Effect of Botox injection in the anterior belly of the digastric on skeletal relapse following mandibular advancement surgery. Randomized controlled trial

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Abstract

Purpose: to test whether Botox injection in the anterior belly of the digastric muscle in sagittal split osteotomy for mandibular advancement could reduce the tendency of postoperative relapse in comparison to the same surgery without Botox injection in bimaxillary orthognathic surgery.
Methods: A total of 24 patients indicated for mandibular advancement bi-maxillary orthognathic surgery were randomly assigned to 2 equal parallel groups; 12 patients were injected with Botulinum toxin type A before surgery (Intervention group), and 12 patients were treated without injection (Control group). The relapse was evaluated by the differences in cephalometric variables at 1 week and 6 months postoperatively. The evaluated cephalometric variables are 3 angular measurements (SNB, ANB, and ArGo-SN) and 2 linear measurements (Pog and B point) concerning Frankfort Horizontal and coronal planes on CBCT image.
Results: There was a statistically significant difference between the Botox and control groups in Pg/coronal horizontal measurement. The Botox group showed a statistically significant lower increase (lower relapse) in Pg/coronal measurement than the Control group. In comparison between the two groups, there was no statistically significant difference in B and Pg concerning the FH plane, B point about the coronal plane, and all angular measurements: SNB, ANB, and Ar-Go/SN.
Conclusion: Botulinum toxin type A injection into the anterior belly of the digastric muscle is an easy and effective approach to decrease relapse following mandibular advancement orthognathic surgery.

Keywords: mandibular advancement; relapse; stability; botulinum toxin type A; anterior belly of digastric; class II orthognathic surgery.

Introduction

The success of orthognathic reconstructive surgery depends on the stability of the surgical correction. Failure to achieve stability can result in a compromised final result[1] Stability remains a significant concern after an advanced bilateral sagittal split osteotomy (BSSO). Despite the advances in diagnostic and orthognathic surgical techniques, a certain amount of skeletal relapse occurs in orthodontically and surgically treated cases. [2,3]

Van den Bempt and colleagues highlighted in their systematic review that the perimandibular muscles contribute to skeletal relapse following advancement BSSO.[4] It has been proposed that moving the mandible forward causes the submandibular soft tissue and the suprahyoid and infrahyoid muscles to stretch. The stretching of these tissues creates a continuous force that opposes the direction of the mandibular advancement.[5]

Given that post-operative relapse after orthognathic surgery is influenced by muscular tension, implementing strategies to alleviate this tension could serve as a practical treatment approach.[6]

Although muscular alteration by myotomy in mandibular advancement is one successful approach to reducing muscle tension[7], cutting muscles is aggressive and has higher rates of complications, such as bleeding and nerve damage. So, introducing Botox injections, which are less invasive procedures to reduce muscle tension, may be a solution for postoperative relapse.

A review of the existing literature regarding the benefits of Botox injections in the anterior belly of the digastric muscle and the mylohyoid muscle suggests that these injections may alleviate muscle tension in the mandible and enhance the stability of orthognathic surgical procedures [8,9,10]

Despite the encouraging results, the overall quality of the scientific evidence is still considered inadequate. The current literature on Botox injections in the anterior belly of the digastric muscle mainly comprises case reports and case series. Consequently, it is crucial to conduct well-designed randomized controlled clinical trials.

So, in this randomized controlled clinical study, we tried to evaluate the effect of Botox injection in the anterior belly of the digastric muscles on decreasing muscle tension and subsequently the postoperative relapse in mandibular advancement orthognathic surgery in comparison to a control group of the same orthognathic surgery without injection.

Materials and methods

This research received approval from the Ethics Committee of Scientific Research, Faculty of Oral and Dental Medicine, Cairo University. All participants engaged in the study voluntarily and provided their informed consent.

Study design and participants.

The research methodology employed is a randomized controlled trial. It included 24 Patients selected from the oral and maxillofacial department, Faculty of Dentistry, Cairo University, from April 2022 to May 2024. All patients underwent sagittal split osteotomy with mandibular advancement in bimaxillary orthognathic surgery. The patients were divided randomly into two groups with a 1:1 allocation utilizing a computer-generated randomization schedule.

- **Group 1 (Intervention group)**: 12 patients received injections of botulinum toxin type A into the anterior belly of the digastric muscles before surgical intervention.
- **Group 2 (Control group):** 12 patients under surgical intervention without injection.

Inclusion criteria:

1. Patients need mandible advancement to treat skeletal class II malocclusion, characterized by mandibular retrognathism.
2. Patients need maxillomandibular orthognathic surgery with sagittal split osteotomy in the mandible.
3. Age of the patients above 18 years.

Exclusion criteria:

1. A patient with a background of facial bone injury and a cleft lip or palate.
2. Patient with active temporomandibular joint disorders.
3. Patients report any systemic conditions that could hinder the normal process of bone healing.
4. Intraosseous lesions or infections that might disrupt surgical procedures.
5. History of prior orthognathic surgical procedures.
6. Individuals with relative contraindications to botulinum toxin injections, including pregnancy, breastfeeding, neuromuscular disorders (such as myasthenia gravis), motor neuron diseases, or allergies to any botulinum toxin components.

Preoperative preparations

After history taking and clinical examination, Preoperative photographs of the patient were obtained, capturing frontal, profile, 45-degree angles, smiling expressions, and dental occlusion. Every patient was directed to an orthodontist for the presurgical stage of their orthodontic treatment to level, align, decompensate, and attain a stable occlusion in not less than three points in the proposed post-operative occlusion position.

Patients underwent CBCT scans in their natural head position utilizing a Planmeca ProFace imaging system. The CBCT scan was acquired in DICOM format and imported into surgical planning software Mimics 21. The dental models were acquired and mounted on the desired final post-operative occlusion, then optically scanned and imported into Mimics 21 software.

A detailed treatment plan and clear visual treatment objectives were established by integrating clinical examinations with the 3D cephalometric analysis of the virtual model. The final post-operative new positioning of the maxilla and mandible was virtually performed on the Mimics 21 software. The cutting guides were crafted on the maxilla to direct the osteotomy and indicate reference holes for future use with the patient-specific repositioning and fixation plate or 2.0 mini pre-bended plates, utilizing CAD software (3-matic 13). Finally, the interocclusal splint was fabricated on mounted dental casts or virtually planned on (3-matic 13) and printed.

In the intervention group: A vial of Botulinum Toxin A containing 50U of Botox (Figure 1) was reconstituted with 1mL of (0.9%) sterile sodium chloride solution for a concentration of 50U/mL according to the recommendation of the manufacturer. The anterior belly of the digastric muscles contracts during the opening of the mouth, so the patient reported opening the mouth widely under force resistance to mouth opening by the hand of the operator. This method allows the anterior belly of the digastric muscles to be felt by the operator's fingers extra orally in the submental area. A total of 25 U of Botox was divided and injected into two points bilaterally in the submental area by using a 1 cc insulin syringe (Figure 2).

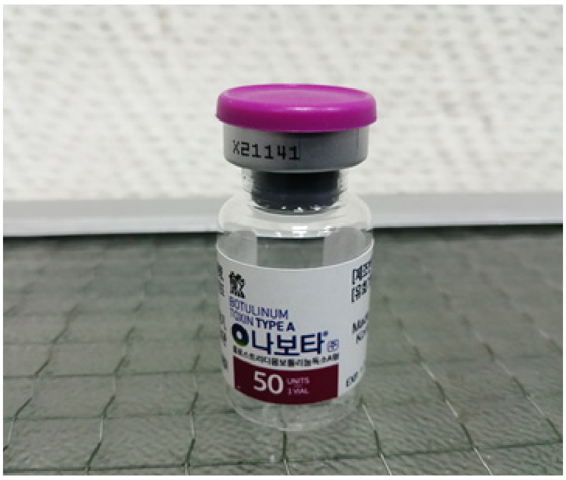

Figure 1. A photograph showing Botulinum toxin type A vial.

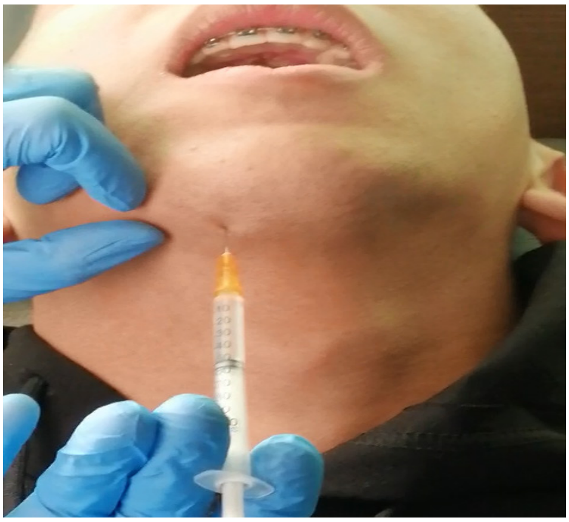

Figure 2. A photograph showing injection of anterior belly of digastric muscle after palpation in sub-mental area.

Intraoperative procedure

All patients had bimaxillary orthognathic surgery under general anesthesia using nasotracheal intubation. For maxillary surgery, the maxillary cutting /screw holes locating surgical guide was positioned on the exposed bony surface. Reference holes were created, and after that, the cut through the lateral wall of the maxilla at the designated slot in the cutting surgical guide was performed. The separation of the maxilla was completed. After adequate mobilization, the osteotomized maxilla was repositioned and fixed either by the custom-made plates with 2.0 mm screws or pre-bent plates with 2.0 mm screws using the reference holes made by the surgical guide.

For mandibular surgery, sagittal split ramus osteotomy was performed, utilizing Epker's adaptation of the Obwegeser, Dal Pont, and Hunsuck osteotomy techniques [11]. The final surgical splint was placed between upper and lower teeth, and intermaxillary fixation (IMF) was achieved using ligature wires or elastics. Mandibular osteosynthesis was successfully performed with either a single 2.0-mm titanium miniplate secured using 5 to 6 monocortical screws or by three positioning screws that were positioned horizontally along the oblique ridge of the mandible. Then the IMF was removed and occlusion was checked regarding the planned final occlusion. Usually, genioplasty was performed using a surgical guide for osteotomy cuts and fixed with a customized 3D plate.

Data Collection methods.

Immediately after one week and 6 months post-operative, CBCT scans were acquired in DICOM format. DICOM data were imported into Mimics software. A 3D model calculated then based on point-based matching iterative closest point (ICP) registration; alignment points were chosen to superimpose the 6-month post-operative 3D virtual model on the one-week post-operative virtual model based on the cranial base structure, which does not alter by the surgical procedure, followed by surface registration for best fit.

2 planes constructed on the virtual superimposed models; coronal and Frankfort horizontal plane (Figure 3). The right Orbital and the right and left porion define the Frankfort plane. The coronal plane is represented by plane 10mm anterior and parallel to the Nasion perpendicular plane, which is constructed perpendicular to the sagittal and Frankfort horizontal planes and passes through the Nasion point.

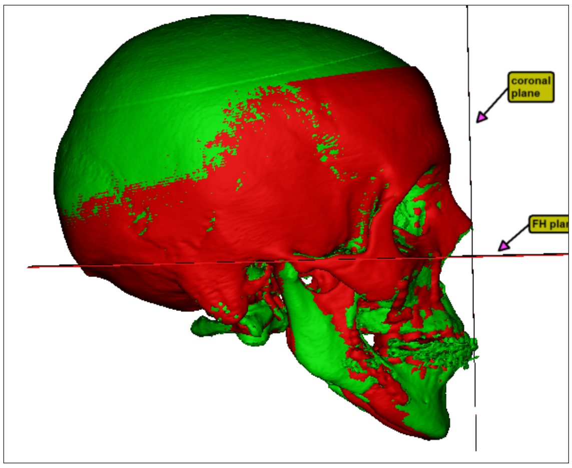

Figure 3. superimposition of 6 month postoperative on one week postoperative virtual 3D model and constructed Frankfort Horizontal (FH) plane and coronal plane on superimposed virtual 3D model.

1.4.1 Linear measurements:

Linear deviation between 1week and 6 months post-operative 3D virtual models using B and Pogonion reference points was measured in relation to two planes (Frankfort horizontal plane (FHP) and coronal plane) using Mimics 21.0 computer software. The data obtained from the reference points (Table 1) revealed a vertical change relative to the FHP and an anteroposterior change relative to the coronal plane. (Figures 4 and 5)

1.4.2 Angular measurements:

The angular deviation between 1week and 6 months post-operative 3D virtual models assessed the angles of (Sella, Nasion, and B point [SNB] and A point, Nasion, and B point [ANB]. In addition, the analysis utilized the angle between two planes, the Articular-Gonion plane and the Sella-Nasion plane (ArGo-SN). (Figure 6)

Statistical methods

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed normal (parametric) distribution except for the ANB angle and the amounts of change in all measurement data, which showed non-normal (non-parametric) distribution. Data were presented as mean, standard deviation (SD), median, and range values. A repeated measures ANOVA test was used to study the changes over time within each

Table 1. Reference points definition (14).

Point	Definition
S(Sella)	The center of sella tursica.
N(Nasion)	The foremost boundary of the frontonasal suture located in the midline of the face.
A-point	The lowest bony point along the premaxilla's outline beneath the ANS.
B-point	The lowest bony point along the mandible's outline above the Pogonion.
Pg (Pogonion)	The most anterior point on the chin.
Ar (articular)	A location where the posterior edge of the mandibular ramus meets the basilar segment of the occipital bone.
Go(gonion)	The most posterior inferior location of the mandible's angle. Alternatively, it can be defined as the point on the curvature of the mandible's angle, determined by bisecting the angle created by the tangential lines to the posterior ramus and the inferior margin of the mandible.
Or(orbital)	The lowest point along the infraorbital margin.
Po(porion)	The highest point at the top of the external auditory meatus.

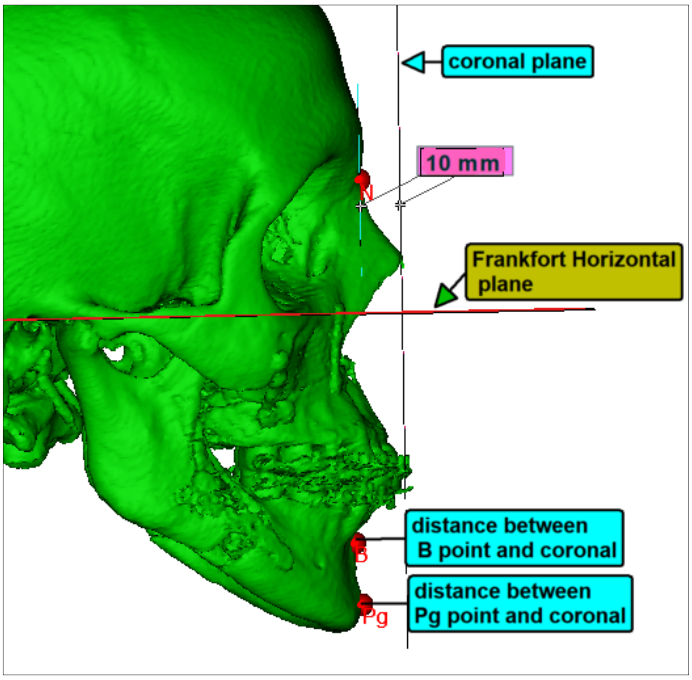

Figure 4. 3D model lateral view showing horizontal linear measurements in relation to coronal plane.

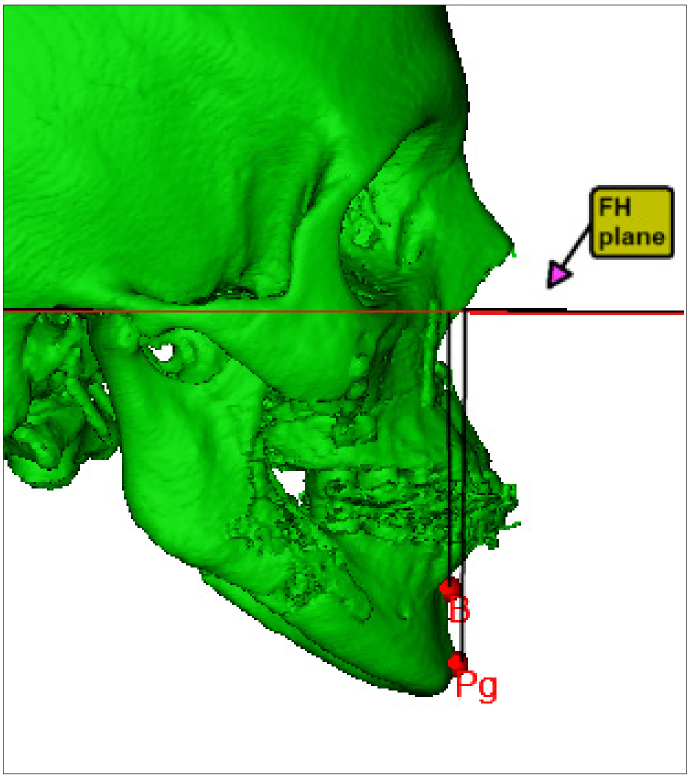

Figure 5. 3D model lateral view showing vertical linear measurements in relation to Frankfort Horizontal plane.

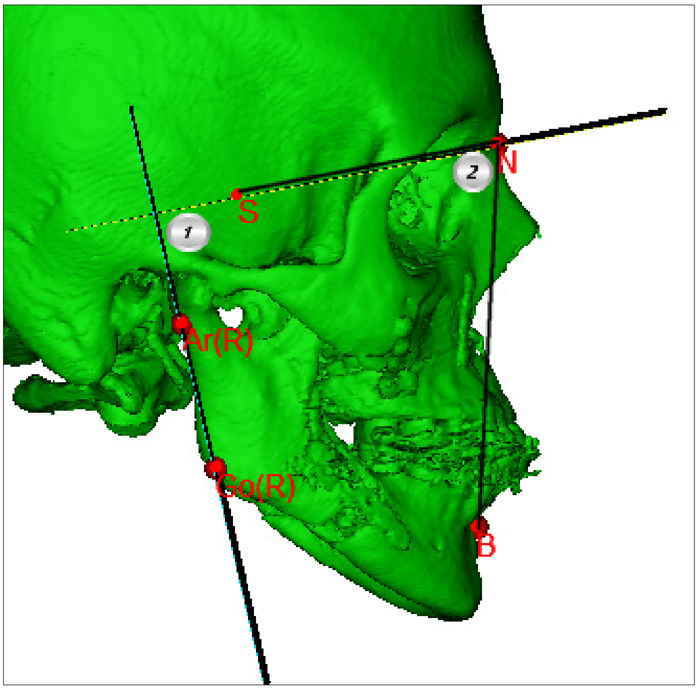

Figure 6. 3D model lateral view showing 2 angular measurement 1- Ar-Go/SN 2- SNB

group for parametric data. Bonferroni's post-hoc test was used for pair-wise comparisons when the ANOVA test is significant. The Mann-Whitney U test was used to compare the two groups for non-parametric data. The Wilcoxon signed-rank test was used to study the changes in ANB within each group. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

Results

Base line characteristics

Twenty four patients (8 male and 16 female) represented the sample in our study. Patients distributed as twelve patients in intervention group and twelve patients in control group.

The Base line characteristics of study participants are presented in Table 2.

Table 2. Frequencies (n), percentages (%), mean and standard deviation (SD) values for base line characteristics in the two groups

Base line characteristics	Botox (n = 12)	Control (n = 12)
Gender [n, (%)]		
Male	5 (41.7%)	3 (25%)
Female	7 (58.3%)	9 (75%)
Age [Mean, (SD)]	22.9 (2.7)	1.3 (2.6)
Amount of advancement [Mean, (SD)]	14.05 (1.6)	14.45 (3.6)

Linear measurements (mm)

The distances between reference points (B-Pg) and the two planes (Frankfurt Horizontal (FH) and coronal (cro)) at time points of immediate post-operative and six-month post-operative were measured.

Results were reported as differences in the distances between immediate and six-month post-operative reference points for each group and between the two groups.

If the differences in the distances between immediate and six-month post-operative reference points are negative, this means relapse (Postoperative movement in the opposite direction to the surgical advancement of the mandible), while positive means Postoperative movement in the same direction as the surgical repositioning.

2.2.1 Frankfurt plane (FH)

- B-FH (mm)

In the Botox group, there was no statistically significant change in B-FH measurement after six months, while in the Control group, there was a statistically significant increase (relapse) in B-FH measurement after six months, where the mean distance at immediate post-operative is (63.35) and at 6 months is (64.23). However, in comparison between the two groups, there was no statistically significant difference in the amounts of change in B-FH measurements as shown in Table 3, 4 and Figure 7

- Pg-FH (mm)

In the Botox group, there was no statistically significant change in Pg-FH measurement after six months, while in the Control group, there was a statistically significant increase (relapse) in Pg-FH measurement after six months, where the mean distance at immediate post-operative is (84.16) and at 6 months is (84.86). However, in comparison between the two groups, there was no statistically significant difference in amounts of change in Pg -FH measurements as shown in Table 3, 4 and Figure 7

- Overall change in the Frankfurt horizontal plane

There was no statistically significant difference between overall changes in relation to the Frankfurt horizontal

Table 3. Descriptive statistics and results of repeated measures ANOVA test for comparison between immediate post-operative and six months' linear measurements (mm) in Frankfurt plane

Measure-ments (mm)	Group	Immediate post-operative		6 months		*P*-value	*Effect size (Partial Eta Squared)*
		Mean	SD	Mean	SD		
B-FH	Botox	66.25	3.26	66.44	3.55	0.597	0.013
	Control	63.35	4.05	64.23	3.21	0.018*	0.229
Pg-FH	Botox	84.26	4.65	84.42	4.81	0.585	0.014
	Control	84.16	4.5	84.86	4.31	0.022*	0.216

*: Significant at P ≤ 0.05

Table 4. Descriptive statistics and results of Mann-Whitney U test for comparison between amounts of change in linear measurements (mm) in Frankfurt plane in the two groups

Measurements (mm)	Botox (n = 12)		Control (n = 12)		*P*-value	*Effect size (d)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
B-FH	-0.19 (-1.09, 0.44)	-0.18 (0.45)	-0.2 (-3.79, 1.23)	-0.88 (1.62)	0.729	0.142
Pg-FH	0.1 (-1.1, 0.41)	-0.16 (0.5)	-0.24 (-2.73, 0.79)	-0.71 (1.32)	0.817	0.094
Overall	-0.11 (-1.1, 0.35)	-0.17 (0.41)	-0.37 (-3.26, 0.76)	-0.79 (1.45)	0.908	0.047

*: Significant at P ≤ 0.05

plane in the two groups, as shown in Table 4 and Figure 7 Figures 8 and 9 represent sagittal radiographic views of examples from the control and Botox groups after repositioning of pre-operative, immediate, and 6-month post-operative CBCT, showing the amount of vertical changes in relation to the FH plane.

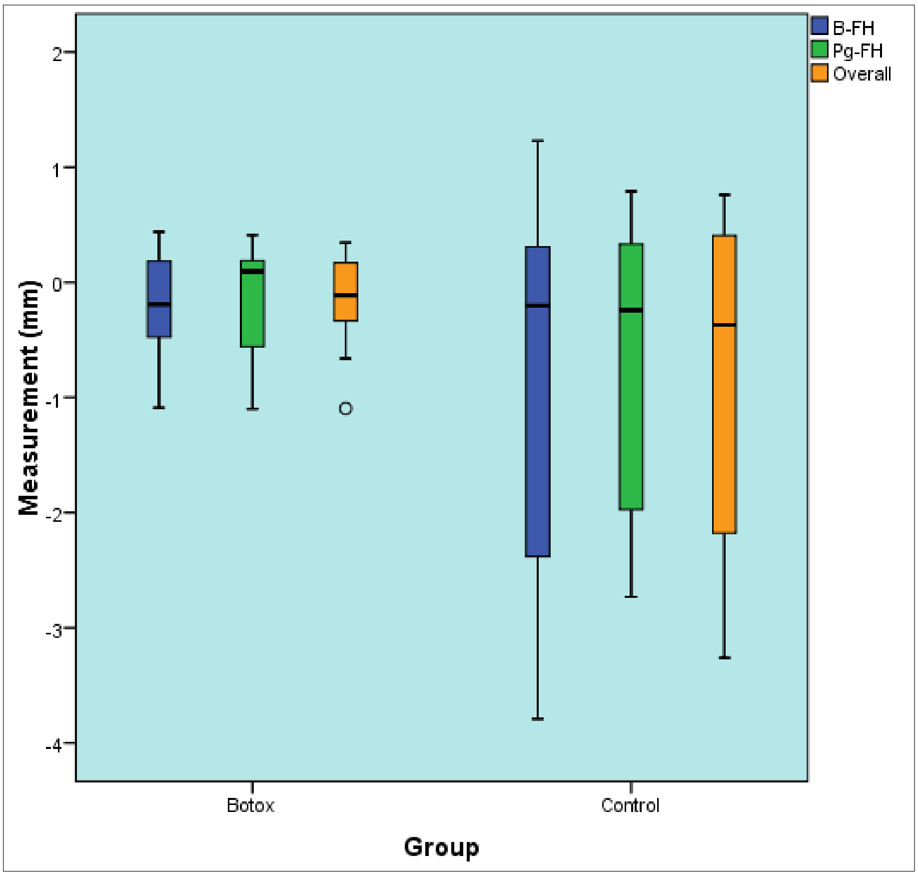

Figure 7. Box plot representing median and range values for changes in linear measurements in Frankfurt plane in the two groups (Circle represents outlier)

Figure 8. radiographic picture showing amount of change in vertical dimension for patient number 5 in control group. The violet color indicates pre-operative, Blue color represent immediate post-operative and red color represent 6 month post-operative.

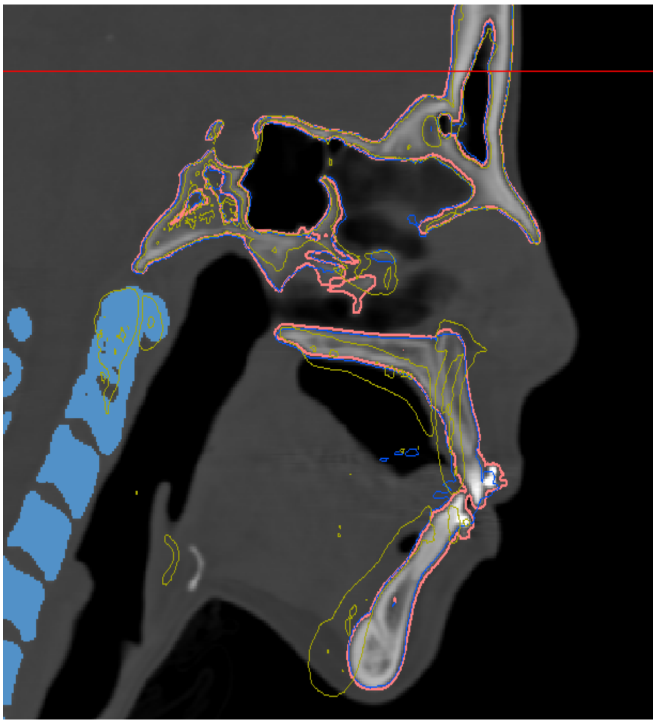

Figure 9. Radiographic picture showing amount of change in vertical dimension for patient number 1 in Botox group. The yellow color indicates pre-operative, Pink color represent immediate post-operative and blue represent 6 months post-operative.

2.2.2 Coronal plane (cro)

In our study, the coronal plan was represented as a plane parallel and 10mm anterior to the Nasion perpendicular plane (a plane passing through the Nasion point and perpendicular to the Frankfort horizontal and sagittal plane) to ensure that all immediate and 6-month post-operative (B-Pg) points are behind the coronal plane and in the same direction from the plane.

- B/cro (mm)

Both groups showed a statistically significant increase (relapse) in B/cro measurement after six months. However, in comparison between the two groups there was no statistically significant difference between amounts of change in B/cro measurements as shown in Table 5, 6 and Figure 10.

- Pg/cro (mm)

Table 5. Descriptive statistics and results of repeated measures ANOVA test for comparison between immediate post-operative and six months' linear measurements (mm) in coronal plane

Measurements (mm)	Group	Immediate post-operative		6 months		*P*-value	*Effect size (Partial Eta Squared)*
		Mean	SD	Mean	SD		
B/cro	Botox	16.98	6.12	18.02	6.33	0.008*	0.282
	Control	8.83	3.27	10.48	4.07	<0.001*	0.496
Pg/cro	Botox	17.78	6	18.96	6.29	0.001*	0.385
	Control	7.42	2.48	9.83	3.27	<0.001*	0.723

*: Significant at P ≤ 0.05

Table 6. Descriptive statistics and results of Mann-Whitney U test for comparison between amounts of change in linear measurements (mm) in coronal plane in the two groups

Measurements (mm)	Botox (n = 12)		Control (n = 12)		*P*-value	*Effect size (d)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
B/cro	-1.17 (-2.45, 1.03)	-1.13 (0.89)	-1.18 (-5.38, 0.13)	-1.65 (1.61)	0.908	0.047
Pg/cro	-1.26 (-2.45, 1.03)	-1.18 (0.96)	-2.59 (-4.18, -0.15)	-2.41 (1.23)	0.009*	1.251
Overall	-1.26 (-2.45, 1.03)	-1.16 (0.9)	-2.06 (-4.78, -0.37)	-2.03 (1.26)	0.106	0.699

*: Significant at P ≤ 0.05

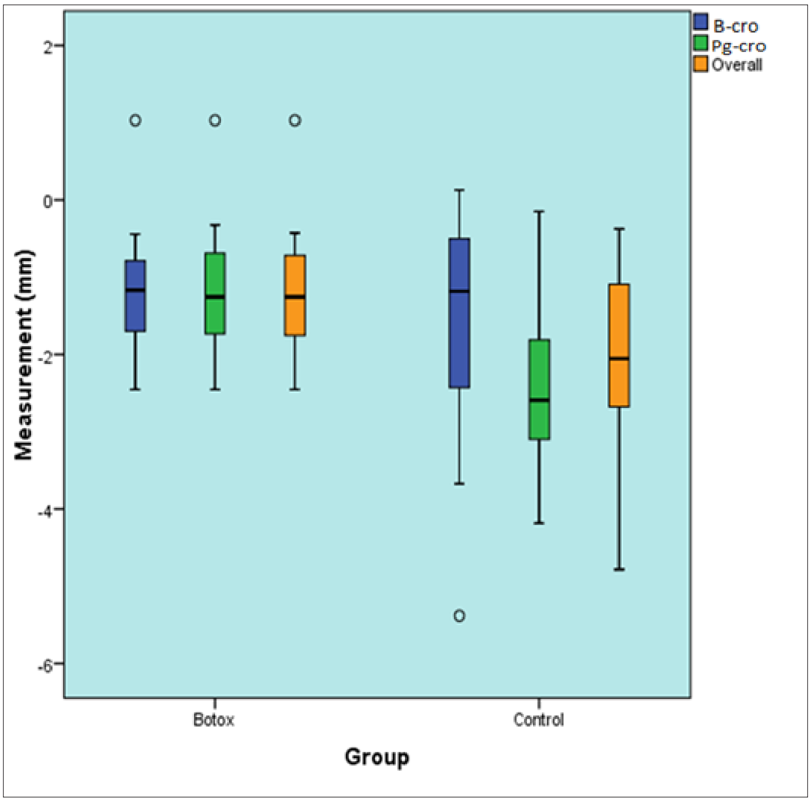

Figure 10. Box plot representing median and range values for changes in linear measurements in coronal plane in the two groups (Circles represent outliers)

In both groups, there was a statistically significant increase (relapse) in Pg/cro measurement after six months while In comparison between the two groups Botox group showed statistically significantly lower increase (lower relapse) in Pg/cro measurement than Control group where the median differences between immediate and 6 month post-operative pogonion point was (-1.26) in Botox group and (-2.59) in control group as shown in Table 5, 6 and Figure 10.

- Overall change in coronal plane

There was no statistically significant difference between overall changes in coronal plane in the two groups as shown in Table 6 and Figure 10.

Figure 11, 12 represent sagittal radiographic views examples from control and Botox groups after repositioning of pre-operative, immediate and 6 month post-operative CBCT showing amount of horizontal (antro-posterior) change in relation to coronal plane.

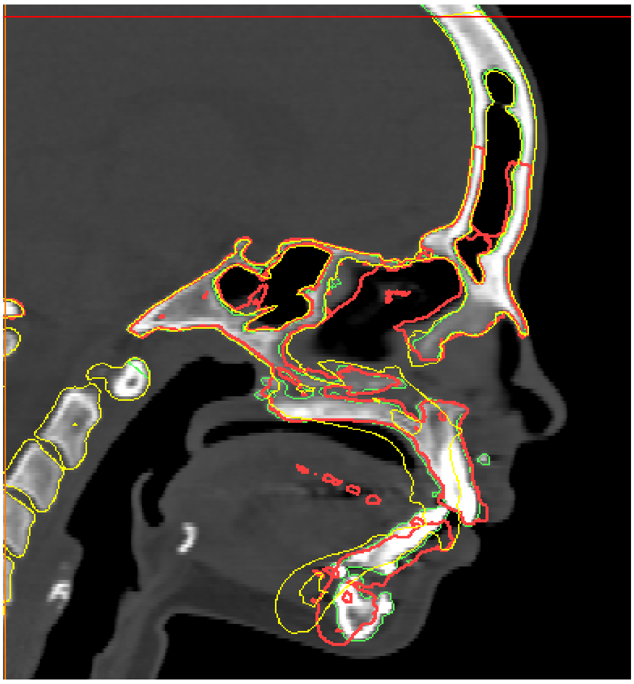

Figure 11. Radiographic picture showing amount of change in horizontal (antro-posterior) dimension for patient number 2 in control group. The yellow color indicates pre-operative, green represent immediate post-operative and red represent 6 months post-operative.

Figure 12. radiographic picture showing amount of change in horizontal (antro-posterior) dimension for patient number 5 in Botox group. The yellow color indicates pre-operative, green represent immediate post-operative and red represent 6 months post-operative.

Angular measurements (°)

Results were reported in the form of differences between immediate and six months post-operative angles of (SNB, Ar-Go/SN (Rt), Ar-Go/SN (Lt) and ANB) for each group and between the two groups.

- SNB (°)

Both groups had a statistically significant decrease (relapse) in SNB measurement after six months. However, in comparison between the two groups, there was no statistically significant difference in amounts of change in SNB measurements as shown in Tables 7, 8, and Figure 13.

- Ar-Go/SN (Rt) (°)

In both groups, there was no statistically significant change in Ar-Go/SN measurement after six months. Also, in comparison between the two groups, there was no statistically significant difference in the amount of change in Ar-Go/SN (Rt) as shown in Tables 7 and 8 and Figure 13.

- Ar-Go/SN (Lt) (°)

Table 7. Descriptive statistics and results of repeated measures ANOVA test and Wilcoxon signed rank test for comparison between immediate post-operative and six months' angular measurements (°)

Measure-ments (°)	Group	Immediate post-operative		6 months		*P*-value	*Effect size (Partial Eta Squared)*
		Mean	SD	Mean	SD		
SNB	Botox	76.39	3.39	75.72	3.43	0.003*	0.336
	Control	79.08	4.36	78.14	4.61	<0.001*	0.506
Ar-Go/SN (Rt)	Botox	86.8	3.86	85.59	4.33	0.066	0.145
	Control	94.48	3.98	93.38	5.53	0.108	0.113
Ar-Go/SN (Lt)	Botox	85.12	1.18	82.67	1.56	0.002*	0.367
	Control	95.57	3.23	93.33	2.97	0.014*	0.243
		Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
ANB	Botox	3.05 (0.21, 7.43)	3.33 (2.06)	2.64 (0.64, 6.37)	2.79 (1.97)	0.008*	*d* = 0.222
	Control	4.65 (2.48, 8.62)	4.97 (1.81)	4.29 (0.87, 8.28)	4.59 (1.99)	0.530	*d* = 0.057

*: Significant at P ≤ 0.05

Table 8. Descriptive statistics and results of the Mann-Whitney U test for comparison between amounts of change in angular measurements (º) in the two groups

Measurements (º)	Botox (n = 12)		Control (n = 12)		*P*-value	*Effect size (d)*
	Median (Range)	Mean (SD)	Median (Range)	Mean (SD)		
SNB	0.69 (0.26, 1.23)	0.67 (0.33)	0.89 (-0.2, 3.14)	0.95 (0.92)	0.751	0.13
Ar-Go/SN (Rt)	0.93 (-2.68, 5.35)	1.2 (2.15)	1.43 (-2, 4.64)	1.1 (2.17)	1	0
Ar-Go/SN (Lt)	2.59 (-0.21, 5.47)	2.45 (1.72)	2.45 (-1.23, 7.9)	2.24 (2.88)	0.419	0.335
ANB	0.55 (-0.43, 1.74)	0.54 (0.55)	0.22 (-1.34, 3)	0.38 (1.36)	0.225	0.511

*: Significant at P ≤ 0.05

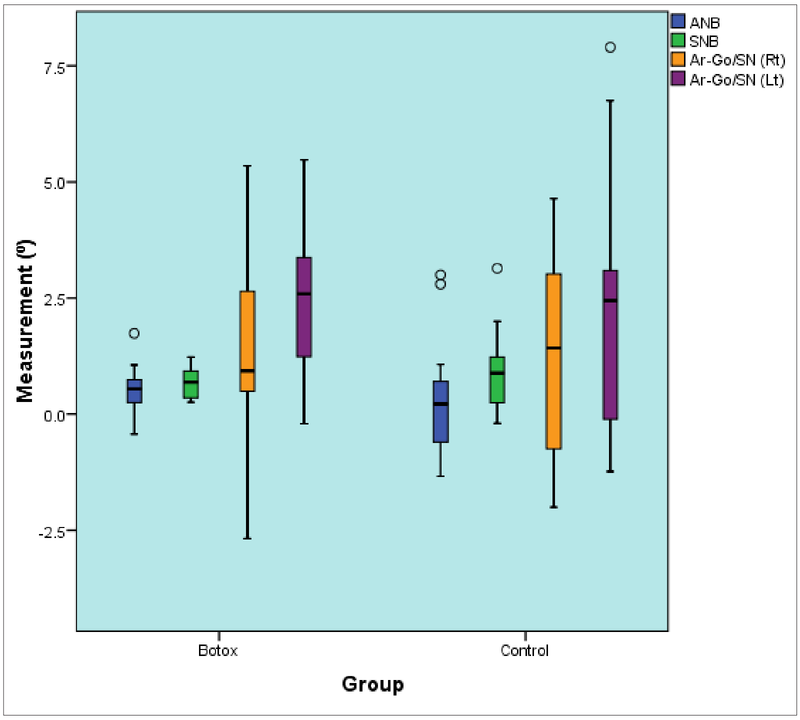

Figure 13. Box plot representing median and range values for changes in angular measurements in the two groups (Circles represent outliers)

Both groups showed a statistically significant decrease in Ar-Go/SN measurement after six months. However, there was no statistically significant difference in the amounts of change in Ar-Go/SN (Lt) between the two groups, as shown in Tables 7 and 8 and Figure 13.

- ANB (º)

In the Botox group, there was a statistically significant decrease in ANB measurement after six months, while in the Control group, there was no statistically significant change in ANB measurement after six months. Also, there was no statistically significant difference between amounts of change in ANB in the two groups, as shown in Table 7, 8 and Figure 13

Discussions

Relapse is one of important post-operative complication in mandibular advancement orthognathic surgery. [12] Our study employed a method to improve stability by reducing muscular activity through the application of Botulinum toxin type A.

There are absences of controlled studies on the use of Botulinum toxin A injections in the anterior belly of the digastric muscle to enhance stability during mandibular advancement orthognathic surgery, where a few previous reports has been mentioned, including case report and case series [10], [13]. So to our knowledge this study is the first randomized controlled trial to compare between post-operative stability in mandibular advancement orthognathic surgery with and without the Botulinum toxin type A injection in anterior belly of digastric muscles.

The justification for the study protocol implemented in the intervention group was based on the temporary paralyzing effect of Botulinum toxin on anterior belly of digastric muscle which decreasing the muscle activity that oppose the direction of mandibular advancement might be the reason for decreasing relapse of the mandible over time.

This method is comparable to research that assesses the advantages of suprahyoid myotomies [14], [15], and other studies that tried to decrease the relapse using Botulinum toxin injections in mylohyoid muscle [8] or anterior belly of digastric muscle[10], [13].

In our study, all patients underwent sagittal split osteotomy with mandibular advancement in Bimaxillary orthognathic surgery. The patient divided into two groups; Intervention group which received injections of Botulinum toxin type A into the anterior belly of the digastric muscles before surgical intervention and Control group which received surgical intervention without injection.

The reason behind injecting the intervention group with Botox preoperatively is due to the clinical effect of Botox is observed within a timeframe of approximately 3 to 7 days, with initial effects typically manifesting after 1 to 3 days post-administration and this was noted by Majid 2010 [16] and followed the same protocol that demonstrated by Mücke et al. [8]

A total of 25 units of Botox were administered, divided and injected into two bilateral points in the anterior belly of the digastric muscle located in the sub mental area. This dosage aligns closely with the 20 units previously reported in case studies and series involving the anterior belly of the digastric muscle [13], [10], as well as in a post-traumatic open bite case study 17and controlled study of mylohyoid muscle injection aimed at preventing relapse in deep bite cases [8]

However, in this study, the Botox was injected bilaterally at only two points (one for each muscle), differing from earlier studies [17], [13], [10] which utilized two injection points for each muscle.

In the present study the patients followed to 6 months post-operative because most of orthognathic relapse occurred during the first 6 month after surgery.[18]

This study employed point-based matching iterative closest point (ICP) registration utilizing anatomical landmarks of the cranial base structure, which does not altered by the surgical procedure to develop superimposition of 6 month post-operative virtual 3D model on the immediate post-operative virtual 3D model on Mimics software, as validated by Kim et al. 2010 and Sun et al. 2013. [19], [20]

Additionally, a manual surface-based registration technique was applied to achieve optimal alignment, ensuring the accuracy of the registration.

In our research, linear measurements were conducted utilizing the B and Pogonion reference points, as outlined by van der Linden et al. (2015) [21.] These reference points are particularly valuable because they illustrate the relapse of mandibular advancement.

These measurements were analyzed in relation to two anatomical planes: the Frankfort Horizontal and the coronal plane, to assess both vertical and horizontal changes.

The angular measurements were conducted, including the angles of [SNB] and [ANB] as described by [22]. In addition, the analysis utilized the angle between (ArGo-SN).

Comparing the results of the two groups in the present study, there was a statistically significant difference between the Botox and control group in the Pogonion point in relation to the coronal plane (anteroposterior dimension).

Although there was a significant increase (relapse) in both groups, the Botox group had significantly lower relapse than the control group, with an effect size of 1.25. This means that Botulinum toxin type A injection in the anterior belly of the digastric muscle is effective in reducing relapse in the anteroposterior dimension.

The result in the Botox group indicated a significant difference (relapse) from immediate post-operative to 6-month post-operative regarding B, Pogonion points in anteroposterior dimension (in relation to coronal plane) and SNB angle disagreement with mandibular advancement case series injected by Botox in the study of Ban et al.[10]

There were horizontal, vertical dimensions with a significant increase (relapse) at B and Pg point in relation to coronal and Frankfort Horizontal plane and a significant decrease (relapse) in SNB angle from immediate post-operative to 6-month post-operative in the control group, which agreed with Franco et al. 2013, Paunonen et al. 2018 and Inchingolo et al. 2023.[2], [3], [12]

In the Botox group, there was no statistically significant change in vertical dimension from immediate post-operative to 6-month post-operative follow-up period, which indicated good vertical stability resembling the result from the orthognathic case report of Kang et al. [13] and the post-trumatic open bite case of Seok et al. [17].

However, there were no statistically significant differences between the Botox and control groups regarding the B-point in relation to the coronal plane and the B and Pogonion points in the vertical dimension (in relation to the Frankfort plane).

There were no statistically significant differences between the Botox and control group regarding all angular measurements of SNB, ANB, right Ar-Go/SN and left Ar-Go/SN. This angular measurements are less important measurements of relapse in mandibular advancement cases due to these angles may be affected by other causes rather than mandibular relapse like bone resorption that increase by time at mandibular angle affecting the gonial point position and anterior nasal spine resorption or reduction in maxillary impaction cases that may affect position of A-point, as well as post-operative orthodontic teeth movement that may affect B-point position.

About the left Ar-Go/SN angle, there was a significant decrease from immediate post-operative to 6-month post-operative in both groups, and this change may be attributed to an increase in mandibular angle resorption over time. While in the right Ar-Go/SN angle, there were no significant differences between the two groups.

About ANB angle there were no significant differences in control group from immediate post-operative to 6 month post-operative while in Botox group there was significant decrease in the angle after 6 month and this may be due to change in position of A point releated to resorption by time in both group with more stability of B-point in Botox group than control group made the ANB angle significantly decrease.

Additional research with a larger sample size and an extended follow-up period of one year or more is suggested to enhance the understanding of the impact of Botulinum toxin type A on the stability of mandibular advancement orthognathic surgery.

Author contributions

Aya Nassar designed the study, performed the experiments, collected, analyzed the data and wrote the article. Gamal moutamed guided and critically reviewed the article structures. Ahmed Yousef contributed to the experiment and revised the article. All authors read and approved the final manuscript as submitted.

Statements and declarations

The investigator of this trial declared that there is
no conflict of interest and this trial is self-funded by the principal investigator (Aya Nassar)

Competing interests

The authors have no relevant financial or non-financial interests to disclose
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