; 4) high occlusal plane angulation of 31° (normal 8°); 5) Class II mal-occlusion with 6 mm anterior open bite; 6) OPAW of 2 mm; and 7) severe sleep apnea (Fig. 3A–C, 4A). Surgery performed in 1991 included: 1) bilateral TMJ reconstruction and mandibular advancement with CCWR using Techmedica TJP; 2) multiple maxillary osteotomies for CCWR, expand, and down-graft posterior; 3) alloplastic genioplasty; and 4) partial reduction turbinectomies. Pogonion was advanced 42 mm in this single-stage reconstruction (Fig. 4B). At 1-year post-surgery (Fig. 3-D-F) pain and sleep apnea were eliminated, good skeletal and occlusal stability, jaw function, and significantly improved facial balance. Longest follow-up for this patient is 24 years (Fig. 3G–I). She has maintained a very stable and pain free outcome.

These 2 case reports created a new paradigm of surgical philosophy and methodology to correct dentofacial deformities by CCWR of the MMC with highly predictable skeletal and occlusal stability, increase the OPAW, achieve normalcy in facial balance and function, eliminate pain and sleep apnea, as well as reconstruct end-stage TMJ pathology. These CCWR of the MMC results in the presence of TMJ pathology were unattainable prior to these innovative developments.

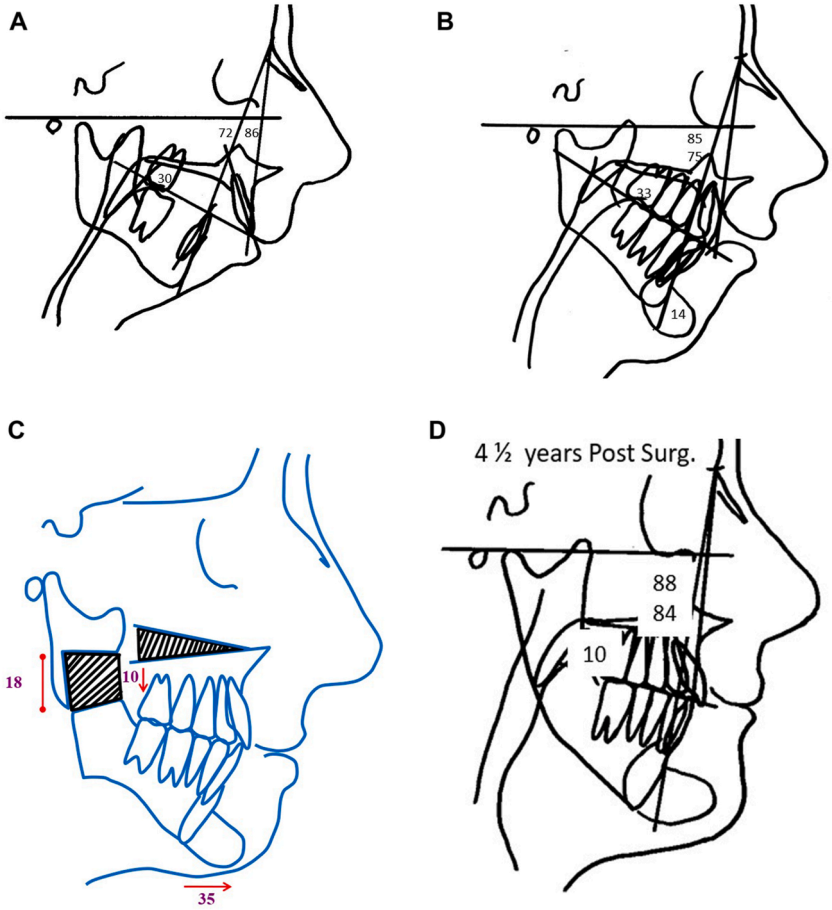

Fig. 2. (A) Cephalometric analysis demonstrating the severe retrusion of the mandible and the maxillary A-P and posterior vertical hypoplasia with high occlusal plane facial morphology. The oropharyngeal airway is less than 2 mm. (B) The initial surgical change following mandibular advancement with bilateral sagittal split osteotomy and a 14 mm alloplastic augmentation genioplasty. The mandible advanced 10 mm at the incisors and 8 mm at bony pogonion. The oropharyngeal airway only increased to 4 mm with severe sleep apnea remaining. (C) Surgical prediction tracing demonstrates the planned surgical moves, advancing the MMC with a CCWR lengthening the ramus 18 mm and down-grafting the posterior maxilla 10 mm. (D) Lateral cephalogram at 4 ½ years post-surgery demonstrates the skeletal and occlusal stability, Improvement in facial balance, and increased OPAW . Pogonion advanced 35 mm from the original position.

3.3. CCWR of the MMC: Effect on OPAW

Kortebein and Wolford [11] were the first to demonstrate the positive effects of CCWR of the MMC on OPAW. Twenty patients with healthy TMJs received double jaw orthognathic surgery for CCWR of the MMC with an average mandibular advancement of 11.4 mm at the genial tubercle and the occlusal plane decreased 10.5°. The OPAW A-P dimension increased 5.2 mm (46% of the mandibular advancement). The study validated the outcome of Case 1.

Reiche-Fischel et al. [12] evaluated 72 patients with healthy TMJs, relative to the amount of mandibular advancement and effect on the increase in OPAW measured at the tongue base. Advancement from 0 to 10 mm had a 66% increase of the OPAW, 10–15 mm was 56% increase, and >20 mm the increase was 41%, indicating the greatest change in the airway dimension occurs with the first 10 mm of CCWR of the MMC.

Mehra et al. [13] in 2001 evaluated 30 patients with healthy TMJs receiving CCWR advancement of the MMC where the mandibular advancement at the genial tubercles averaged 7.5 mm, the oropharyngeal airway space increased 76% of the amount of mandibular advancement at the base of the tongue and 47% at the soft palate level.

Goncalves et al. [14] in 2006 evaluated 56 patients with healthy TMJs that had CCWR of the MMC with an average mandibular advancement of 13.1 mm. The narrowest retroglossal airway measurement increased at the lowest retropalatal airway 3.7 mm and at the retroglossal area 4.4 mm and remained stable long term.

Giralt-Hernando et al. [20] in 2021 evaluated 103 patients with no TMJ surgery, that were Class II for airway changes with single or double jaw advancements. Compared to mandibular advancement and double jaw advancement without CCWR, patients receiving double jaw surgery with CCWR of the MMC had significantly better outcomes relative to increase of the volume and cross-sectional area of the OPAW. The OPAW increased by 61.4 mm^3 for every 1 mm of mandibular advancement, or 102.4 mm^3 for every 1 mm of downward movement of the PNS (posterior nasal spine) [20].

Fig. 3. (A–C) 15 year-old female diagnosed with JIA presented with severely resorbed condyles, maxillary anterior vertical hyperplasia, posterior vertical and transverse hypoplasia, severe mandibular hypoplasia, Class II occlusion with anterior open bite, and an oropharyngeal airway dimension of 2 mm. She was treated with bilateral Techmedica TMJ TJP and maxillary osteotomies for CCWR of the MMC, alloplastic augmentation genioplasty, and partial turbinectomies. Pogonion advanced 42 mm. (D–F) The patient is seen one-year post-surgery demonstrating improved jaw alignment and facial balance. (G–I) At 24 years post-surgery the patient maintains good function, occlusion, facial balance, and is pain free.

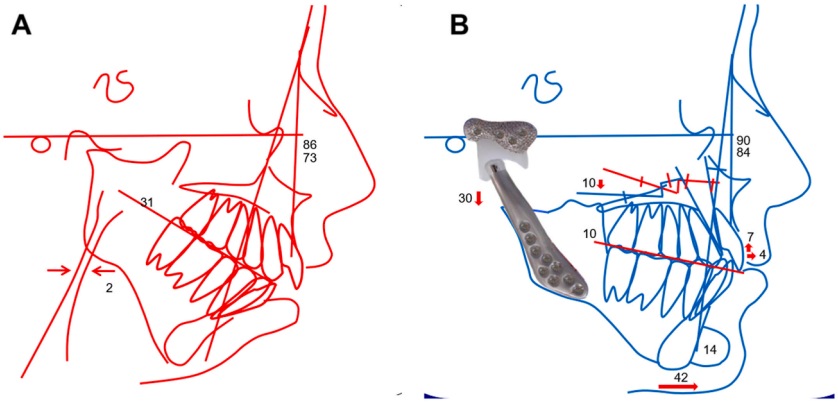

Fig. 4. (A) Lateral cephalometric analysis demonstrates the initial severe dentofacial deformity and high occlusal plane angle facial morphology. (B) Surgical prediction tracing demonstrates the major movements including anterior maxilla positioned upward 7 mm and posterior maxilla down-grafted 10 mm, occlusal plane decreased 20°, and pogonion advanced 42 mm including the 14 mm chin augmentation.

3.4. TMJ TJP with CCWR of the MMC: Effect on OPAW

There are four papers in the literature that evaluate OPAW changes using TMJ Concepts total joint prostheses in conjunction with CCWR of the MMC. Coleta al. et [21] reported on 47 females treated with TMJ Concepts TJP and CCWR of the MMC. Mandibular mean advancement at menton was 17.3 mm. The occlusal plane angle decreased 14.9°. The OPAW at the narrowest retroglossal airway space presurgery was 7.3 mm and post-surgery increased an additional 4.9 mm–12.2 mm (67% increase).

Goncalves et al. [22] in 2013, performed a 3-dimensional assessment of OPAW changes following TMJ Concepts TJP and CCWR of the MMC. The average mandibular advancement was 9.65 mm at point B and occlusal plane angulation decreased 9.8°. The AP dimension of the retroglossal area presurgery was 7.9 mm and increased 3 mm. The oropharyngeal surface area increased 42% and the OPAW volume increased 72%.

Yuen et al. [23]] reported on 137 patients receiving TMJ Concepts TJP for CCWR of the MMC. The average mandibular advancement was 12 mm. Presurgery, the mean oropharyngeal volume was 8.97 cm^3 and post-surgery increased to 15 cm^3 for a 67% volume increase. A cross-sectional area at the soft palate level increased post-surgery by 95% and a cross-sectional at the base of the tongue increased by 57%.

Wolford and Kesterke [19] in 2022, reported on oropharyngeal airway surgical outcomes for 42 JIA patients treated with TMJ Concepts TJP and CCWR of the MMC. Mean age at surgery 21.6 years and mean follow-up 44.2 months. Mean advancement at Point B 16 mm, pogonion 24 mm, and occlusal plane decreased a mean 17.2°. The mean oropharyngeal airway dimension presurgery was 4 mm at the soft palate and increased to 9 mm (125% increase), and at the tongue base presurgery was 4 mm and increased to 10 mm (150% increase). The oropharyngeal airway at the soft palate and tongue base levels increased by more than double the original diameter, so airflow should be significantly improved.

These studies clearly demonstrate the positive effect on the airway of CCWR of the MMC in patients with healthy TMJs and also with TMJ Concepts TJP, creating a significant improvement in the oropharyngeal airway. Although the oropharyngeal airway is not a true cylinder, according to Poiseuille's law and equation, doubling the diameter of a cylinder increases the airflow 4-fold [24, 25].

3.5. TMJ TJP with CCWR of the MMC: Effect on pain, function, quality of life

Henry and Wolford [26] in 1993 presented the first large study on outcomes using custom TMJ TJP, reporting on 107 patients that received autogenous tissue grafts or Techmedica TJP to reconstruct TMJs severely damaged by failed Vitek Proplast/Teflon TMJ devices. A 4-year follow-up evaluation for pain, occlusal stability, and jaw function reported poor outcomes for autogenous tissue grafts with success ranging from only 8%–31%, while the Techmedica TMJ TJP had an 86% success, demonstrating the superiority of TJP over autogenous tissues in reconstructing the severely compromised TMJ.

Wolford et al. [18] in 1994 reported on 56 patients (100 prostheses) receiving TMJ reconstruction with Techmedica TJP, relative to pain, jaw function and occlusal stability. Patients with 0–1 previous TMJ surgery had success rates of 84% in the good outcome group, 16% in the fair group, and 0% in the poor group. For patients with 2 or more previous failed TMJ surgeries, the success rates decreased to 55% in the good group, 26% in the fair group, and 19% in the poor group, with pain as the major factor for poor results. This is the paper that included the first case reports of TMJ TJP and CCWR of the MMC.

Pinto et al. [27] in 2009 reported on 47 female patients with end-stage TMJ pathology treated with TMJ Concepts TJP and maxillary osteotomies for CCWR of the MMC. There were statistically significant improvements at longest follow-up for TMJ pain, headaches, jaw function, diet, disability, and MIO.

Brown et al. [28] in 2020 reported improvement at longest follow-up (mean 30.9 months) with pain and dysfunction for 20 JIA patients treated with custom TJP, 11 of which had concomitant maxillary osteotomies. Using a Likert scale, there were significant improvements in pain, headaches, diet, disability, and TMJ function. All patients at the time of surgery were in active treatment by a pediatric rheumatologist with 15 patients taking DMARDs prior to and at the time of surgery that were ineffective in controlling the condylar resorption, associated pain, and dysfunction.

Trevedi et al. [29] in 2022 evaluated 44 patients with TMJ JIA, treated with TMJ Concepts TJP and maxillary osteotomies for CCWR of the MMC. Mean age at surgery 20.4 years and follow-up 43 months. Using median Likert scores, TMJ pain improved from 4 to 0, headaches 4 to 0, jaw function 5 to 0, diet 4 to 0, and disability 4 to 0. MIO improved from 36.4 mm to 43.7 mm. Overall, 94.6% of the patients reported an improved quality of life, 2 remained the same, and none were worse.

3.6. TMJ TJP with CCWR of the MMC: Effect on skeletal and occlusal stability

Al-Moraissi and Wolford [17] in 2017 performed a systematic literature review and meta-analysis study designed to determine the stability of CCWR of the MMC in orthognathic surgery with or without surgical correction of co-existing TMJ pathology. The results suggested that CCWR of the MMC is a stable procedure for patients with healthy TMJs, patients undergoing concomitant TMJ disc repositioning with Mitek anchors, and patients with custom TMJ TJP, but unstable in the presence of untreated TMJ disc displacements and when TMJ status is not assessed.

Coleta et al. [30] in 2009 evaluated 47 female patients treated with TMJ Concepts TJP for CCWR of the MMC, with a mean follow-up 40.6 months. The mandible was advanced a mean of 18.4 mm at pogonion with relapse of 0.1 mm, and the occlusal plane decreased a mean of 14.9° with a change of 0.6° post-surgery, documenting the stability of TJP with orthognathic surgery for CCWR of the MMC.

Mehra et al. [31] in 2009 evaluated 15 patients with rheumatoid arthritis, treated with TMJ Concepts TJP and CCWR of the MMC. Point B advanced a mean 21.7 mm with relapse 0.1 mm, Pogonion advanced 29.2 mm with relapse 0.2 mm, and the occlusal plane

angle decreased 20.7º with relapse 0.4º. This study demonstrated the surgical stability of TMJ TJP and orthognathic surgery for the rheumatoid patient.

Mehra et al. [32] in 2016 reported outcomes of 21 patients diagnosed with idiopathic condylar resorption treated with TMJ Concepts TJP and mandibular CCWR advancement with or without maxillary osteotomies. Mean age was 25 years and mean follow-up was 6.2 years. Mean mandibular advancement at Point B was 24.3 mm and mean decrease of the occlusal plane angle was 10.2°. Long term follow-up showed excellent stability of surgical movements with a decrease in TMJ pain, myofascial pain, headaches, and dietary restrictions.

Mehra et al. [33] in 2018 evaluated outcomes for 29 patients with autoimmune or connective tissue diseases who had TMJ reconstruction divided into 2 groups. Group 1 (n = 9) were reconstructed with either rib grafts or sternoclavicular grafts, and Group 2 (n = 20) with 13 patients reconstructed with TMJ Concepts TJP and CCWR of the MMC, and 7 with only TJP. Group1 relapsed 32% at Point B, whereas Group 2 relapsed 5% at Point B, indicating significantly better stability with the TJP alone or with CCWR of the MMC, as compared to autogenous grafts.

Wolford and Kesterke [19] in 2022 reported outcomes for 42 JIA patients treated with TMJ Concepts TJP and CCWR of the MMC. Mean age at surgery 21.6 years and mean follow-up was 44.2 months. Mean advancement at Point B was 15.9 mm, pogonion 23.8 mm, and occlusal plane decreased 17.2º. Long-term post-surgery, there were no statistically significant changes for any of these anatomical landmarks. All devices were well tolerated by the patients and none of the devices required removal.

Although the life expectancy of the TMJ Concepts TJP is unknown, Wolford et al.34 published a 20-year follow-up study of 56 patients who had received the Techmedica TJP between 1989 and 1993. There were statistically significant improvements for MIO, jaw function, TMJ pain, and diet, with 85.7% of the patients reporting significant improvement in their quality of life. There were no reports of device removal due to material wear or failure.

4. Discussion

Two case reports have been presented that have had an impact on the practice of TMJ surgery, orthognathic surgery, and the correction of sleep apnea related to a decreased OPAW. The first case report demonstrated that CCWR of the MMC will significantly increase the OPAW, while decreasing or eliminating sleep apnea symptoms [8]. The second case presentation demonstrated that TMJ reconstruction with Techmedica custom TMJ TJP and orthognathic surgery for CCWR of the MMC can be performed concomitantly with predictable outcomes [18].

Patients with end-stage TMJ pathology may have associated dentofacial deformities with resultant retruded mandible, high occlusal plane facial morphology, jaw and TMJ dysfunction, malocclusion, TMJ pain, headaches, ear symptoms, etc. and decreased OPAW with sleep apnea. End-stage TMJ pathology or conditions that may benefit from TMJ TJP and CCWR of the MMC include: 1) TMJ arthritis with non-salvageable articular discs; 2) advanced stages of adolescent internal condylar resorption (AICR); 3) traumatic injuries (i.e. fractured displaced condyles, damaged condyles and discs); 4) reactive arthritis; 5) osteoarthritis; 6) tumors; 7) absent or deformed anatomical structures resulting in loss of posterior mandibular vertical dimension (i.e., absence of condyles and portions of the ramus/body as the result of previous trauma, surgery, pathology, or congenital deformity); 8) high or low inflammatory, metabolic arthritic diseases; 9) connective tissue/autoimmune diseases (i.e., rheumatoid arthritis, juvenile idiopathic arthritis, scleroderma, Sjogren's syndrome, lupus, etc.); 10) fibrous or bony ankylosis; 11) multiply operated TMJs (two or more previous surgeries); 12) failed autogenous grafts; 13) failed TMJ alloplastic implants; and 14) other end-stage pathologies [34]. These end-stage TMJ pathologies may require reconstruction to provide adequate jaw function, stability, decrease in pain, and improved airway. Autogenous grafts were the traditional method for TMJ reconstruction into the late 1990's, but after the development of TMJ custom TJP and the studies that have proven superiority over autogenous grafts, the TJP is the preferred method for TMJ reconstruction, particularly when CCWR of the MMC is required [34].

4.1. TMJ prostheses

There are two TMJ prostheses available in the United States: Stock (off-the-shelf devices) and custom systems. Components of the stock prostheses (Biomet Inc., Jacksonville, FL) come in an assortment of sizes and shapes so that the surgeon then selects the fossa and mandibular components that best fit the presenting anatomy. This approach does not require significant presurgical preparation, may require significant intraoperative bony preparation, but does require an inventory of “parts” for selection. These devices are not indicated for CCWR of the MMC since the mandibular components available lengths are 45, 50, and 55 mm, significantly limiting the amount of mandibular advancement and vertically lengthening of the ramus. In addition, there is no posterior stop on the fossa component so the mandibular component can become posteriorly displaced to the fossa component if any posterior forces are applied such as in CCWR of the MMC. This can cause skeletal and occlusal instability, mal-occlusion, and pain. Biomet custom devices are available overseas, the custom devices have a posterior stop, and the mandibular components can be created for any desired length.

The TMJ Concepts patient-fitted TJP devices are custom-designed to fit the patient's specific anatomical requirements with the mandible in the final planned post-surgical position providing a good fit of the components to the anatomical structures. The fossa component has a posterior stop, critical for predictable skeletal and occlusal stability. The fossa and mandibular components osseointegrate for long term stability. Several studies have shown the skeletal and occlusal stability using Techmedica/TMJ Concepts TJP for TMJ reconstruction and mandibular advancement with concomitant maxillary osteotomies for CCWR of the MMC [18, 29–32]. Wolford et al. [35] published a 20-year follow-up study confirming the long-term efficacy and durability of these devices.

Studies are included that show that CCWR of the MMC will significantly improve the dimensions of the oropharyngeal airway [11–14, 20]. Giralt-Hernando et al. [20] compared mandibular advancement, to maxillary-mandibular advancement, to maxillary-

mandibular advancement with CCWR of the MMC. The outcomes were much better for the patients receiving the CCWR of the MMC with significant improvement of the OPAW.

Studies using the TMJ Concepts TJP were presented that document significant improvement in TMJ pain, headaches, jaw function, diet, disability, and quality of life including CCWR of the MMC [25–28]. Quality of results are better when the TMJ TJP surgery is performed as the first or second TMJ surgical intervention as compared to patients who have had 2 or more prior TMJ surgeries where the outcomes are less predictable relative to pain and jaw function [18,25,26].

4.2. Fat grafts

The placement of fat grafts around the functional area of the TJP has been shown to improve long-term outcomes by preventing fibrous tissue and heterotopic bone from forming around the articulating area of the TJP. The theory for using fat grafts is as follows: (1) eliminates dead space, (2) prevents blood clot formation around the TJP articulating area, (3) inhibits bone growth and fibrosis, (4) decreases pain, and (5) improves joint function [36–38].

The Wolford and Karras study [36] evaluated two groups of patients. Group 1consisted of 15 patients (13 females and 2 males) and 22 joints (7 bilateral, 8 unilateral) that received fat grafts around the prostheses. Group 2 included 20 patients (18 females and 2 males) and 33 joints with 17 bilateral and 3 unilateral. For group 1, no additional surgery was required post-surgery when the fat grafts were placed concomitantly with the total joint prostheses. In group 2 that did not receive fat grafts at the initial surgery, 35% of the patients required reoperation for heterotopic

bone and/or fibrosis. The most common donor site for fat harvesting is the abdomen, where there is usually abundant or at least adequate fat for most cases [36–38].

5. Conclusion

Occasionally, a case report will have a significant impact in treatment philosophy and surgical protocol improving the quality of patient care. This paper presents two events where case reports provided a major impact and change in the treatment paradigm for patients with retruded jaws with or without sleep apnea. In the presence of healthy TMJs, CCWR of the MMC is stable and significantly improves the OPAW, jaw function, and facial balance. For patients with additional end-stage TMJ pathology, custom TMJ TJP in conjunction with orthognathic surgery for CCWR of the MMC is very stable skeletally and occlusally, reduces pain, improves jaw function, diet, OPAW, quality of life, and normalizes facial balance. These treatment protocols have significantly improved the standard of care for patients and provide outcomes that prior to these initial case reports, were unattainable.

Author contributions

Conception and design: LW; Administrative support: None; Provision of study materials or patients: LW, OPAG; Collection and assembly of data: LW, OPAG; Data analysis and interpretation: LW, OPAG; Manuscript writing: LW, OPAG; Final approval of manuscript: LW, OPAG.

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Declaration of competing interest

Neither Dr. Wolford, Dr. Amaya or any members of their families have a financial arrangement or affiliation with any corporations, commercial products, or services that are discussed in this document.

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