Clinical evaluation of the temporomandibular joint and masticatory muscles 10-15 years after mandibular setback surgery and six weeks of inter-maxillary fixation

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ABSTRACT

Objectives. The purpose of this study was to clinically evaluate the TMJs and masticatory muscles 10-15 years after orthodontic-surgical treatment of mandibular prognathism.

Material and methods. Thirty-six patients where included in this study. All patients had been operated with the intraoral vertical ramus osteotomy (IVRO) technique and subsequent inter-maxillary fixation (IMF) for six weeks. Mean follow-up period after surgery was 12.5 years, and mean age at the long-term follow-up examination was 34.1 years (range 27.2 – 59.8 years). At the long-term follow-up consultation, the masticatory muscles and TMJs were examined according to the Helkimo clinical dysfunction index. The participants also completed a questionnaire.

Results. Mean maximum unassisted mouth opening 10-15 years after surgery was 50.1 mm, (range 38-70 mm, SE 1.2). Statistically significantly greater in males compared to females ($p=0.004$). Mean Helkimo Dysfunction group was 1.5. None of the patients reported to have pain while chewing or opening the mouth on a weekly or daily basis. However, eight patients reported weekly ($n=6$) or daily ($n=2$) difficulties with maximum opening of the mouth.

Conclusion. The results of the present study show that 10-15 years after IVRO setback surgery and subsequent IMF for six weeks, mandibular range of movement is satisfactory and the patients report few functional limitations or symptoms related to the TMJs and/or masticatory musculature.

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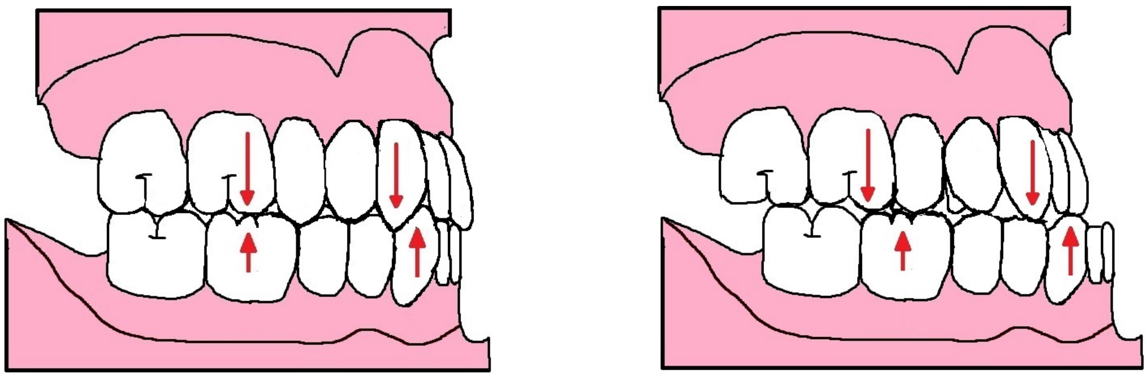
INTRODUCTION

Class III malocclusion

Classification of malocclusion was first presented by Angle in 1899 (1). Although Angle´s description is well known, it does not describe whether the malocclusion is of dental or skeletal origin. In Angle Class I occlusion, the mesiobuccal cusp of the upper first molar occludes in the sulcus between the middle and the mesial buccal cusp of the lower first molar. If there is no discrepancy in tooth size or number between the upper and lower jaw, the upper canine then occludes between the lower canine and first premolar (1) (Figure 1A). This occlusal pattern is by Angle described as the ideal occlusion. Class III malocclusion occurs when the lower first molar occludes at least two millimeter mesial to the Class I position (Figure 1B) (2). If there is no discrepancy in tooth size or number between the jaws, the dental arches are well aligned, and there is no dental compensation, the lower incisors then occlude edge-to-edge or mesial to the upper incisors, a so-called negative overjet (Figure 1B).

Figure 1

A. Angle Class I **B.** Angle Class III



Class III molar and canine relationship combined with a negative horizontal overjet is often a result of excess growth of the mandible (3), but may also be due to maxillary deficiency or a combination of an underdeveloped maxilla and overdeveloped mandible. Staudt et al. found that among 3358 subjects with Class III malocclusion, 75,4% were of skeletal origin, while 24.6% were strictly dentoalveolar (4). Forty-seven percent of the Class III malocclusions where due to mandibular prognathism, while maxillary deficiency alone accounted for 19.3% of the malocclusions (4). About 9% where due to a combination of maxillary deficiency and mandibular prognathism (4).

Prevalence of Class III malocclusion

The prevalence of Class III malocclusion reported in the literature varies, and it depends upon several factors:

1) Ethnicity

A study by Soh et al. about occlusal status among Asian males, comparing subjects with Chinese, Malay and Indian ethnicity, reports increased prevalence of Angle Class III malocclusion among males with Malay ethnicity. Twenty-seven percent of the Malays had Class III malocclusion while the prevalence was 22.9% and 4.8% among the Chinese and Indian males respectively (5). Lew et al. reported the prevalence of Class III malocclusion to be 12.6% among 1050 Chinese adolescents aged 12-14 years (6). In comparison, the prevalence of Class III malocclusion among 12-year-old Caucasian subjects is reported to be 3.5% (7). None of the above-mentioned studies differentiated between dental or skeletal origin of the Class III malocclusion.

A study including 357 Swedish men aged 21-54 years, showed a prevalence of 6.2% of Class III malocclusion (8). A Norwegian study including 202 subjects aged 30-41 years, reported the prevalence of Class III to be 1.5% (9). These two studies did also not report whether the malocclusion was of skeletal or dentoalveolar origin. In the previous mentioned study by Staudt et al, 2.3% of the 3358 Swiss army recruits aged 17-23 years had Class III malocclusion (4).

2) Gender

Some studies suggest higher Class III prevalence among males (10, 11). One of these studies included 501 Egyptians aged 18-24 years (11). The other study included 1094 Caucasians aged 3-57 years (10). The two studies did not report whether the malocclusion was of dentoalveolar or skeletal origin.

3) Different stages of development

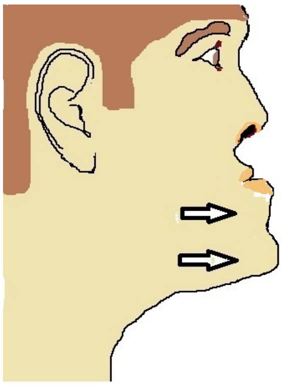
An epidemiological study including 4724 Colombian children aged 5-17 years reports that the prevalence of Class III malocclusion varies between different stages of dental development (12). There is also a strong hereditary component in Angle Class III malocclusion (13, 14).

Treatment of Class III malocclusion

Angle Class III malocclusion including negative overjet that are strictly of dentoalveolar origin, or due to a mild skeletal discrepancy, can be treated with removable or fixed orthodontic appliances depending on the patient's dental development and maturation stage. If a skeletal discrepancy is detected during early mixed dentition stage, functional appliances can be indicated. These are orthodontic appliances that aim to stimulate anterior growth of the maxilla or reduce anterior growth of the mandible. Depending on severity of the skeletal discrepancy, type of growth pattern, and amount of vertical incisal overlap, some patients are successfully treated with this type of appliance, while others do not benefit that well and/or grow back into mesial occlusion.

Mild skeletal discrepancies, when growth has ceased, are treated with fixed appliances, often in combination with extractions in the lower jaw. More severe skeletal Angle Class III malocclusions will need a combination of orthodontic treatment and orthognathic surgery when the patient is full grown. The surgical Class III patients have characteristic facial features such as prominence of the lower third of the face, particularly the chin, and the area associated with the lower lip (3) (Figure 2). In the most severe cases, patients will not be able to obtain adequate lip closure without abnormal stain of muscles (3).

Figure 2. Angle Class III in profile



Surgical treatment

Mandibular surgery vs maxillary surgery/bimaxillary procedures

Mandibular prognathism was one of the first dentofacial discrepancies treated by orthognathic surgery (3). Mandibular surgery can be used to correct mandibular deformities such as asymmetry, mandibular prognathism or retrognathism (15). Several techniques are in use, of which the sagittal split osteotomy (SSO) is the most common nowadays. For mandibular setbacks, vertical ramus osteotomies are also occasionally performed.

Maxillary surgery such as the Le Fort I osteotomy are used to correct maxillary anomalies, in particular maxillary retrognathism or apertognathia (open bite).

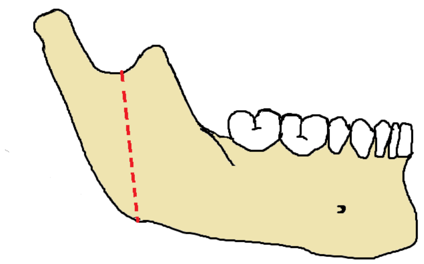
Bimaxillary surgery, i.e. surgery in both jaws, are indicated when 1) the magnitude of movement of a single jaw is unrealistic/too large, 2) asymmetries where three-dimensional repositioning of both jaws are necessary, 3) telegnathic surgery is being performed for obstructive sleep apnea syndrome, 4) mandibular surgery is needed and maxillary transverse dimension requires widening and surgically assisted rapid maxillary expansion, and 5) due to overall esthetic considerations (16).

Intraoral Vertical Ramus Osteotomy (IVRO)

In the early 1950s, Caldwell and Letterman (17) popularized a surgical technique where the osteotomy is performed on the ramus of the mandible for correction of mandibular prognathism. The lateral aspect of the ramus is exposed through a retromandibular incision. The ramus is sectioned vertically, from the sigmoid notch to the angle of the mandible, and the entire body of the mandible is moved posteriorly (17). The proximal segment of the ramus overlaps the anterior segment (17). The teeth are placed in proper occlusion, and the anterior segment is stabilized by the use of miniplates and/or screws. The method is rarely used today due to the retro-mandibular scar, and risk of damaging the facial nerve.

An identical osteotomy may also be accomplished using an intraoral approach with an angulated oscillating saw (intraoral vertical ramus osteotomy, IVRO) (Figure 3). Advantages with the intraoral technique is no skin incision, and reduced risk of damaging the facial nerve (18). With the IVRO technique, the two bone segments cannot be fixated with mini-plates or screws, and therefore requires inter-maxillary fixation (IMF). IMF is a technique used to secure post-operative hypo-mobilzation of the jaws, to promote healing, and secure correct post-operative occlusion. IMF is also used for fixation after mandibular fractures (19). Concerning IMF after a mandibular setback surgical procedure, the fixation is made by a steel wire that ties the upper and lower jaw together in correct, or best possible occlusion. The wire is tied around surgical hooks attached to the braces in the patient's upper and lower jaw. The steel wires are twisted to loops, and tightened, thereby holding the jaws together in occlusion (20). The IMF period varies, but is usually 4-6 weeks.

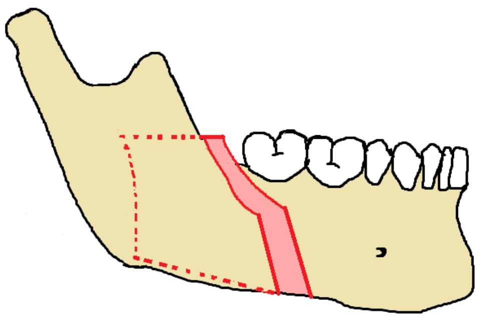
Figure 3. Intraoral Vertical Ramus Osteotomy. The surgical cut is marked in red.



Sagittal Split Osteotomy (SSO)

Another technique for correction of mandibular prognathism is the sagittal split osteotomy (SSO), first described by Trauner ans Obewegeser (21) and later modified by Dalpont (22) Hunsick (23) and Epker (24). An incision is made along the external oblique ridge of the mandible to the first molar region, quite similar to the intraoral approach for the vertical ramus osteotomy. The ramus of the mandible is "cleaved" with a sagittal osteotomy running from above the mandibular foramen and anterior almost to the mental foramen allowing anterior and posterior movement of the mandible (Figure 4). The mandible can then be repositioned in several directions due to the telescoping effect created by the osteotomy, providing large and flexible areas of bony overlap. The disadvantage with this procedure is the possibility of traumatizing the inferior alveolar nerve, resulting in decreased sensation in the area of the lower lip and chin (25). The fixation of the mandible after a sagittal split osteotomy can be performed with lag screws through the buccal- and lingual cortex (26) or miniplates with monocortical screws (27).

Figure 4. Sagittal split osteotomy.



Genioplasty

Genioplasty is an isolated surgical correction of the prominence of the chin. An intraoral approach using sliding osteotomy was described by Trauner and Obwegeser (21). There have been some improvements or modifications in the technique over the years, and genioplasty can now be performed in all directions. The genioplasty most relevant in cases with mandibular prognathism is chin reduction (Figure 5A and 5B). Previously the fixation was performed by wiring the bone, but the development of fixation screws have improved the segment stabilization of the mandible (28). Chin implants made of silicone and polyethylene (among others) is an alternative method for esthetic enhancement of the chin (29).

Figure 5A Chin reduction genioplasty. The surgical cut marked in red.

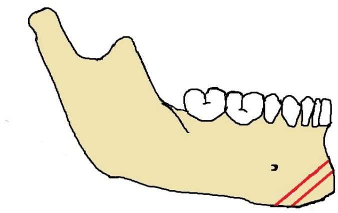
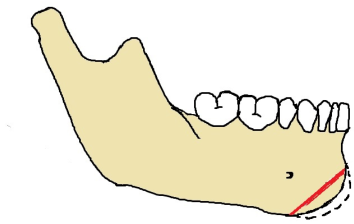


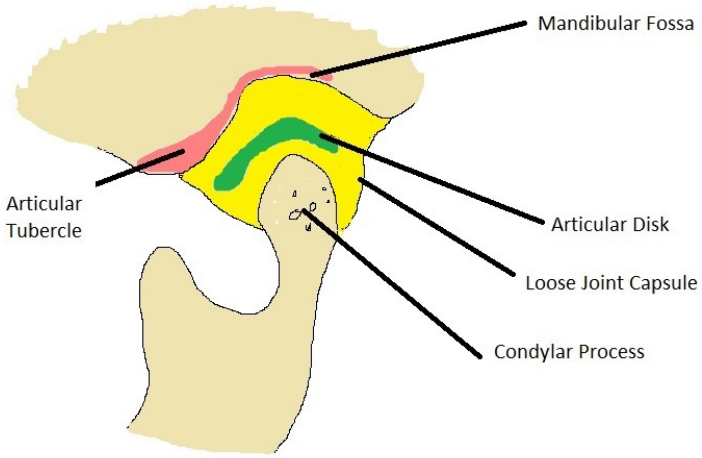
Figure 5B After adjustments and fixation.



Temporomandibular disorders

The temporomandibular joint (TMJ) consist of four basal components; the condylar process, the mandibular fossa of the temporal bone, the articulating disc, and the loose joint capsule, which is strengthened by a fibrous lateral ligament (Figure 6) (30). The movements of the mandible are facilitated by the masticatory and suprahyoid muscles (31). Disorders related to the temporomandibular joint and masticatory muscles are, quite nonspecific, called temporomandibular disorders (TMD). Examples of symptoms of TMD may be restriction of jaw movements, orofacial pain and joint sounds such as clicking or crepitation (32).

Figure 6. The temporomandibular joint.



Possible external etiological factors associated with TMD:

1) Psychological factors

Schwartz suspected stress, emotional tension and muscular tension as causes of TMD (33). It is believed that stress induce muscular hyperactivity. The hyperactivity leads to para-functional habits, which again may result in pain (34). Students are a social group that is exposed to stress, and this may be a reason for the high prevalence of TMD symptoms observed among students (35, 36). Another study suggests that depression and anxiety levels are associated with TMD (37).

2) Trauma

Trauma may also cause temporomandibular joint dysfunction (38). Disk displacement and mandibular fractures such as condylar fractures may lead to derangements in the joint and consequently TMD (38). Mandibular fractures can be classified according to the involved anatomic structures. These areas are the condylar process, the coronoid process, the ramus, the angle or body of the mandible, and the alveolar process (39). Condylar fractures (Figure 7) are fractures of the condylar process which is the superior part of the ramus (40). Fractures of the mandibular angle (Figure 8) are fractures positioned between a hypothetical line defining the posterior border of the masseter muscle and a hypothetical line defining the anterior border of the masseter muscle (41). Body fractures (Figure 9) are classified as fractures located between the hypothetical line corresponding to the anterior attachment of the masseter muscle to the distal part of the symphysis (40). Patients that have a combination of condylar fracture and contralateral body- or angle fracture (Figure 10) are more likely to develop TMD than other mandibular fractures (42).

Fracture types:

Figure 7. *Condylar fracture*

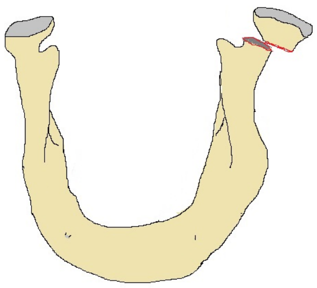


Figure 8. Angle fracture

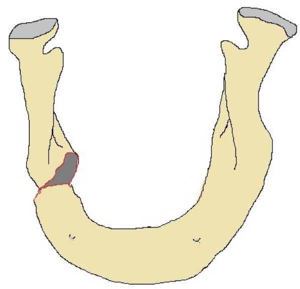


Figure 9. Body fracture

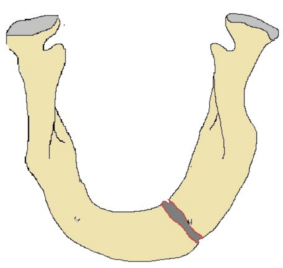
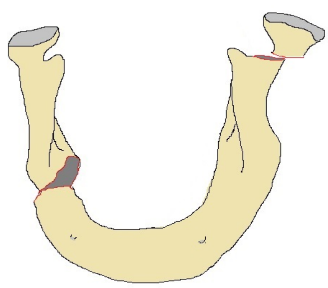


Figure 10. Condylar fracture with a contralateral angle fracture



3) Parafunctions

Parafunctions such as teeth clenching (43), excessive gum chewing (44), and bruxism (45) are associated with TMD. The simultaneous presence of both sleep- and awake bruxism increases the risk of TMJ pain (46). Another study suggests a correlation between the combination of excessive gum chewing and bruxism, and TMJ pain (44).

4) Gender differences

Symptoms of TMD occur more often in women than in men (47). Women have a 2-4 times greater risk of developing TMD during their lifetime (48).

5) Maxillomandibular deformities

The prevalence of TMD reported among patients with different maxillomandibular deformities requiring orthognathic surgery varies (49). One study reported a prevalence of 26.5% (50), while another reported a prevalence of 73% (51). However, these studies did not distinguish between the different types of deformity. Some studies suggest that Class III malocclusion is associated with increased prevalence of TMD (52, 53). Onizawa et al. reported one or more subjective symptoms from the TMJ in 88,2% of surgical Class III patients (54). Others have reported that Class III patients have lower preoperative prevalence of TMD symptoms compared to Class II patients (49, 55, 56). As described above, maxillomandibular deformities may lead to TMD-symptoms, but a challenge when comparing results from different studies is the lack of consistency in diagnostic criteria. Systematic reviews are difficult to carry out because different diagnostic criteria for TMD are used (57-59).

6) Inter-maxillary fixation after orthognathic surgery

There is no consensus in the literature concerning the effects of inter-maxillary fixation on the TMJ and masticatory musculature. Athanasios et al. found no association between the use of IMF and development of TMD in orthognathic patients treated with the IVRO technique (60). A ten years follow-up study by Per Johan Wisth at the University of Bergen, Norway in 1984 reported a lower Helkimo dysfunction index among patients treated with vertical ramus osteotomy (VRO) and subsequent IMF, compared to a control group (61). In comparison, Magnusson et al. found no statistically significant difference in TMD symptoms before and after surgery in patients treated with the SSO technique where rigid fixation with bicortical screws were used (62). Another study suggests that SSO may actually improve TMD symptoms (50). However, a comparison between VRO and SSO in a study including more than 1500 patients showed that preoperatively, 44% of the VRO- and 44% of the SSO-patients reported subjective TMD symptoms. Postoperatively, only 22% of the VRO-treated patients reported subjective symptoms of TMD while 35% of the SSO-treated patients reported symptoms (63). Hu et al. suggests that VRO with a following one week of IMF for treating mandibular prognathism might be the preferred method as it seems to be more beneficial for the TMJ compared to SSO (64).

Dervis et al. reported increased TMD symptoms and reduced jaw mobility after the use of inter-maxillary fixation (65). These findings have been explained by the transient muscular atrophy following the enforced jaw hypo-mobilization that follows the six weeks of IMF. These findings were reported to be temporary, and reversed after 1-2 years. Boyd and colleagues reported advantages concerning post-operative mobility and TMD symptoms using rigid fixation, such as miniplates or screws, compared with IMF (66). However, this study only included 23 patients in total. Others have not been able to find any difference in TMD development after rigid fixation, or wired IMF, (67, 68).

Prevalence of TMD

A systematic review including six studies with a total of 2491 patients aged 23-46 years reported the prevalence of myofacial pain to be 9.7%, disk displacement to be 11.4%, and arthralgia to be 2.6% (69). Two epidemiological studies on the prevalence of TMD among adolescents in Norway reported the prevalence to be about 7% (70) (71).

The Helkimo index

In 1974, Helkimo presented three indices to measure function and dysfunction of the masticatory system; the clinical dysfunction index, the anamnestic dysfunction index, and the index for occlusal state (72). The clinical dysfunction index is a clinical evaluation of the masticatory system. The index is divided into five categories where each of the five categories provides a score (0, 1 or 5 points) according to the severity of the symptoms, and a total score is calculated as the sum of the scores from the five categories (Range 0-25 points) (Table 1 and 3). The higher score, the more severe the disorder. The patients are further divided into five clinical dysfunction groups as described in Table 2. Patients in clinical dysfunction group 0 are clinically symptom free and have the clinical dysfunction index value 0 (D_i0). The clinical dysfunction group 1 includes patients with mild dysfunction and represents the clinical dysfunction index 1 (D_iI). Clinical dysfunction group 2 includes patients with moderate dysfunction (D_iII). The patients with severe dysfunction (clinical dysfunction group 3-5) are given the index value 3 (D_iIII) (Table 2).

Table 1. Clinical dysfunction index, D_i, based on five different symptoms as described by Helkimo (72)

A. Symptom:	*Impaired range of movement index*	
Criteria:	Normal range of movement	0
	Slightly impaired range of movement	1
	Severely impaired mobility	5
B. Symptom:	Impaired TMJ function	
Criteria:	Smooth movement without TMJ-sounds or deviation on opening or closing <2mm	0
	TMJ-sounds in one or both joints and/or deviation >2mm on opening or closing movements	1
	Locking and/or luxation of the TMJ joint	5
C. Symptom:	Muscle pain	
Criteria:	No tenderness to palpation in masticatory muscles	0
	Tenderness to palpation in 1-3 palpation sites	1
	Tenderness to palpation in 4 or more palpation sites	5
D. Symptom:	Temporomandibular joint pain	
Criteria:	No tenderness to palpation	0
	Tenderness to palpation laterally	1
	Tenderness to palpation posteriorly	5
E. Symptom:	Pain on movement of the mandible	
Criteria:	No pain on movement	0
	Pain on one movement	1
	Pain on two or more movements	5
F.	Sum A+B+C+D+E-dysfunction score (0-25points)	
G.	Dysfunction group 0-5, according to code	
H.	Clinical dysfunction index, D_i, according to code	

Table 2. Dysfunction group and index according to code (72)

Code:	*0 points*	*=*	*Dysfunction group 0*	*Clinically symptom free*	*D_i0*
	1-4 points	=	Dysfunction group 1	Mild dysfunction	D_iI
	5-9 points	=	Dysfunction group 2	Moderate dysfunction	D_iII
	10-13 points	=	Dysfunction group 3	Severe dysfunction	D_iIII
	15-17 points	=	Dysfunction group 4	Severe dysfunction	D_iIII
	20-25 points	=	Dysfunction group 5	Severe dysfunction	D_iIII

Table 3. *Mandibular range of movement (72)*

A.	Maxim~~al~~um opening of the mouth	
	>40mm	0
	30-39mm	1
	<30mm	5
B.	Maximum lateral movement to the right	
	>7mm	0
	4-6mm	1
	0-3mm	5
C.	Maximum lateral movement to the left	
	>7mm	0
	4-6mm	1
	0-3mm	5
D.	Maximum protrusion	
	>7mm	0
	4-6mm	1
	0-3mm	5

Code: 0 points = mobility index 0 = normal mandibular mobility

1-4 points = mobility index 1 = slightly impaired mobility

5-20 points = mobility index 5 = severely impaired mobility

Aims

The aim of this study was to clinically evaluate the temporomandibular joints and masticatory muscles 10-15 years after mandibular setback surgery by the IVRO technique and subsequent IMF for six weeks. The patients' self-reported symptoms from the masticatory muscles were also addressed.

MATERIAL AND METHODS

Patients

The patients included in this study were patients with genuine mandibular prognathism who had undergone IVRO surgical treatment with subsequent IMF for six weeks during the period January 1998 through December 2002. Patients who had additional maxillary surgery or genioplasty were not included. The surgeries were performed at Department of Maxillofacial surgery, Haukeland University Hospital in Bergen, Norway. Pre- and post-surgical orthodontic treatment had been performed in all patients.

The patients were contacted by mail and invited to attend a 10-15 year clinical and radiological follow-up examination during the year 2012. Out of 84 patients who fulfilled the inclusion criteria, 37 patients (44%) agreed to participate in the study. Thirty-nine patients (46.6%) did not reply to the invitation, six patients (7.1%) were occupied during the time the data collection took place, and two patients (2.4%) did not want to participate. One of the 37 participants was excluded due to a history of mandibular fracture during the follow-up period. The final study group consisted of thirty-six patients (24 females and 12 males). Their mean age at the follow-up examination was 34.1 years (range 27.2 – 59.8 years). The mean time between surgery and the long-term follow-up examination was 12.5 years (range 9.7-14.5 years).

Ethical approval

This study was given ethical approval by the regional ethics committee (REK Vest) (2011/1604/ REK Vest) and was conducted in accordance with the Declaration of Helsinki. Written informed consent was collected from all the participants prior to enrolment.

Methods

Clinical examination

Examination of the masticatory muscles and the TMJs was performed as described by Helkimo (66). Maximum mouth opening, maximum lateral movements and maximum, protrusion of the mandible were measured by a ruler with 0.5 mm measurement scale. The TMJs were examined for joint sounds, deviations, locking and luxation during function. The patients were asked to report any pain when moving the mandible in the different directions. The examined masticatory muscles and the palpation sites are presented in Table 4. Only muscles that were clearly tender to palpation were registered as painful (66).

Table 4. Examined muscle sites

Muscle	**Palpation sites**
Masseter	Profound masseter
	Superficial masseter
Temporal	Posterior temporal
	Anterior temporal
	Attachment on the coronoid process
Pterygoid	Lateral pterygoid
	Medial pterygoid

Questionnaire

The questionnaire included five questions concerning pain and symptoms from the TMJs and masticatory musculature (Table 5). One of the thirty-six included patients did not return the questionnaire.

Table 5. Questionnaire

	Never	Rarely	Weekly	Daily
Pain while chewing/mouth opening				
Crepitation from TMJ				
Clicking from TMJ				
Restricted mouth opening				
Jaw fatigue				

Statistical methods

Descriptive statistics (frequency calculations, mean values with standard errors (SE) and confidence intervals (CI)) were used to report age and gender distribution among the participants, and also to report the clinical results and the responses to the questionnaires. Mean values were calculated for the measurements on jaw mobility and the Helkimo dysfunction score. Shapiro Wilkes test was performed to test if the continuous variables could be assumed to have a normal distribution. If the test resulted in a non-significant p-value, the data were assumed to have an approximated normal distribution, and two-sample *t*-tests were used to test for differences between the genders. If the Shapiro Wilkes test showed that the data were not normally distributed, the non-parametric Kruskal Wallis test was used. Fisher's exact tests were used to test for differences between the genders for dichotomized variables. Level of significance was set to 5%. The statistical software STATA/IC 14.1 (StataCorp LP, College Station, TX, USA) was used for the analyses.

Table 6. Age distribution at the examination 10-15 years after surgery (years)

	Mean	SE	95% CI	Min	Max
Male n=12	34.8	0.8	33.2-36.5	30.3	38.8
Female n=24	33.7	1.5	30.6-36.8	27.2	59.8
All n=36	34.1	1.0	32.0-36.2	27.2	59.8

SE, standard error, CI; confidence interval

RESULTS

Clinical examination

A. Range of movement

Mean maximum unassisted mouth opening was 50.1 mm, (range 38-70 mm, SE 1.2), and statistically significantly greater in males compared to females (p=0.004). Mean maximum lateral movement to the right was 10.2 mm (range 7-15 mm, SE 0.3). Mean maximum lateral movement to the left was 10.1 mm (range 4-14 mm, SE 0.3). The female patients had significantly greater mean maximum lateral movement to the left compared to the male patients (p=0.02). Mean maximum protrusion was 8.1 mm (range 4-12.5 mm, SE 0.3) (Table 7A). Twenty-eight percent of the patients had slightly impaired mobility according to the Helkimo mobility index and 72% had normal range of mobility (Table 7A).

B. Function of the TMJ

Eighty-one percent of the patients (29/36) had a straight opening and closing path, while the remaining 19% had lateral deviation during opening or closing of the mouth. Crepitation in either one or both TMJs where diagnosed in two patients (5.6%). Clicking in the joint, either uni- or bilaterally, was registered in 33% of the patients (12/36). Locking of the TMJ during mouth opening was observed in one patient. Luxation of the mandible was not observed in any of the patients (Table 7B).

C. Muscle pain

All the patients experienced pain on palpation of one or more of the masticatory muscles, either uni- or bilaterally. Seventy-two percent (26/36) of the patients had 1-3 muscles that were painful upon palpation, while 28% (10/36) of the patients felt pain on palpation in four or more palpated muscles. Palpation of the lateral pterygoid muscle was painful in all the patients. The masseter muscle was the second most painful muscle (Table 7C).

D. Pain on palpation of the TMJs

Thirty-one percent of the patients (11/36) reported pain on palpation of the TMJ either uni- or bilaterally. Twenty-eight percent (10/36) of the patients experienced pain on palpation of the lateral aspect of the condyle, while one patient reported pain when the condylar head was palpated posteriorly via the auditory canal (Table 7D).

E. Pain during jaw movements

The majority of the patients (69%, 25/36) had no pain on any movement of the mandible. Ten patients (28%) experienced pain on maximum opening of the mouth. Three (8.3%) patients experienced pain on lateral movement to the right, two patients (5.6%) reported pain on lateral movement to the left, and one patient (2.8%) reported pain during maximum protrusion (Table 7E).

F. Helkimo clinical dysfunction score

The mean Helkimo dysfunction score was 4.0 (range 1-10, SE 0.45) (Table 7F).

G. Helkimo clinical dysfunction group

Mean clinical dysfunction group was 1.5 (range 1-3, SE 0.10). Ninety-four percent of the patients (34/36) were diagnosed to be in dysfunction group one or two. No patients had a clinical dysfunction score representing the two most severe dysfunction groups (group 4 or 5) (Table 7G).

H. Helkimo clinical dysfunction index (D_i)

None of the patients were placed in D_i0. Most of the patients were placed in the dysfunction index D_iI (21 patients) or D_iII (13 patients). Only 2 patients fulfilled the requirements of D_iIII (Table 7H).

Table 7. Clinical dysfunction index

A. Range of movement

Max jaw movements (mm)	Mean	SE	Conf.int.	Min	Max	n
Mouth opening	50.1	1.2	47.7 - 52.4	38	70	36
Right laterotrusion	10.2	0.3	9.5 - 10.9	7	15	36
Left laterotrusion	10.1	0.3	9.3 - 10.8	4	14	36
Protrusion	8.1	0.3	7.5 - 8.8	4	12.5	36

Mobility index	n	%
0 (normal range of movement)	26	72.2
1 (slightly impaired mobility)	10	27.8
5 (severely impaired mobility)	0	0
Total n	**36**	**100**

B. Function of the TMJ

	Yes		No		Total
	n	%	n	%	n
Straight opening and closing path	29	80.6	7	19.4	36
Crepitation	2	5.6	34	94.4	36
Clicking	12	33.3	24	66.7	36
Lateral deviation ≥ 2 mm during opening/closing	7	19.4	29	80.6	36
Locking during movement	1	2.8	35	97.2	36
Luxation during movement	0	0	36	100.0	36

C. Muscle pain

	Yes		No		Total
	n	%	n	%	n
Profound masseter	22	61.1	14	38.9	36
Superficial masseter	23	63.9	13	36.1	36
Masseter total	**26**	**72.2**	**10**	**27.8**	**36**
Posterior temporal muscle	11	30.6	25	69.4	36
Anterior temporal muscle	9	25.0	27	75.0	36
Temporal muscle on the coronoid process	6	16.7	30	83.3	36
Temporal muscle total	**15**	**41.7**	**21**	**58.3**	**36**
Lateral pterygoid muscle	**36**	**100**	**0**	**0.0**	**36**
Medial pterygoid muscle	**25**	**69.4**	**11**	**30.6**	**36**

D. Pain on palpation of the TMJs

	Yes		No		Total
	n	%	n	%	n
Total	11	30.6	25	69.4	36
Lateral	10	27.8	26	72.2	36
Posterior	1	2.8	35	97.2	36

E. Pain during jaw movements

	Yes		No		Total
	n	%	n	%	n
Pain on any movement of the mandible	11	30.6	25	69.4	36
Pain on max opening	10	27.8	26	72.2	36
Pain on right laterotrusion	3	8.3	33	91.7	36
Pain on left laterotrusion	2	5.6	34	94.4	36
Pain on protrusion	1	2.8	35	97.2	36

F. Helkimo clinical dysfunction score (Sum A+B+C+D+E)

Total sum	n
1	7
2	7
3	6
4	1
5	4
6	2
7	6
8	1
10	2
Mean	4

G. Helkimo clinical dysfunction group

group	n
1	21
2	13
3	2
4	0
5	0
Mean	1.5

H. Helkimo clinical dysfunction index)

Index group	n
D_i0	0
D_iI	21
D_iII	13
D_iIII	2

Questionnaire

The responses to the questionnaire are presented in Table 8. On a weekly or daily basis, none of the patients reported any problem with pain while chewing or opening the mouth. However, eight patients reported weekly (n=6) or daily (n=2) difficulties with maximum opening of the mouth. The two patients reporting difficulties with maximum mouth opening on a daily basis had maximum opening capacity measured to 38.0 mm and 47.5 mm at the clinical examination. Four patients reported to have clicking in the TMJ at least once a week, and three patients experienced clicking in the TMJ every day.

Table 8. Responses to the questionnaire (n=35)

	Never		Rarely		Weekly		Daily		Missing	
	n	%	n	%	n	%	n	%	n	%
Pain during chewing/mouth opening	23	63,9	12	33.3	0	0	0	0	0	0.0
Crepitation sounds from TMJ	23	63.9	8	22.2	1	2.8	0	0	3	8.6
Clicking sounds from TMJ	16	44.4	9	25.0	4	11.11	3	8.33	3	8.6
Difficult to fully open the mouth	20	55.6	6	16.7	6	16.7	2	5.6	1	2.9
Fatigue in the jaws	12	33.3	17	47.2	6	16.7	0	0	0	0.0

DISCUSSION

Orthognathic surgery is an established method for treating dentofacial anomalies. Several surgical techniques are in use. It has previously been reported that patients are generally satisfied with the treatment (73-76), and the results are reported to be stable (20, 77). The IVRO is a simple technique, with few surgical complications reported, but the need for IMF has been discussed to be a risk factor for later TMJ-related problems.

According to the consensus judgements of the Permanent Impairment Conference, a normal mouth opening movement is 40-50 mm and lateral movements are 8-12 mm (78).
A systematic review by Al-Riyami et al. (2009) including 12 studies reports prevalence of TMD after orthognathic surgery as well as mandibular range of movement. Most of the studies in the review included patients with Class II malocclusion treated with SSO, Le Fort 1 osteotomy or bi-maxillary surgery. Most of the studies reported reduced maximum mouth opening after surgery. However, the studies with longer follow-up period showed improvements of maximum mouth opening over time, suggesting that mandibular range of movement gradually normalizes after surgery (57, 59). Two studies including 36 and 217 patients found no statistically significant reduction in mandibular mobility before and up to two years after surgery (60, 79). Other studies including 55 and 150 orthognathic patients comparing SSO and IVRO found the most reduction in mandibular movement among the SSO-treated patients (80, 81).

In another study, statistical significant reduction of maximum mouth opening was observed among the VRO-treated patients after surgery, while the SSO-treated patients had no significant reduction. However, the VRO-treated patients reported less symptoms from the TMJs compared to the SSO-treated patients (82).

Even though several studies have shown that maximum mouth opening is reduced after orthognathic surgery (60, 80, 81), the results of the present study indicate that mandibular range of movement 10-15 years after surgery is comparable to a healthy population (83). It may seem that mandibular range of movement gradually recovers to its original range.

A study on prevalence of mandibular dysfunction in a healthy random Norwegian population aged 30-41 years, showed a prevalence of 3,8 % females and 2.0 % males with severe dysfunction (D_iIII) according to Helkimo (9). In a similar study including 145 Norwegian men aged 18-25 years, 2 % of the participants were diagnosed to have severe dysfunction (D_iIII) measured by the Helkimo index (84). Severe dysfunction according to Helkimo (D_iIII), is present if the clinical dysfunction score is more than nine on a scale from zero to twenty-five. The two patients (6%) in the present study diagnosed to have severe dysfunction according to the Helkimo index both had a dysfunction score of 10, the lowest score representing severe dysfunction.

The previously mentioned systematic review from 2009 by Al-Riyami et al. (Part 1 and 2) included studies that used the Helkimo index to diagnose TMD before and after surgery. The review concludes that TMD patients treated with orthognathic surgery would probably experience improvements in their signs and symptoms of TMD after surgery (57, 59). Pahkala et al. compared the Helkimo dysfunction index before and after surgery among 72 SSO-treated patients aged 16-53 years and also reported improvement of TMJ symptoms after surgery (85). On the other hand, Athanasios et al. found no significant improvement of the Helkimo dysfunction index before and after surgery (60).

Another systematic review, also including a meta-analysis, from 2017 on TMD after orthognathic surgery including 29 studies, also suggests that orthognathic surgery most likely will improve TMD symptoms (86). Ten of the studies used in the systematic review were questionnaire-based studies. A Swedish questionnaire-based study from the review, including 1516 patients, reported a significant reduction in subjective TMD symptoms after surgery. Preoperatively 43% reported subjective symptoms, while two years after surgery this was reduced to 28% (63). Another Swedish study showed the same findings, with significant reductions in the subjective TMD symptoms and also reduction in recurrent headaches after surgery (87). A Study form Finland, consisting of 60 patients showed the same reduction in TMD symptoms postoperatively, and an even more dramatic reduction in patients' self-reported recurrent headache, being reduced from 63% to 25% (88). The conclusion of the review, which suggests an improvement of post-operative complaints of TMD symptoms, corresponds well with the present study. None of the patients reported on the questionnaire to have pain during chewing or opening the mouth on a daily or weekly basis. This is of outmost importance for the patient's wellbeing. It is also of interest to the clinician, when discussing treatment options and risk factors with the patients before treatment.

The use of the Helkimo clinical dysfunction index makes the results comparable to several other studies. The mean Helkimo dysfunction group in the present study was 1.5, which represent mild to moderate dysfunction. A major contributing factor to the result of the Helkimo score was muscle pain. The degree of pain from the masticatory muscles depends on the amount of force used by the examiner during palpation. In the present study, the Helkimo scores concerning muscle pain were higher than expected and did not reflect the self-reported symptoms recorded on the questionnaires. One operator examined all the patients. Calibration with other examiners before the study was undertaken, could possibly have affected the results.

Lack of comparable pre-operative data is a weakness of this study. Pre-treatment and post-operative clinical data were available from the patient archive, but the data were not comparable with the data collected at the long-term follow-up examination.

We are aware of that the Helkimo index is old and has its limitations compared to more recent developed indices like the RDC/TMD. However, the Helkimo index is relatively short and simple to conduct, and was therefore chosen for this study. It has been suggested that Cl. III malocclusion is associated with increased prevalence of TMD (52, 53). It is difficult to say if the moderate dysfunction diagnosed in 36% of the patients in the present study was due to the previous orthognathic treatment including six weeks of IMF, or if the previous Class III malocclusion patients had a preexisting TMD before surgery.

The use of IMF is a classic method also for fixation of mandibular fractures (89). Advances in osteosynthesis techniques have made the use of IMF in trauma cases less needed, and in some environments IMF is considered almost obsolete. This is unfortunate, as IMF may still be an excellent treatment option in many cases. In particular for high unilateral condylar neck fractures IMF may prevent surgical interference with TMJ structures. IMF is also a valid choice when high-end surgical facilities are not available, eg. in the developing world, when follow-up is uncertain, or major surgery is contraindicated for medical or other patient-related reasons. The results of the present study showing that IMF does not have detrimental effects on the patients' mandibular range of movement or patient discomfort 10-15 years after surgery, supports the continuing use of IMF also in the treatment of trauma cases.

CONCLUSION

The results of the present study show that 10-15 years after IVRO setback surgery and subsequent IMF for six weeks, mandibular range of movement is satisfactory, and the patients report few functional limitations or symptoms related to the TMJs or masticatory muscles.

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