Skeletal stability following mandibular advancement with and without advancement genioplasty

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at this research report is my own work. It is being submitted in partial fulfilment of the requirements for the degree of Master in the Science of Dentistry, in the department of Oral and Maxillofacial Surgery, at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any other degree or examination at this or any other university.

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gements

My sincerest thanks and gratitude to my supervisor, Prof JP Reyneke, and my father Dr WJ van der Linden. Without your sound advice and encouragement, this research report would not have been completed.

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The correction of most skeletal class II mandibular deficient cases require the surgical advancement of the mandible for the treatment of the malocclusion. Often genioplasty is included to the procedure to improve the soft tissue profile.[2,30] Long term skeletal stability is an important goal for the surgeon and orthodontist following Bilateral Sagittal Split Osteotomy (BSSO) and is influenced by the muscles attached to the mandible. Following the surgical advancement of the mandible the suprahyoid muscle complex is certainly stretched and even more so when the procedure is combined with surgical advancement of the chin.[10,11]

This retrospective comparative study determined the long term skeletal stability of 29 patients, whom had undergone surgical advancement of the mandible by means of BSSO with advancement genioplasty, compared to 29 patients whom had undergone mandibular advancement surgery (BSSO) without advancement genioplasty.
All the subjects were evaluated using pre-operative (T_1), 1 week post-operative (T_2) and at least 6 months (T_3) follow-up cephalometric radiographs.

This research report concluded that the post-operative hard tissue relapse following BSSO advancement, with or without genioplasty, was clinically insignificant.

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Antero-posterior mandibular dento-skeletal discrepancies that cannot be treated by orthodontic techniques alone, should be corrected by surgical repositioning of the mandible. The technique of splitting the mandibular ramus in the sagittal plane was first described by Trauner and Obwegeser [1] in 1957 **(Fig. 1)**. The technique was modified by Dal Pont[2] in 1961 and further refined by Hunsuck[3] in1968 and later by Epker[4] in 1977 **(Fig. 2).**

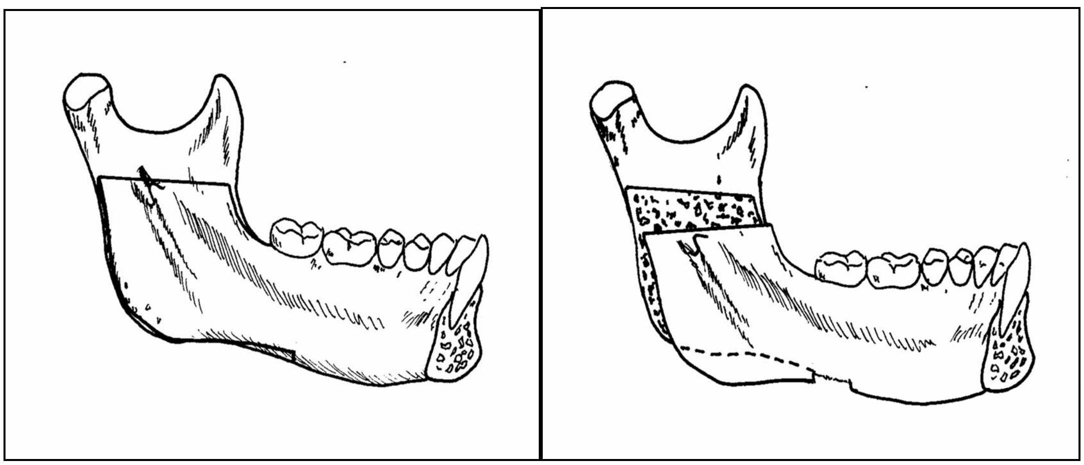


Figure 1. Conventional Sagittal Split Osteotomy according to Trauner and Obwegeser

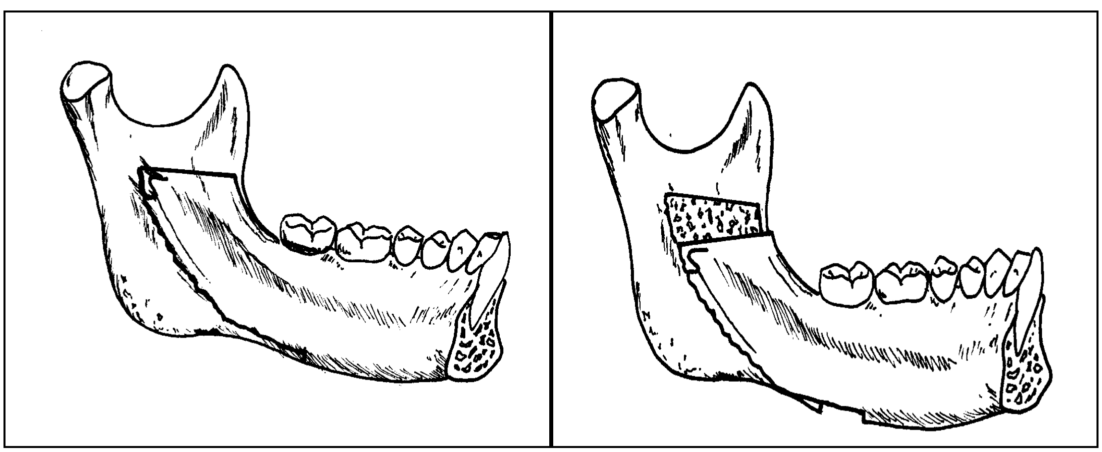


Figure 2. Modified Sagittal Split Osteotomy according to Epker

…s to predictably establish optimal occlusal function and improve facial harmony and balance by surgical repositioning the mandible. Post-operative skeletal stability is key to any surgical correction. Several factors may influence the longterm stability of the mandible following surgical advancement: [5,6,7,8,9]

Correct seating of the condyles: Peripheral condylar sag is caused by remodeling of the condyle post surgically,[9] with an alteration of the relationship of the condyle within its fossa resulting in a malocclusion.

The magnitude of advancement: It has been reported that advancements of 7mm and more are more prone to horizontal relapse.[6,9]

The soft tissue and muscle stretch: Surgical advancement of the mandible causes stretching of the soft tissue drape, periosteal tissue and the suprahyoid muscles. When the procedure is combined with surgical advancement of the chin, these components are stretched even further. [8,9,10,11]

The mandibular plane angle: In a study of mandibular advancement alone, Joss and Vassalli[6] found that patients with a low mandibular plane angle will have an increased tendency to vertical relapse. Patients with a high mandibular plane angle will have an increased tendency to horizontal relapse.[9]

Use of wire versus rigid fixation: Several studies have shown that the post-operative skeletal stability following a Bilateral Sagittal Split Osteotomy (BSSO) is improved if rigid internal fixation (RIF), rather than wire fixation is utilized. [9,12,13,14-28] I am aware of only one study of skeletal stability following BSSO with RIF combined with advancement genioplasty.[29]

Distal segment rotation: Counterclockwise rotation of the distal segment of the mandible in BSSO has been reported to result in greater relapse than if clockwise more recent reports indicate that if the "short split" modification as described by Epker[4] is combined with the stripping the medial pterygoid muscle and stylomandibular ligament, which allows for the rotation of the distal fragment within the soft tissue envelope, relapse is minimal if rigid fixation is used.[30]

Neuromuscular adaptation: Mandibular function involves entrenched neuromuscular pathways. Altering mandibular position requires new pathway patterns to be developed. Habitual patterns may resist these positional changes resulting in surgical relapse.[5]

Remaining growth: If BSSO is performed in growing individuals, it may result in incongruous growth of the mandible and maxilla causing the development of a new malocclusion.[9]

The skill of the surgeon: Inexperienced surgeons suffer greater relapses in their operated cases.[9]

Long term skeletal stability is an important goal following orthognathic surgery. Relapse after surgery can be determined radiologically by comparing the immediate post-surgical skeletal positions to the positions a minimum of 6 months post-surgery. Recent investigations have shown that the greatest amount of relapse occurs in the first 6 months following surgery.[8,31]

Advancement genioplasty is a valuable and reliable technique for the aesthetic enhancement of the lower facial skeleton by improving the soft tissue profile. Lip competence may also be improved in certain cases. Reyneke[32] suggested that when considering a genioplasty procedure, two important aspects should be kept in mind:

r mandibular surgery and 2. Chin shape or contour is more important than chin position (antero-posterior position of Pogonion). If a retrusive mandible is corrected by performing a genioplasty rather than mandibular advancement surgery, a poor aesthetic result will follow. When the chin itself is retrusive with an obtuse labiomental fold, an obtuse lip-chin-throat angle, and chin-neck length is deficient, genioplasty in addition to a BSSO is the treatment of choice.[32]

The suprahyoid musculature has been implicated as a factor responsible for relapse after mandibular advancement surgery. A study by Ellis and Carlson[33] on Rhesus monkeys supported the hypothesis that stretching the suprahyoid musculature as a result of mandibular advancement surgery, was a major contributor to skeletal relapse. Previous studies indicated that the muscle and connective tissues comprising the suprahyoid muscles must adapt to the increased length brought about by mandibular advancement for skeletal stability to be achieved.[10] The value of suprahyoid myotomies and cervical collars has not been proved.[34]

One study has assessed the impact of genioplasty on skeletal stability following BSSO with RIF combined.[29] Reyneke has suggested that the influence of suprahyoid muscle stretch on long-term stability needs further research.[32]

The suprahyoid musculature consists of the following muscles: Digastric, Geniohyoid, Mylohyoid, Genioglossus, Hyoglossus, Stylohyoid. Of the muscle complex, the Geniohyoid, Mylohyoid and Digastric muscles are involved in a BSSO procedure.

(Fig. 3 and 4)

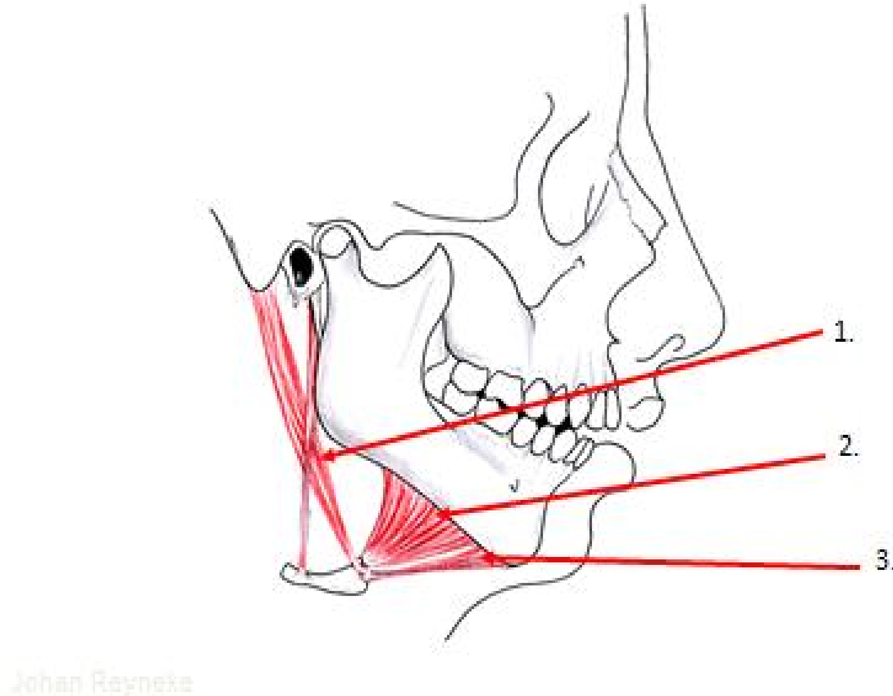


Figure 3. Suprahyoid muscles involved in a BSSO: 1. Digastric muscle 2. Mylohoid muscle 3. Geniohyoid muscle

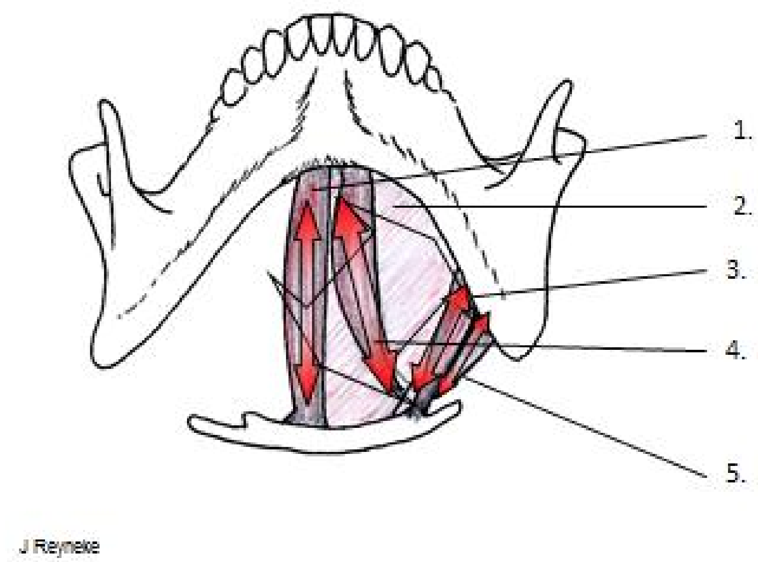


Figure 4. Suprahyoid muscles involved in BSSO from an inferior view:
1. Geniohyoid muscle 2. Mylohyoid muscle 3. Stylohyoid muscle 4. Anterior belly of Digastric muscle 5. Posterior belly of Digastric muscle

7. Rationale

The increase muscle lengthening as a result of the addition of an augmentation genioplasty following BSSO will cause increased post-operative skeletal relapse.

8. Aim

The purpose of this retrospective study is to assess the skeletal stability following mandibular advancement with and without advancement genioplasty.

ethods

The cephalometric records of 58 patients with antero-posterior mandibular deficiency who had undergone surgical correction a Class II malocclusion were analysed. Patients with known Temporo-Mandibular Joint problems were excluded from the study. 29 Patients received a BSSO and advancement genioplasty (Group 1) and 29 patients only had a BSSO performed (Group 2). Each group comprised of males and females at an age when growth had been completed. Growth completion was determined and confirmed by hand-wrist x-rays for subjects of less than 21 years of age.

All surgeries were performed by the same surgeon. Rigid internal fixation was accomplished utilizing three bicortical screws positioned in a triangular or straight-line fashion on each side. Post-operatively, light occlusal guiding elastics were positioned in the canine region (3.5 ounce, ¼ inch), and a soft diet was recommended for a period of 4 weeks. For patients in Group 1, a sliding genioplasty was utilized to advance the chin and two tricortical screws were employed to fixate the bone segments.

Skeletal changes achieved by surgery and the stability thereof, was evaluated by examining the study cohortôs lateral cephalometric radiographs. All radiographs were taken by the same practitioner on a Planmeca 2002 CC Proline XC analogue X-ray machine. All cephalometric radiographs were traced by hand and digitized by scanning the radiographs into the Viobox3 version 3.1.1 Software System (Dhal Software). The same individual traced and analyzed all the radiographs.

…the films at 3 different points in time: one week pre-operative (T_1), one week post-operative (T_2) and the longest follow-up of at least 6 months following surgery (T_3). Three cephalometric points were identified for each point in time (T_1, T_2, T_3): Mandibular B-point (B), Pogonion (Pog) and Menton (Me) as depicted in Figure 5.

Vertical and horizontal reference lines were created from which the three points were measured: vertical measurements were made to the True Horizontal Plane (THP) (measured at 7 degrees to a line through Sella-Nasion). Horizontal measurements were made to a constructed Vertical Plane (VP) (a perpendicular line to THP drawn through Sella). **(Fig. 5)**

B-point (supramentale) is defined as the most posterior midline point in the concavity of the mandible between the most superior point on the alveolar bone overlying the lower incisors (infra-dentale) and pogonion. This point is chosen as it will always remain superior to the genioplasty osteotomy line. It acts as an ideal reference point to differentiate between mandibular advancement and advancement of the chin.

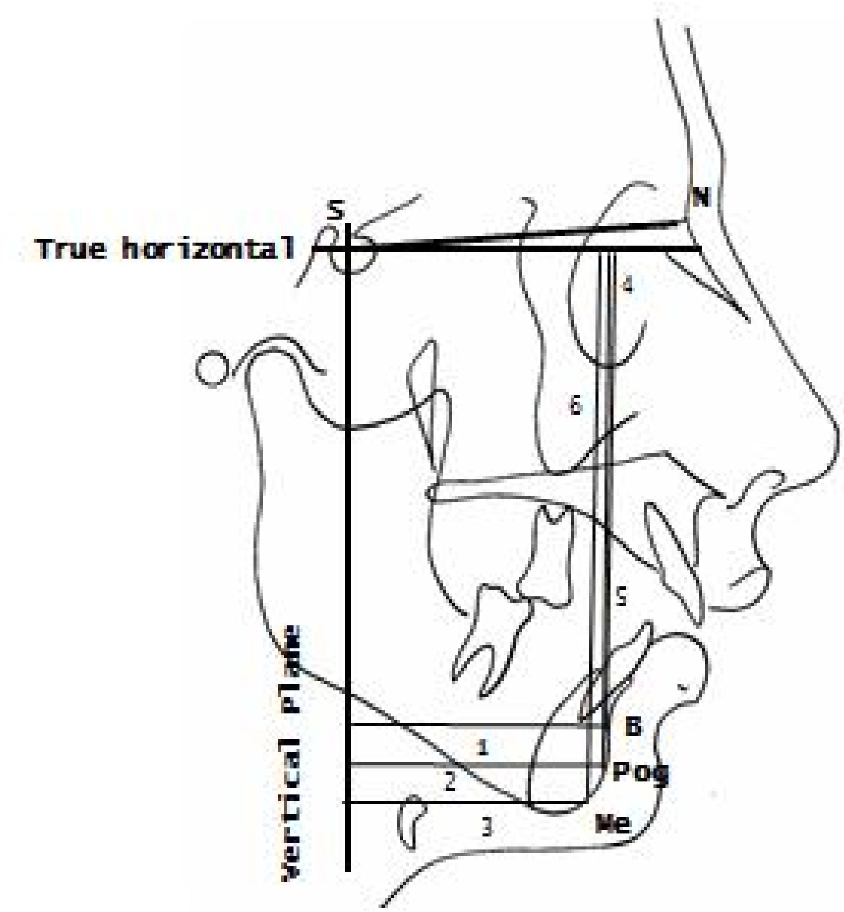


Figure 5. Cephalometric measurements
1. VP to B 2. VP to Pog 3. VP to Me 4. THP to B 5. THP to Pog 6. THP to Me

measurements at the three time points were assessed using the Intra-Class Correlation (ICC), i.e. the closer to 1, the higher the reliability. For intra-rater, the researcher remeasured 20 (10 Group1; 10 Group2) randomly selected cephalograms, while for inter-rater, a colleague measured the same randomly chosen cephalograms once.

10. Objectives

The study groups were compared with respect to the specified reference points for surgical and post-surgical changes at the allocated points in time:

i. Post-operative anterior-posterior changes, were measured from the VP to:

1. B-point
2. Pog
3. Me

ii. Post-operative vertical changes were assessed from the THP to:

4. B-point
5. Pog
6. Me

Surgical advancement was assessed by comparing T_2 and T_1. Surgical relapse was determined by comparing T_2 to T_3. Long term post-operative skeletal changes (T_3 - T_2) in the opposite direction of the surgical advancement of the mandible or chin, were denoted as negative relapse. Post-operative movement in the same direction as the surgical repositioning was deemed positive.

11.1 Intra- and inter-rater reliability

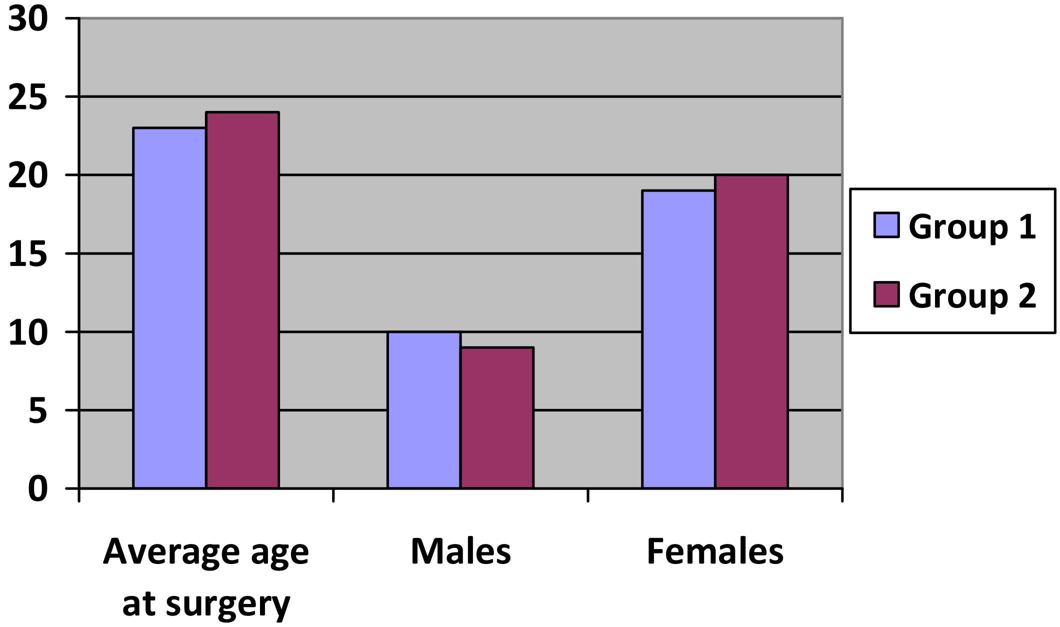
ICC for researcher initial and remeasured data measures intra-observer reliability (agreement), while ICC for researcherôs first reading and the colleagueôs reading measures inter-rater reliability (agreement). Excellent intra- and inter-rater reliability was observed as depicted in Table 1:

liability for B-point, Pogonion and Menton at

			ICC	
LANDMARK	TIME	DIRECTION	INTRA-RATER	INTER-RATER
B-point	T1	Vertical	0.99135	0.97366
		Horizontal	0.98822	0.97490
	T2	Vertical	0.98892	0.9843
		Horizontal	0.99546	0.99721
	T3	Vertical	0.97988	0.99255
		Horizontal	0.99609	0.99555
Pogonion	T1	Vertical	0.99002	0.97318
		Horizontal	0.99858	0.98183
	T2	Vertical	0.95166	0.99267
		Horizontal	0.99838	0.9961
	T3	Vertical	0.9884	0.99799
		Horizontal	0.99855	0.99764
Menton	T1	Vertical	0.99941	0.98390
		Horizontal	0.99416	0.97828
	T2	Vertical	0.99932	0.99869
		Horizontal	0.99728	0.98681
	T3	Vertical	0.99934	0.99934
		Horizontal	0.994410	0.99505

Surgical change and relapse

Group 1 consisted of 10 males and 19 females compared to Group 2 which consisted of 9 males and 20 females. Average age at time of surgery was 23.0yrs (14 - 46 years) in Group 1 and an average of 24.0yrs (15 ï 46 years) in Group 2. The mean follow-up time for Group 1 was 11.7 months (6 - 28 months) and 9.1 months (6 - 20 months) in Group 2. (Graph 1)



Graph 1. Patient demographics according to age and sex distribution

B-POINT

In Group 1 (BSSO with advancement genioplasty) the mean vertical surgical repositioning (T_2 - T_1) at B-point was 2.7mm (-2.6 ╥+8.6) inferiorly with an average relapse at T_3 of -0.8mm (-4.8 ï +2.7) (28%). Group 2 had a mean vertical change of 2.9mm (-0.2 ╥+8.3) inferiorly and a relapse at T_3 of -0.9mm (-3.5 ╥+2.2) (29%). (Table 2)

TABLE 2: Mean vertical distance over time, surgical repositioning and relapse in mm of B-point by study group

GROUP	T_1	T_2	T_3	MEAN SURGICAL POSITIONING	SURGICAL POSITIONING T_2-T_1	MEAN RELAPSE	RELAPSE mm (%) T_3-T_2
1	95.5	98.2	97.4	-2.6 ┐+8.6	2.7	-4.8 ╥ +2.7	-0.8 (28%)
2	93.4	96.3	95.3	-0.2 ┐+8.6	2.9	-3.5 ┐+2.2	-0.9 (32%)

POGONION

Pogôs average vertical change (T_2 - T_1) in Group 1 was 0.9mm (-3.4 ╥+5.9) inferiorly, and the average longterm relapse (T_3 - T_2) was +0.7mm (-2.5 ╥+5.9) (72%) further downwards. In Group 2 Pog was moved inferiorly (T_2 - T_1) by 2.9mm (-0.3 ╥+6.5) and relapsed at T_3 by ï 0.8mm (-4.1 ╥+2.3) (27%). (Table 3)

over time, surgical change and relapse in mm at

GROUP	T_1	T_2	T_3	MEAN SURGICAL POSITIONING	SURGICAL POSITIONING	MEAN RELAPSE	RELAPSE mm (%)
1	61.9	72.6	71.7	-3.4 ┐+5.9	10.6	-2.5 ┐+5.9	-0.9 (8%)
2	68.1	73.0	72.5	-0.3 ┐+6.5	5.0	-4.1 ┐+ 2.3	-0.6 (11%)

MENTON

In Group 1 Me moved 1.9mm (-1.8 ╥+5.6) inferiorly and relapse at $T_3$was -0.8mm (-3.9 ╥+1.5) (39%). In Group 2 Me was moved 3.1mm (+0.2 ╥+7.3) inferiorly and relapsed by ï 0.7mm (-3.9 ╥+1.9) (23%) at T_3. (Table 4)

TABLE 4: Mean vertical distance over time, surgical change and relapse in mm of Me by study group

GROUP	T_1	T_2	T_3	MEAN SURGICAL POSITIONING	SURGICAL POSITIONING	MEAN RELAPSE	RELAPSE mm (%)
1	117.4	119.3	118.6	-1.8 ┐+5.6	1.9	-3.9 ┐+1.5	-0.8 (39%)
2	115.7	118.8	118.1	0.2 ï 7.3	3.1	3.9 ┐+1.9	-0.7 (23%)

B-POINT

The average advancement (T_2 - T_1) at B-point in Group 1 was 4.8mm (0.9 ╥+12.8). Relapse (T_3 - T_2) for Group 1 was -0.6mm (-3.3 ╥+3.2) (11%). Group 2 B-point advanced (T_2 - T_1) 5.2mm (1.7 ╥+10.2). Relapse at T_3 was -0.8mm (-5.4 ╥+4.7) (15%). (Table 5)

TABLE 5: Mean horizontal distance over time, surgical advancement and relapse in mm of B-point by study group

GROUP	T_1	T_2	T_3	MEAN SURGICAL REPOSITIONING	SURGICAL REPOSITIONING T_2-T_1	MEAN RELAPSE	RELAPSE mm (%) T_3-T_2
1	61.7	66.7	66.2	0.9 ┐12.8	4.8	1.7 ╥10.2	-0.6 (11%)
2	65.4	70.6	69.8	-3.3 ┐+3.2	5.2	-5.4 ┐+4.7	-0.8 (15%)

POGONION

Group1 - Pogôs position advanced (T_2 - T_1) 10.6mm (-0.1 ╥+17.9), with relapse (T_3 ï T_2) of -0.9mm (-5.6 ╥+3) (8%) at T_3. Group 2 - mean surgical advancement (T_2 - T_1) was 5.0mm (0 ╥+11.2) and relapse (T_3 - T_2) of -0.6mm (-5.4 ╥+4.9) (11%). (Table 6)

nce over time, surgical advancement and relapse in

GROUP	T_1	T_2	T_3	MEAN SURGICAL REPOSITIONING T_2-T_1	SURGICAL REPOSIITONING	MEAN RELAPSE	RELAPSE mm (%) T_3-T_2
1	61.9	72.6	71.7	-0.1 ┐+17.9	10.6	-5.6 ┐+3	-0.9 (8%)
2	68.1	73.0	72.5	0 ┐11.2	5.0	-5.4 ┐+4.9	-0.6 (11%)

<u>MENTON</u>

In Group 1 Me was anteriorly repositioned by 10.8mm (-0.7 ╥+16.8). The mean longterm horizontal relapse (T_3 - T_2) was -0.7mm (-4.4 ╥+4.2) (6%). The mean distance Menton was advanced (T_2 ï T_1) in Group 2 was 4.9mm (-0.8 ╥+12.6) and an average of -0.5mm (-5.6 ╥+5.5) (10%) longterm relapse (T_3 - T_2) was measured. (Table 7)

TABLE 7: Mean horizontal distance over time, surgical advancement and relapse in mm of Me by study group

GROUP	T_1	T_2	T_3	MEAN SURGICAL REPOSITIONING	SURGICAL REPOSITIONING T_2-T_1	MEAN RELAPSE	RELAPSE mm (%) T_3-T_2
1	54.9	65.7	65.0	-0.7 ┐+16.8	10.8	-4.4 ┐+4.2	-0.7 (6%)
2	62.3	67.1	66.6	-0.8 ┐+12.6	4.9	-5.6 ┐+5.5	-0.5 (10%)

Statistical Analysis

From an analysis of covariance (ANCOVA), it followed that with respect to relapse ($T_3 - T_2$), adjusted for surgical change ($T_2 - T_1$), groups did not differ significantly with respect to any of the landmarks in either direction. These results were also confirmed with ANCOVA for ranks, a non-parametric approach. Testing was done at $p < 0.05$ which denotes significance.

TABLE 8: p-Values associated to group comparisons with respect to horizontal surgical change and relapse at B-point, Pog and Me.

LANDMARK		HORIZONTAL
B- point	ANCOVA	0.6664
	ANCOVA for ranks	0.3027
Pogonion	ANCOVA	0.1292
	ANCOVA for ranks	0.0906
Menton	ANCOVA	0.2593
	ANCOVA for ranks	0.3296

group comparisons with respect to vertical point, Pog and Me.

LANDMARK		VERTICAL
B- point	ANCOVA	0.6671
	ANCOVA for ranks	0.2154
Pogonion	ANCOVA	0.1544
	ANCOVA for ranks	0.1616
Menton	ANCOVA	0.1684
	ANCOVA for ranks	0.3016

12. Discussion

12.1 Result Analysis

Stability of the occlusion following orthognathic surgery is dependent on postoperative skeletal stability. The stability of operated segments is therefore key to successful treatment. The influence of an advancement sliding genioplasty on the stability of a BSSO advancement has not been extensively studied.[10,32] A study done by Dolce et al[29] in 2001 concluded that there is little influence, whereas animal studies by Ellis et al[33] indicated that the stretch of the suprahyoid muscles may cause increased relapse. They opined that suprahyoid myotomies may be indicated under certain conditions.[32,34]

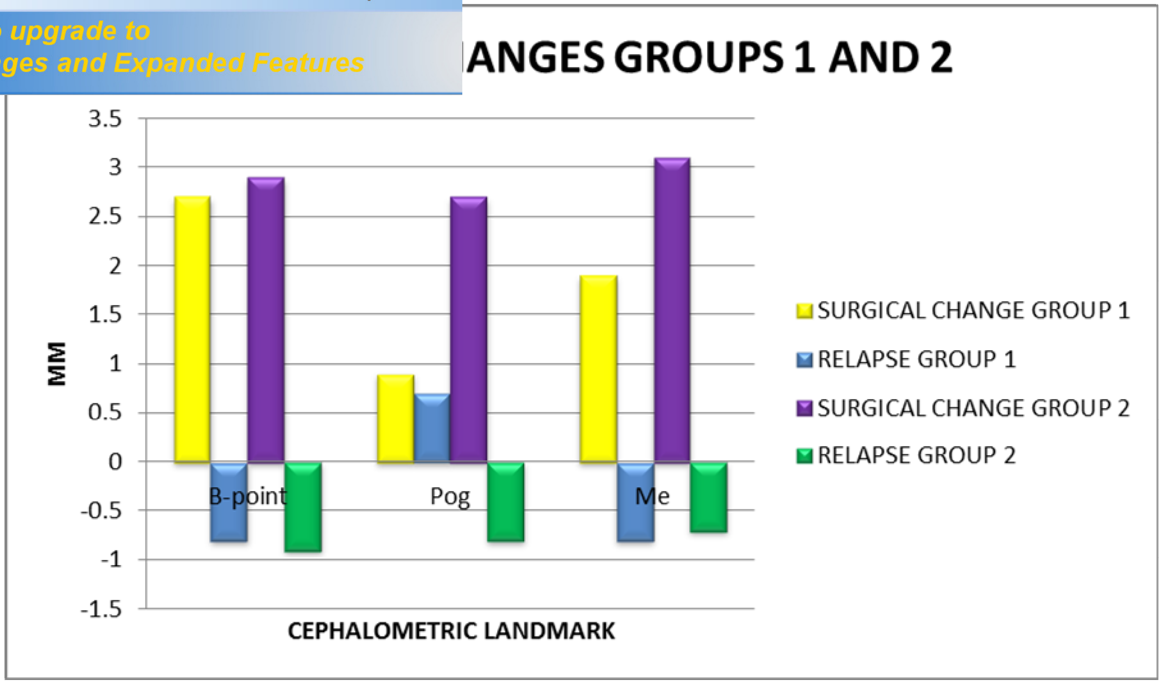
[illegible] a concomitant genioplasty with BSSO (Group 1) had a smaller advancement in a horizontal direction (4.8mm) at B-point compared to the 5.2mm advancement in Group 2. The added advancement genioplasty resulted in the large horizontal surgical advancement observed at Pog and Me (10.6mm; 10.9mm), compared to advancing the mandible alone, as seen in Group 2 (5.0mm; 4.9mm). Blomqvist and Isaksson[35] determined that there was a positive correlation between the amount of advancement and post-surgical stability. This study found that the mean horizontal relapse in Groups 1 and 2 were minimal at both Pog and Me, as relapse showed to be less than 11%. This observation is comparable to most studies in the current literature.[14, 37-41]

Very limited clinical research material is available on the effect of the suprahyoid muscle complex on the long term skeletal stability following a BSSO with or without a genioplasty.[10] It has been suggested that by advancing the mandible, the submandibular soft tissue drape is stretched together with the suprahyoid and infrahyoid muscles. As a consequence, the hyoid bone, fixed by these muscles, is pulled forward, but will return to its original position several months postoperatively. Stretching of these tissues gives rise to a constant force opposite to the vector of the mandibular advancement.[8]

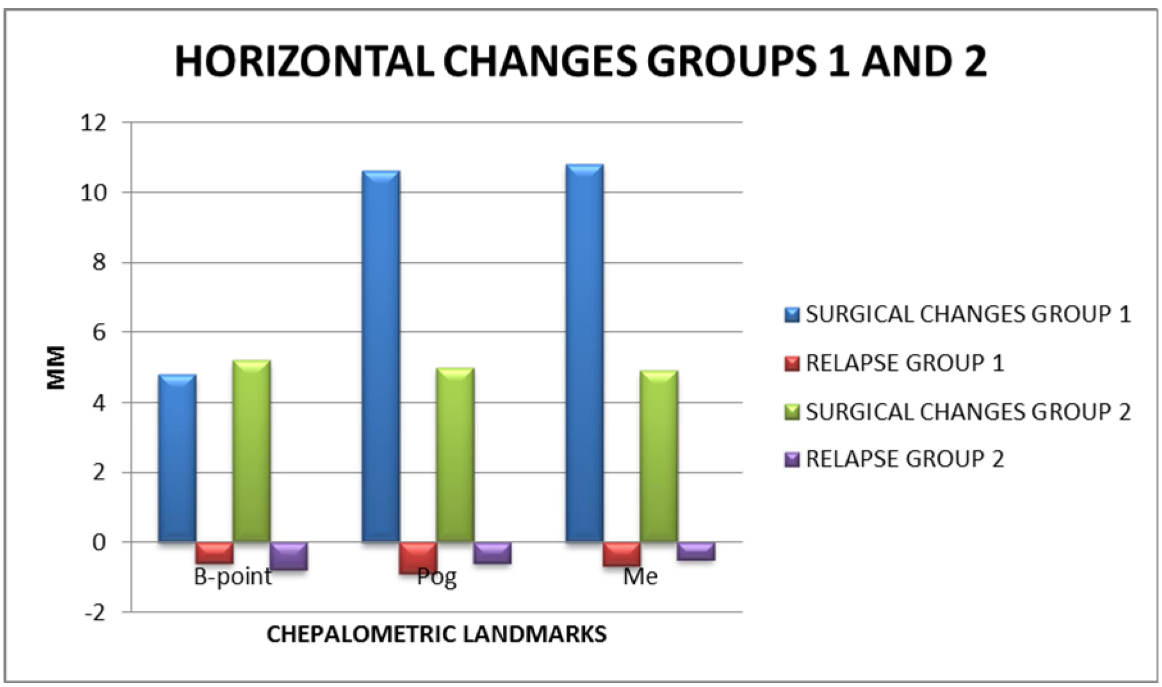
The apparent lack of influence of the suprahyoid musculature is surprising when considering the amount of advancement at Pog and Me in the Group 1 (10.6mm and 10.8mm respectively), as compared to Group 2 (5.0mm and 4.9mm respectively). This may be because the hyoid bone is not a fixed structure ï it has ligamentous attachments to the epiglottis (hyo-epiglottic ligament) and the styloid process (stylohyoid ligaments) and is attached to the thyroid cartilage of the larynx (thyrohyoid membrane).[42]

as its intermediate tendon held to the hyoid bone by a fibrous loop. The remaining suprahyoid musculature insert into the hyoid bone, which is clearly not fixed, and therefore can be repositioned in the soft tissue environment. This allows the muscles to adapt in a way similar to the remaining soft tissue envelope without undue influence on the more stable bony counterpart ï the mandible.[8]

It is interesting to note that the surgical repositioning and relapse at Pog and Me in Group 1 differs **(Graphs 2 and 3)**, although both cephalometric landmarks are referenced on the same bone segment. One would therefore expect the movement of Pog and Me to be equal and that the relapse also to be similar.
By examining the actual geography of the surgical repositioning of the genial segment during the genioplasty the difference can be explained**. (Fig.6)** The genial segment, in most cases, is advanced on a superiorly angled osteotomy plane and is often also rotated superiorly by the placement of rigid fixation **(Fig.6)** This will cause Pogonion and Menton to be repositioned differently in a horizontal as well as vertical plane and may even move in opposite directions. The relapse of these two points will therefore also be different. **(Fig.6 and Graphs 2 and 3)**



Graph 2. Vertical changes for Groups 1 and 2



Graph 3. Horizontal changes for Groups 1 and 2

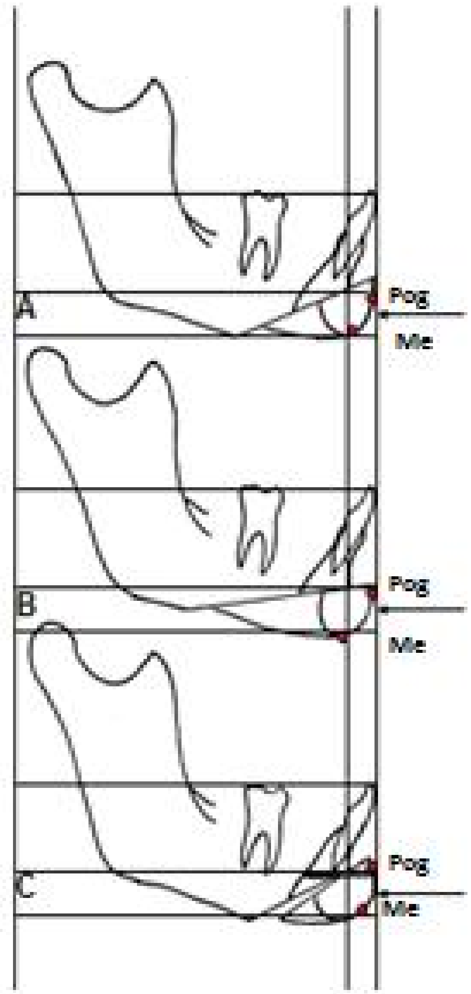


Figure 6. The differential repositioning of Pog and Me. The vertical and horizontal repositioning of Pog and Me is influenced by the genioplasty osteotomy design. With a superiorly angled osteotomy as in (A), the vertical repositioning and advancement at Me is more than with a more horizontal osteotomy, as in (B). This discrepancy in geographic movement is accentuated when the rigid fixation rotates the genial segment as in (C).

Of interest was the positive inferior relapse shown by the Group 1 at Pog (0.7mm), related to the negative superior relapse (0.8mm) in the Group 2. Group 2 consisted predominantly of Class II deep bite cases with a favorable chin contour, not requiring genioplasty.

otation (downward rotation) at Me and Pog. Orthodontic setting is most probably responsible for the upwards relapse. Following advancement sliding genioplasty, remodeling that occurs due to the stretching of the soft tissue drape over the osteotomy segment with function and time may cause a small downwards and backwards movement of Pog (ñbow-tie effectò). There may also be an element of inaccuracy caused by the study design, where a pencil tip point difference would equate to a 0.5mm discrepancy. The significance of this difference in relapse is not considered clinically important.

In this retrospective study the data indicates that the suprahyoid musculature and soft tissue drape does not have a pronounced influence on longterm stability of the mandible following advancement of 7mm and less by means of BSSO with concurrent use of rigid fixation. This lack of influence may be ascribed to lack of a fixed insertion point of the suprahyoid muscles onto the mobile hyoid bone. Further studies to determine changes of hyoid bone position brought about by BSSO, and whether these changes influence the surgical outcome, if any, may need to be considered.

The results of this study showed that the post-operative hard tissue relapse following BSSO advancement, with or without genioplasty, were clinically insignificant. It was furthermore shown that the difference in post-operative skeletal relapse between the two groups of patients were also clinically insignificant. The results confirm previous findings by Talebzadeh and Pogrel[43] and Dolce et al.[29]

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