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Short-term postoperative changes in temporomandibular joints and masticatory muscles of Angle class II patients after mandibular advancement surgery: Clinical findings

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SUMMARY

Background and objective. The aim of the study was to detect postoperative changes in the temporomandibular joints (TMJs) and masticatory muscles of Angle class II malocclusion patients who underwent mandibular advancement surgery.

Material and methods. Twenty-three patients were selected for mandibular advancement by bilateral sagittal split ramus osteotomy (BSSO). Cephalograms and clinical evaluation were performed before the surgery as well as fourteen days and six months after surgery. Clinical examination included measurement of overjet, overbite and of the amplitude of mandibular movements, registration of deviation on mouth opening, of TMJ pain and pathological sounds and of tenderness of masticatory muscles on palpation. Mandibular position was determined by cephalometric analysis. Statistical analyses were performed using a mixed-level longitudinal random intercept model with a confidence level of 95% and a P-value of 0.05 to reveal significant differences.

Results. Statistical results showed a mean mandibular advancement of 4 mm (3.1–5.0). Cephalometric measurements, overjet and overbite remained stable six months after surgery. Postoperative amplitude of mandibular movements was limited and did not completely recover 6 months later. Mouth opening was the most affected, showing an average reduction of 7.5mm six months after surgery. Deviation on mouth opening, pathological TMJ sounds, TMJ pain and masticatory muscle tenderness did not show significant changes.

Conclusions. Moderate mandibular advancement surgery offers stable results, yet the amplitudes of mandibular movements, were significant smaller after surgery and did not completely recovered 6 months following surgery. TMJ and masticatory muscles symptoms did not change after the surgery, suggesting that mandibular advancement surgery does not change the course of TMD.

Keywords: mandibular advancement surgery, bilateral sagittal split osteotomy, orthognathic surgery, temporomandibular joint, masticatory muscle pain.

INTRODUCTION

Orthognathic surgery has gained considerable popularity not only for its aesthetic results but also for the functional rehabilitation that it permits to achieve (1). The procedure allows to change the relationship between the mandible and maxilla, repositioning the jaws in relation to the skull base and correcting the patient's occlusion, also presenting an effective means for enlarging the patient's upper airway to treat obstructive sleep apnea (2, 3).

The most frequently used surgical technique to correct mandibular dysgnathia is the bilateral sagittal split ramus osteotomy (BSSO). With this technique, the mandibular body can be bilaterally separated from the ramus and repositioned according to the desired plan (4). However, the procedure may lead to subsequent changes in the condylar position which could result in malocclusion, increase the risk of relapse and increase the likelihood of development of temporomandibular disorders (TMD) (5).

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Several studies have shown condylar translational displacements of at least 1.5 mm in the posterior, superior, or mediolateral direction immediately after BSSO (6).

The quality of sagittal repositioning is considered to be the main factor contributing to good occlusion and bone stability. Good functional results and, in particular, recovery of mandibular motion after surgery, can be related to the limiting of condylar torque.

Orthodontic and surgical plan, patient biotype, muscular action, proper condylar positioning and pre-existence of TMD are some of the factors that need to be considered to achieve a good and stable outcome in orthognathic surgery.

The prevalence of TMD is significantly increased in patients with dentofacial deformities who are referred for orthognathic surgery. Midline shift, large overjet and deep overbite, among others, have been associated with signs and symptoms of TMD (7). Hence, the preoperative status of the temporomandibular joints (TMJs) is an important factor to consider when planning the treatment of patients with severe malocclusions.

It is particularly difficult to achieve the correct positioning of the condyle in the temporal fossa during orthognathic surgery in Angle class II patients with TMD. Patients with preexisting TMD who undergo orthognathic surgery, in particular mandibular advancement surgery, are likely to experience worsening of the TMJ dysfunction. Due to these reasons, some authors recommend intraoperative surgical repositioning of the displaced articular disc during orthognathic surgery as a means of facilitating postoperative condylar bone apposition (5).

Condylar repositioning devices which could improve intraoperative condylar positioning are seldom used in orthognathic surgery because they extend operating time and also because it has not been shown that they are likely to provide a better functional outcome in the long term.

In recent years, the use of virtual surgical planning (VSP) in orthognathic surgery has improved the results of the procedure, even though recent studies that assessed the effect of VSP on the accuracy of condylar positioning after bilateral sagittal split osteotomy (BSSO) concluded that VSP does not reduce postoperative shifts in condylar position in comparison to conventionally planned procedures (8, 9).

The effect of orthognathic surgery on TMJs have been examined in several studies, but systematic reviews of these studies cannot provide a conclusive answer to the question of how exactly orthognathic surgery affects the signs and symptoms of TMJs (7). More recent systematic review and meta-analysis have demonstrated that the postoperative course of the TMD of patients undertaking orthognathic surgery is unpredictable and it is not possible to identify, for instance, by the type of jaw deformity, whether the patient's TMD would improve, remain unchanged, or worsen after surgery. There is still controversy about whether orthognathic surgery negatively or positively affects TMDs (5).

The aim of this study is to investigate clinical postoperative changes in TMJs and masticatory muscles of Angle class II malocclusion patients after bilateral sagittal split ramus osteotomy for mandibular advancement.

MATERIALS AND METHODS

Angle class II patients referred to the Department of Oral and Maxillofacial Surgery of the North Estonia Medical Centre (Tallinn, Estonia) for orthognathic surgery between September 2010 and September 2013 underwent pre- and postoperative clinical and radiographic examinations of the facial region. The study included 23 young adult patients with Angle class II malocclusion – 10 males and 13 females aged 18 to 40 years – who had orthognathic surgery for isolated mandibular advancement. No conventional control group was included in the study because its aim was to detect the effect of mandibular advancement on the patients' TMJs and masticatory muscles by repeated assessment over time.

Exclusion criteria were severe systemic or mental disease, malocclusion types other than Angle class II, congenital craniofacial anomalies, previous history of post-traumatic treatment, systemic inflammatory joint disease or neuromuscular disorder. Two female patients dropped out during the study: one did not turn up for her preoperative and for the second postoperative examination and the other patient for the second postoperative examination.

All patients undertook preoperative orthodontic treatment for dental alignment and decompensation according to maxillary bone base.

Orthognathic surgery was performed on the patients by two qualified maxillofacial surgeons with more 10 years of specialized experience. BSSO procedures were performed as described by Dal Pont in 1961 (10). Following osteotomy, the lower jaw was positioned according to dental splints fixed to the upper dental arch. Mandibular osteosynthesis

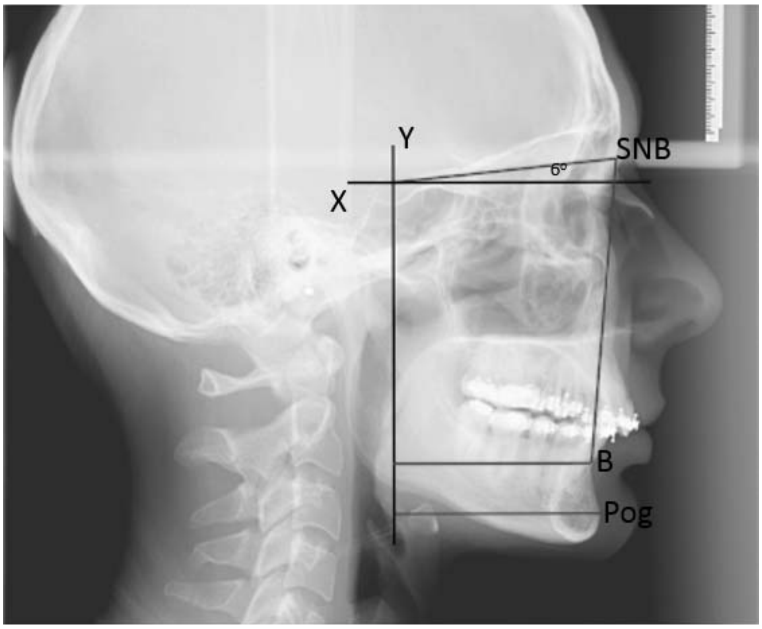

Fig. 1. Cephalometric analyses: Cephalometric parameters used to measure mandibular advancement: linear coordinates drawn with the use of a horizontal line through sella rotated down anteriorly 6° as the horizontal reference axis (X) and a perpendicular drawn from the sella as the vertical reference axis (Y). Three different cephalometric measurements of the mandibular position were performed in relation to skull base: Sella–Nasion–Supramentale (SNB) angle and linear horizontal measurements: B–Y (Supramentale distance to Y-axis) and Pog–Y (Pogonion distance to Y-axis)

was performed by three interfragmentary screws on each side of the mandible or by titanium miniplates (thickness: 2.0 mm) with monocortical screws. Intermaxillary fixation with elastics was established on the second postoperative day and maintained for 14 days. Postoperative orthodontics were performed to adjust minor residual malocclusions including the routine use of class II elastics for 6 about months.

Clinical evaluation was performed and cephalograms were taken preoperatively (up to 14 days before the surgery: T1), 14 days after surgery (T2) and 6 months (T3) after surgery.

Clinical examination included measuring the overjet, overbite and the amplitude of mandibular movements with a ruler scaled in millimeters, using the superior and inferior central incisive borders and dental midlines as reference. The examination also registered TMJ pain on palpation and on mandibular excursion, detected TMJ sounds by stethoscope during mandibular excursion, registered mandibular deviations during mouth opening and closing as well as any tenderness of masticatory muscles on palpation. Pain in the TMJ and masticatory muscles was measured by the visual analogue scale (VAS) (11).

Cephalograms were performed using the digital cephalometric imaging system Instrumentarium Orthoceph OC200D (Finland) to measure the amplitude of mandibular advancement and to check postoperative stability. All cephalograms were taken with the same cephalometric radiograph unit, with the patient's head oriented such that the Frankfurt plane was parallel to the floor, with the mandible occluding. Cephalometric measurements were performed by the first author using Agfa Impax Software in accordance with the parameters used in the study of Pangrazio-Kulbersh *et al.* in 2001 (4), (Figure 1). Repeated cephalometric measurements showed an average intra-observer variation of 1.57%.

The study was conducted according to the Helsinki Declaration and was approved by the Tallinn National Institute for Health Development Medical Research Ethical Committee in (*Tallinna Meditsiiniuuringute Eetikakomitee*) Decision no. 2102. All procedures were explained to the patients, informed consent forms from patients and institutional approval were obtained to conduct the study.

Statistical analysis

For the overall analysis of the cephalometric values and clinical measurements of overjet, overbite and mandibular movements, we used a mixed-level longitudinal random intercept model for repeated measurements. The measurements were included as dependent variables and time was modelled as repeated variable. Age, sex, presence of pain, sound in the TMJ and deviation in mouth opening were added as fixed effects to control for possible confounding. As a random effect, the patient code was used to indicate a Level 2 grouping. Mixed models provided adjusted estimated mean values and coefficients for preoperative measurements as well as for those taken respectively two weeks and six months after surgery. In addition, we analyzed the difference between the two postoperative measurements using the ordinary least squares linear regression method to highlight possible influences on TMJ and muscular pain after surgery. A confidence level of 95% and a two-sided *P*-value of 0.05 were used to reveal significant differences.

Some of the VAS data for muscle and TMJ pain show positively skewed distribution and a large percentage of zero values. For statistical inference from VAS data, we used bias-corrected bootstrap confidence intervals that are shown to capture the true value of the mean and to correct for bias and skewness of bootstrap parameter estimates (12;

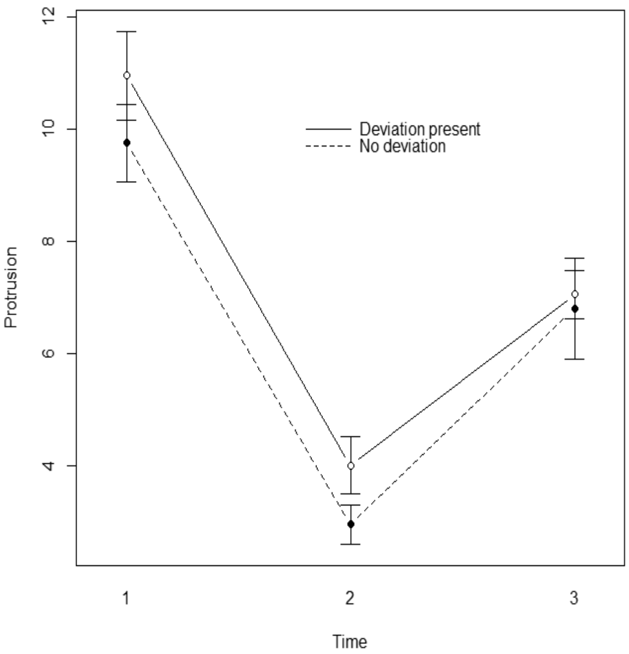

Fig. 2. Mandibular protrusion and deviation on mouth opening, T1–T3: Amplitude of mandibular protrusion (in millimeters) in patients with and without deviation on mouth opening at T1, T2 and T3. Patients with larger protrusion showed higher incidence of mandibular deviation on mouth opening in all measurement windows.

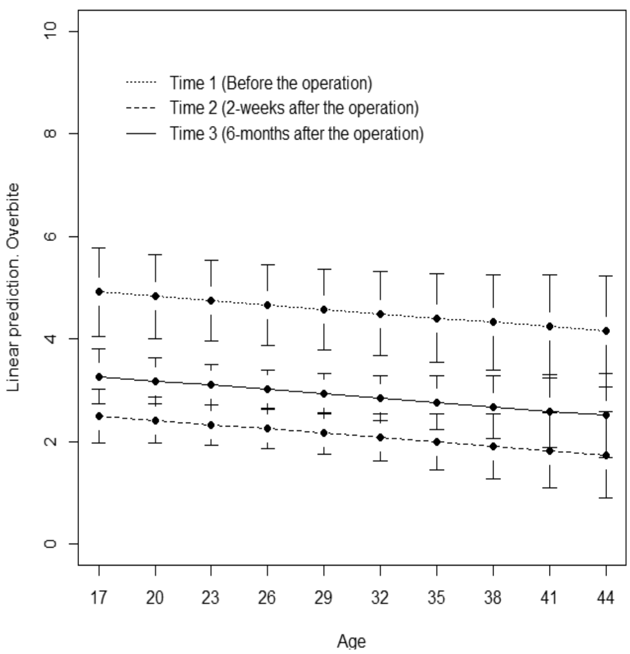

Fig. 3. Linear prediction of overbite and overjet: in millimeters by 3-year age intervals at T1 (up to 14 days before the surgery), T2 (14 days after surgery) and T3 (6 months after surgery)

13). We used the R package ordinalCont, which implements continuous ordinal regression methods and was developed to analyze response variables measured on linear VAS scales (14).

All analyses were performed using STATA IC version 14 (StataCorp, College Station, TX, USA) and R 4.0.5 (Core Team, 2020) (15).

RESULTS

Cephalometric analysis

Postoperative cephalometric analyses at T2 showed an average increase of the SNB angle by 2.6° and an average increase of B–Y and Pog–Y distances by 4 mm. At T3, SNB and B–Y values (Table 1)

Table 1. Cephalometric analysis of mandibular position adjusted for age and gender. Sella–Nasion–Supramentale (SNB) angle in degrees and linear horizontal measurements in millimeters: B–Y (Supramentale distance to Y-axis) and Pog–Y (Pogonion distance to Y-axis), at T1 (up to 14 days before the surgery, T2 (14 days after surgery) and T3 (6 months after surgery). Each data cell shows the average value of the corresponding measurement and, in parentheses, the range of the measurements).

	T1	T2	T3	T2 vs T1	P-value	T3 vs T1	P-value	T3 vs T2	P-value
SNB	75.66 (74.73–76.6)	78.3 (77.45–79.14)	77.8 (76.89–78.71)	2.63 (2.22–3.05)	0.000	2.14 (1.61–2.67)	0.000	-0.49 (-0.83–-0.16)	0.004
B-–Y	56.31 (54.45–58.16)	60.52 (58.79–62.25)	59.6 (57.82–61.38)	4.21 (3.39–5.04)	0.000	3.29 (2.37–4.22)	0.000	-0.92 (-1.54–0.31)	0.003
Po–Y	56.62 (54.25–58.99)	60.55 (58.3–62.81)	60.00 (57.66–62.33)	3.93 (3.12–4.73)	0.000	3.37 (2.37–4.38)	0.000	-0.55 (-1.21–0.1)	0.099

Table 2. Range of mandibular movements in millimeters adjusted for age and gender at T1 (up to 14 days before the surgery), T2 (14 days after surgery) and T3 (6 months after surgery). Each data cell shows the average value of the corresponding measurement and, in parentheses, the range of the measurements).

	T1	T2	T3	coeff T2 vs T1	P-value	coeff T3 vs T1	P-value	coeff T3 vs T2	P-value
Mouth opening	47.85 (45.27–50.42)	25.21 (23.37–27.04)	40.45 (38.42–42.48)	-22.64 (-25.6–-19.68)	0.000	-7.4 (-10.47–-4.32)	0.000	15.24 (12.75–17.74)	0.000
Lateralization to right	10.65 (9.41–11.89)	4.7 (4.01–5.39)	7.41 (6.77–8.05)	-5.95 (-7.26–-4.64)	0.000	-3.24 (-4.52–-1.96)	0.000	2.71 (1.94–3.48)	0.000
Lateralization to left	10.22 (9.11–11.33)	5.62 (4.99–6.25)	7.89 (7.16–8.63)	-4.6 (-5.72-3.48)	0.000	-2.33 (-3.51—1.15)	0.000	2.27 (1.52–3.03)	0.000
Protrusion	10.29 (9.39–11.19)	3.58 (2.81–4.34)	6.94 (6.15–7.74)	-6.71 (-7.89–-5.54)	0.000	-3.35 (-4.54–-2.15)	0.000	3.37 (2.27–4.47)	0.000

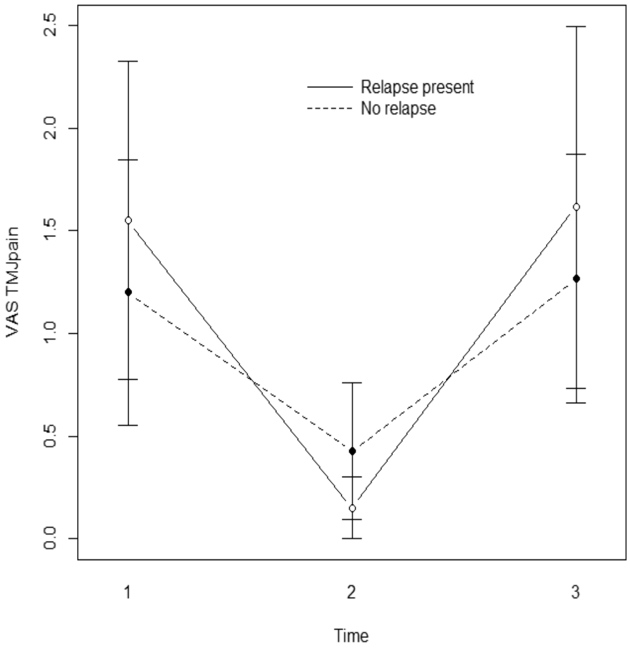

Fig. 4. TMJ VAS scores and post-surgical relapse: Mean VAS scores for TMJ pain at T1 (up to 14 days before the surgery, T2 (14 days after surgery) and T3 (6 months after surgery) for patients with and without post-surgical relapse.

showed a statistically significant average decrease of less than 1 unit. Post-surgical relapse was deemed to have occurred where at least two cephalometric measurements from T2 to T3 presented a reduction by 2 or more units. According to this criterion, two patients relapsed. Linear regression analysis showed relapsed patients' average increase of the SNB angle (from T1 to T2, *P*=0.04) to exceed that of non-relapsing patients' by 1.4 degrees. B–Y and Pog–Y measurements did not show any significant changes in mandibular advancement by reference to relapse status.

Mandibular movements

The amplitude of all mandibular movements decreased two weeks after surgery and partially recovered six months later, but still remained inferior to preoperative values (Table 2). On average, women presented mouth opening values that were by 4.3mm lower compared to those of men (p=0.002) and each

Table 3. Mixed logistic models for mandibular deviation on mouth opening adjusted for sex and years of age. Odds ratios (OR) at T1 (up to 14 days before the surgery, T2 (14 days after surgery) and T3 (6 months after surgery).

	Deviation 95% CI			
	OR	lower	upper	p-value
T1	1.00			
T2	2.01	0.75	5.4	0.164
T3	1.37	0.62	3	0.436
Women	1.26	0.52	3.05	0.611
Age	1	0.94	1.06	0.906

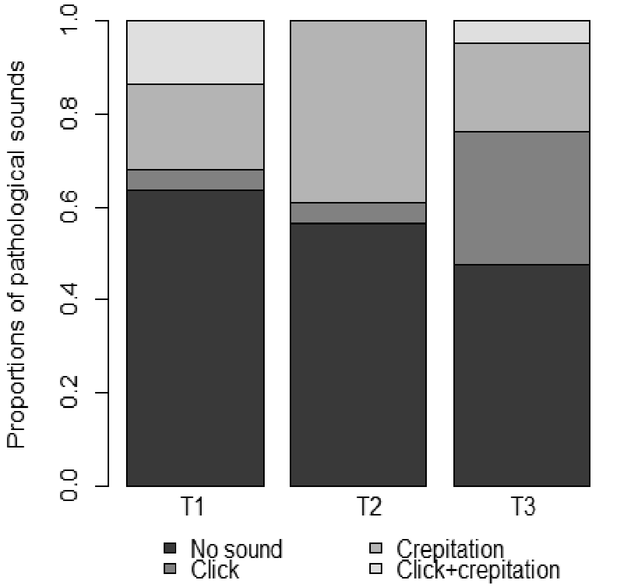

Fig. 5. TMJ pathological sounds at T1, T2 and T3: Presence and proportions of pathological sounds in the TMJ (up to 14 days before the surgery), T2 (14 days after surgery) and T3 (6 months after surgery).

additional year of age was related to a reduction of about 0.1 mm in the amplitude of mandibular protrusion (p=0.02).

The odds of having a mandibular deviation were twice as high compared to preoperative measurement and declined in 6 months (T3). These odds ratios were not statistically significant. 45% of the patients presented deviation at T1, 63% at T2 and 52% at T3. The odds rate for women was 1.26 times higher, but not all coefficients in the model were statistically significant (Table 3).

Mandibular deviations on mouth opening were associated with larger protrusions (*P*-value 0.049), with an empirical optimal cut point value of 7 mm for the protrusion (Figure 2). SNB angle was, on average, by 0.4° smaller in patients who presented deviations on mouth opening (*P*-value 0.026), the empirical cut point value of SNB angle for deviation was 78.85.

Overjet and overbite

Mixed level linear regression for overjet and overbite showed significant postoperative decrease with the difference remaining stable at T3 (Table 4). Linear prediction of overbite and overjet showed that both values decrease with age, although the decrease was not statistically significant given the sample size of our study (Figure 3).

TMJ pain

The VAS score for TMJ pain did not show statistically significant changes over time (Table 5). The mean TMJ pain VAS score of patients that

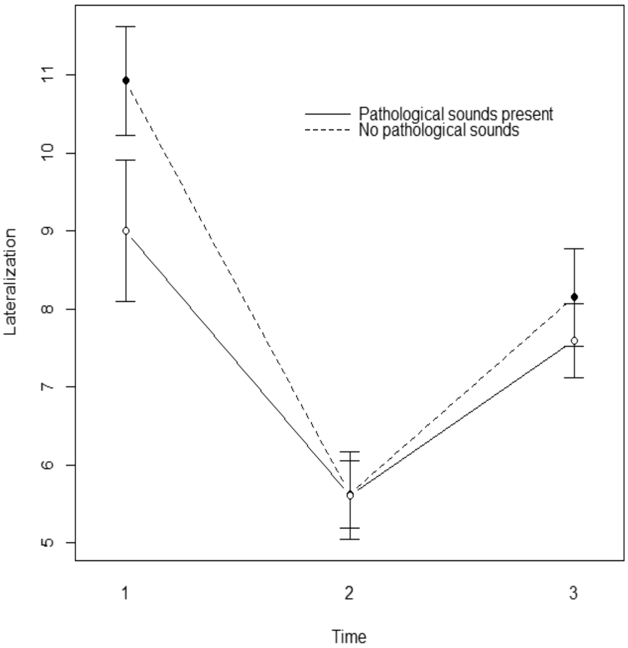

Fig. 6. Lateral movement and TMJ pathological sounds at T1, T2 and T3: Amplitude of lateral movements in millimeters in patients with and without pathological sounds in the TMJs, at T1 (up to 14 days before the surgery), T2 (14 days after surgery) and T3 (6 months after surgery).

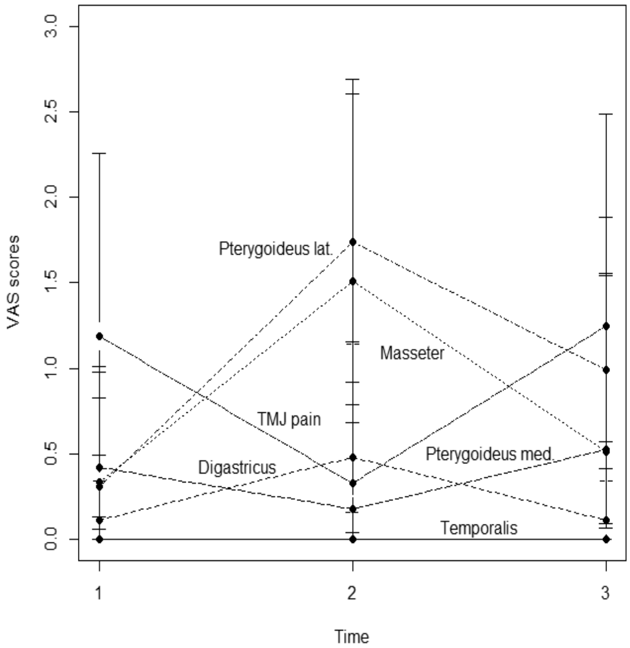

Fig. 7. Masticatory muscle and TMJ VAS scores at T1, T2 and T3: Mean VAS scores for pain in masticatory muscles and TMJs at T1 (up to 14 days before the surgery), T2 (14 days after surgery) and T3 (6 months after surgery) with bias-corrected bootstrap confidence intervals.

presented a surgical relapse was slightly higher at T1 and T3, although these differences were not statistically significant (Figure 4).

Pathological sounds in the TMJ

The presence of pathological sounds in the TMJ did not show any statistically significant difference across the three measurement windows (T1–T3). Pathological sounds were registered in 36% of the patients at T1, 44% at T2 and 52% at T3. However, statistically significant changes were found by type of pathological sound: the click was more frequent at T3, crepitation at T2 and the presence of concomitant sounds at T1 (Pearson chi-square P=0.038) (Figure 5). Pathological sounds in the TMJ were associated with deviation on mouth opening at T1 (Pearson chi-square P=0.035), but this association disappeared after surgery. Presence of pathological sounds in TMJs did not influence the scores for pain in the TMJ, but the amplitude of lateralization movements at T1 was significantly smaller in the presence of pathological sounds (P=0.033). Lateralization was on average by 0.72 mm smaller for patients with TMJ pathological sounds at T1 (Figure 6).

Muscular pain

Mixed level regression of masseter muscle pain scores adjusted for sex and age shows increased levels of pain at T2 (compared to T1). Pain scores return to initial levels at six months after surgery. After adjustment for multiple comparisons, the differences were not statistically significant (Figure 7).

No significant pain score differences over time were detected for the *pterygoideus medialis* muscle.

Table 4. Overjet and overbite in millimeters at T1 (up to 14 days before the surgery), T2 (14 days after surgery) and T3 (6 months after surgery). Each data cell shows the average value of the corresponding measurement and, in parentheses, the range of the measurements).

	at T1	at T2	at T3	coeff T2 vs T1	p-value	coeff T3 vs T1	p-value	coeff T3 vs T2	p-value
Overjet	7.77 (6.95–8.59)	2.32 (1.74–2.9)	3.32 (2.92–3.72)	-5.45 (-6.46–-4.44)	0.000	-4.45 (-5.37–-3.53)	0.000	1 (0.29–1.71)	0.006
Overbite	4.66 (3.88–5.44)	2.25 (1.87–2.62)	3.02 (2.64–3.39)	-2.41 (-3.25–-1.58)	0.000	-1.64 (-2.48–-0.81)	0.000	0.77 (0.3–1.24)	0.001

Table 5. VAS scores of temporomandibular joint (TMJ) pain at T1 (up to 14 days before the surgery), T2 (14 days after surgery) and T3 (6 months after surgery). Each data cell shows the average value of the corresponding measurement and, in parentheses, the range of the measurements.

	at T1	at T2	at T3	P-value T2 vs T1	P-value T3 vs T1
TMJ pain	1.19 (0.5–2.26)	0.33 (0.04–1.16)	1.25 (0.57–2.48)	0.183	0.831

However, significant differences were found in all of the study's measurements (T1–T3) among patients whose TMJs had both click and crepitation sounds during mouth opening and whose mean pain scores were on average 3.5 times higher than those of patients who did not present pathological sounds.

Pain scores for the right-side *pterygoideus lateralis* muscle increased significantly (P=0.013) two weeks after the operation (from VAS 0.2 to 1.3) and decreased at six months after surgery (to VAS 0.6), to a level that was slightly higher than that of the initial measurements' but did not register as statistically significant. The mean predicted VAS score for pain in the right *pterygoideus lateralis* muscle was 0.22 at T1, 1.35 at T2 and 0.54 at T3. The mean scores for pain in the left *pterygoideus lateralis* muscle were similar to those for the right side, except for a significant increase of the pain at T2 (P=0.04). Predicted mean VAS score for pain in the left *pterygoideus lateralis* muscle was 0.26 at T1, 1.00 at T2 and 0.87 at T3.

Pathological sounds in the TMJs did not influence VAS scores for pain in the *pterygoideus lateralis* muscle. However, an increase by one scale unit of VAS score for pain in *pterygoideus lateralis* was associated with a reduction of the maximum mouth opening value by 0.85 mm (P=0.023).

The overall trend of pain in the *digastricus* muscles slightly increased two weeks after surgery and decreased six months after surgery, but the changes were not significant. Mean predicted VAS pain score for the right *digastricus* was 0.11 at T1, 0.24 at T2 was and 0.11 at T3, and, for the left *digastricus*, 0 at T1, 0.3 at T2 and 0 at T3. Pathological sounds in the TMJs had no influence on pain scores for *digastricus* muscles.

None of the patients presented pain in the *temporalis* muscle at T1 and no statistically significant changes were recorded at T2 and T3.

DISCUSSION

Based on cephalometric and clinical measurements, the patients selected for the study received an average mandibular advancement of 4 mm and an increase of 2.6º in the SNB angle. The patients' overjet was reduced on average by 5.6mm and overbite by 2.5mm. Six months after surgery these measurements did not show any statistically significant changes. Considering that larger mandibular advancements have a greater tendency to relapse than smaller ones it is likely that the moderate extent of the mandibular advancement performed in the study was a factor that contributed to the stability of mandibular position at T3. In the study, only two patients presented relapse and a linear regression analysis of the data showed that their SNB angle increased on average by 1.4º more than that of non-relapsed patients. Yet T-test and linear regression of cephalometric measurements did not show mandibular advancement to be greater among patients whose SNB, B–Y or Pog–Y values decreased at T3. It is also known that counter-clockwise rotational movements have a tendency to relapse (9), which seems to play a more important role in relation to instability than larger advancements that do not involve rotation.

Our study also found that the average reduction by 0.4º in the SNB angle of patients that presented mandibular deviation on mouth opening was statistically significant, as was the fact that patients with an SNB angle below 78.8º had a higher incidence of deviation. These findings suggest that a smaller SNB angle may be associated with mandibular deviation. A similar association between mandibular retrusion and deviation on mouth opening has been previously reported in the study by Xia *et al.* in 2016 (16), which formulated the hypothesis that anterior disc displacement may cause mandibular malformations, especially among adolescents, which in turn might affect the growth of the condyle and contribute to subsequent mandibular retrusion and deviation on mouth opening. However, mandibular advancement surgery did not significantly change the presence of deviation on mouth opening. The deviation is probably associated to internal derangements of the TMJ or asymmetric joint morphology and these alterations cannot be corrected by mandibular advancement surgery without additional treatment.

The results of our study also showed that mandibular deviation on mouth opening was associated with larger amplitudes of protrusive movements (see Fig. 2). Further investigations are needed to understand the causes of this correlation, which could be due to anatomical particularities of the glenoid fossa and condyles or to a hyper-elasticity of temporomandibular ligaments and masticatory muscles. Mandibular deviation could also be associated with a tendency to temporomandibular disc displacement.

The amplitudes of all mandibular movements were reduced at T2 and increased at T3, but still did not totally recover compared to T1 levels. The most affected mandibular movement was the mouth opening, which was reduced on average by 7.5mm at T3. Protrusion measurements at T3 were on average reduced by about 3.4mm and lateral movements by 2.9mm. Pain in the *pterygoideus lateralis* muscle was statistically significantly associated with reductions in the amplitude of mouth opening, with increase of one scale unit of VAS pain score for the muscle being associated with a reduction of 0.85 mm in the maximum mouth opening value. Among all masticatory muscles, only the *pterygoideus lateralis* presented a small but statistically significant increase of pain scores from T1 to T2, which may be related to postoperative changes in the position of the condyle and the disc to which the muscle is attached. These are probably some of the factors that – in addition to trismus of masseter and *pterygoideus medialis* muscles – contribute to the decrease of postoperative mouth opening.

Reductions in maximal incisal opening have been previously reported following periods as long as one year after orthognathic surgery (17, 18) and reductions in the range of mandibular movement in the vertical and antero-posterior directions seem to be more significant than lateral reductions (18). Early physiotherapy after surgery can improve jaw motion during the first six postoperative months (19). The results of the study reported here, however, only reflect the natural course of mandibular function recovery following mandibular advancement surgery, as our patients did not receive any instructions for myofunctional physiotherapy.

In our study, the incidence of pathological TMJ sounds did not change statistically significantly over time, however there were statistically significant changes by type of pathological sound over the period of the study: clicks were more frequent at T3, crepitation at T2 and the presence of both sounds at T1. Increase of the incidence of crepitation 2 weeks after surgery could be explained by the mechanisms behind the TMJ remodeling process. Where crepitation (a sign of joint tissue degradation) appears immediately after surgery, it may indicate the beginning of the remodeling process (resorption of bone surfaces). As bone is a dynamic tissue, the processes of resorption and apposition are expected as an adaptive response to postoperative changes in occlusal and mandibular position, which is probably the reason for the decrease in crepitation at T3. The study also showed that pathological sounds were associated to preoperative jaw deviation on mouth opening but this association disappeared at T2 and T3. A possible explanation for this could be the reduction of mandibular movement after surgery. Still, the incidence of deviation did not show statistically significant changes at T2 and T3.

The presence of pathological sounds in the TMJ did not influence TMJ pain scores, yet the amplitude of lateralization was significant smaller in the presence of such sounds. Impairment of lateralization movements should therefore be considered as an important sign of TMD. And the same goes for pain in the *pterygoideus medialis* muscles, which was on average higher by 3.7 scale units for patients of the study that presented clicks and crepitation in the TMJ.

Our study showed a tendency of reduction in the incidence of TMJ pain 6 months after mandibular advancement surgery, although the results were not statistically significant given the relatively small sample of patients. Orthognathic surgery for correction of maxillo-mandibular position and establishment of a harmonic occlusion probably has a beneficial effect on the TMD. Significant reduction of TMJ pain after mandibular advancement surgery has been previously reported by several studies (20; 21). Angle class II malocclusion patients who had undergone mandibular advancement surgery presented less TMD related myalgia and arthralgia than class II malocclusion patients who had not received similar treatment (21). The risk of persistent pain in the TMJ after orthognathic surgery seems to be higher for female patients, particularly those with an abnormal psychological profile (22).

In our study, masticatory muscle pain displayed a slight increase two weeks after surgery and decreased six months after surgery, but the changes were not statistically significant, except for pain in the *pterygoideus lateralis* muscles, which presented a small but statistically significant increase two weeks after surgery. These results correspond to those of the study by Rodrigues-Garcia *et al.* published in 1998 (23) which also showed a small, but statistically significant difference in the muscular pain and discomfort of patients who had undergone mandibular advancement surgery.

CONCLUSIONS

Moderate mandibular advancement surgery offers stable results, yet the amplitudes of mandibular movements, specially of mouth opening, were significant smaller after surgery and – without recourse to physical therapy – were not completely recovered 6 months following surgery.

The incidence of pathological TMJ sounds, mandibular deviation on mouth opening and intensity of pain in the TMJ and in masticatory muscles did not present any statistically significant changes after surgery. This suggests that mandibular advancement surgery does not change the course of TMD.

STATEMENT OF CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest to report.

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