EVALUATION OF SKELETAL RELAPSE AFTER MANDIBULAR SETBACK SURGERY WITH NM LOW Z PLASTY TECHNIQUE IN SKELETAL CLASS III PATIENTS

BY

SARUNPONG IMAMPAI

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE PROGRAM IN ORTHODONTICS
FACULTY OF DENTISTRY
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MR. SARUNPONG IMAMPAI

ENTITLED

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IN SKELETAL CLASS III PATIENTS

was approved as partial fulfillment of the requirements for
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Thesis Title	EVALUATION OF SKELETAL RELAPSE AFTER MANDIBULAR SETBACK SURGERY WITH NM LOW Z PLASTY TECHNIQUE IN SKELETAL CLASS III PATIENTS
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ABSTRACT

Bilateral sagittal split osteotomy (BSSO) was considered an effective mandibular setback surgery to improve prognathic profile in patients with skeletal Class III malocclusion characterized by mandibular prognathism, maxillary deficiency, or some combination of these two features. Novel Modification of Low Z Plasty (NM-Low Z) is a BSSO technique introduced in our center since 2016. **Purpose**: To evaluate skeletal changes after mandibular setback surgery with NM-Low Z. **Methods:** Three lateral cephalograms were obtained from 38 skeletal Class III malocclusion patients. Films were traced and digitized with Dolphin Imaging software at different stages: presurgical (T0), immediate postsurgical (T1), and six months to one-year postsurgical (T2). Mean skeletal changes were defined in distance between B-point to SN7 perpendicular line in immediate postsurgical change (T1-T0) and postsurgical stability (T2-T1). A reliability test was analyzed with six randomly selected films retraced at two week intervals. Paired t-tests were computed. **Results:** Mean mandibular setback at B point was 9.78 mm, and mean skeletal relapse at B point was 2.61 mm, representing an 26.69% skeletal relapse rate. Statistical analysis showed significant differences between postsurgical stabilities ($p>0.05$). Vertical measurement showed significantly decreased in B-SN7 immediately after surgery and in the postsurgical period.

Conclusions: Mandible was significant relapsed in forward and upward direction after mandibular setback surgery using NM-low Z plasty tecnique. Lower incisors was retroclined after surgery to compensate the autorotational counterclockwise of mandible. Patient selection, overcorrection and orthodontic mechanics to deal with relapse must all be considered. **Clinical significance:** With rotational relapse (forward-upward movement of the mandible) immediately after surgery, might benefit from decreased facial height in skeletal Class III malocclusion patients and hyperdivergent patterns. However, hypodivergent and normodivergent patients must be treated cautiously. Vertical control of overbite and anterior facial height were considered in the finishing-stage for normal overbite.

Keywords: Skeletal relapse, Mandibular setback, Orthognathic surgery, Orthodontics, Malocclusion, Skeletal Class III malocclusion patients

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Sarunpong Imampai

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LIST OF ABBREVIATIONS

Symbols/Abbreviations	Terms
BSSO	Bilateral sagittal split osteotomy
NM-low Z	Novel modification low Z
COS	Conventional orthognathic surgery
SFA	Surgery first approach
RAP	Regional acceleratory phenomenon
OGS	Orthognathic surgery
IAN	Inferior alveolar nerve
IVRO	Intraoral vertical ramus osteotomy
TMDs	Temporomandibular disorders
IMF	Intermaxillary fixation
PLLA	Poly-L-lactic acid
mm.	Millimeter
°	Degree

CHAPTER 1
INTRODUCTION

1.1 Background and rationale

Skeletal Class III is skeletal discrepancy featured by mandibular prognathism with or without maxillary retrognathism. Patients with this problem have concave facial profile and Class III malocclusion. In Southeast Asian populations showed the highest prevalence rate (15.08%)[1] in Class III malocclusion.

Possible treatments to correct skeletal Class III problems are growth modification in growing patients, dental camouflage by orthodontic treatment and orthognathic surgery combined with orthodontic treatment in adults. Some severe skeletal Class III cases cannot be accomplished by only one jaw correction. To achieve facial esthetics, two jaws surgery is indicated. Mandibular setback surgery can be achieved to move mandible backward, rotated and move down anteriorly to increase anterior facial height. The most popular surgical method to move mandible back is Bilateral sagittal split osteotomy (BSSO). This procedure was first introduced since 1957.[2] After that many modifications were proposed, for instance, modifications by Dalpont, Hunsuck and Epker.[2, 3] In 2016, Prasan et al. was introduced BSSO low Z plasty technique (Prasan's modification). This technique allows for a more extensive positioning of the mandible and also eliminates potential problems.[4] With this technique, skeletal stability and satisfactory result can be achieved.

Afterward, Chaiprakit et al. proposed the Novel Modification low-Z (NM-low Z) plasty technique[5], which suggested to remove bony interference on the internal surface of proximal segment. Thus, the surgeon could conduct mandible surgery in three dimensions much more easily. Nowadays, this technique is one of the surgical procedures used in Thammasat University Hospital.

Conventional orthognathic surgery (COS) comprises of 3 stages; pre-surgical orthodontic treatment (12-24 months), surgical procedure and post-surgical orthodontic treatment (5-11 months). With COS, patients take long total treatment time and receive psychosocial problems caused by worsening profile from the dental decompensation.(6) Surgery first approach (SFA) was proposed in 1991(7). This “surgery-first and orthodontics second” has purpose to reduce some disadvantages and facilitate inconveniences of pre-surgical orthodontics. SFA eliminates pre-surgical orthodontic treatment. Hence, decreased treatment time resulted from 2 main possibilities; without pre-surgical orthodontic treatment and with the regional acceleratory phenomenon (RAP) which lasts for 3-4 months after surgery(8) then induce accelerated orthodontic tooth movement.(9, 10)

Numerous studies have shown that orthognathic surgery by surgery first approach is an appropriate method(11-13) but no study about skeletal changes after mandibular setback surgery with NM-low Z plasty technique in skeletal Class III patients. Our study aims to evaluate skeletal changes after mandibular setback surgery with NM-low Z plasty technique in skeletal Class III patients.

1.2 State of problem/ gap of knowledge

To date, there has not been reported about skeletal changes after mandibular setback surgery using the NM-low Z plasty technique in skeletal Class III patients. Therefore, the objective of this study is to assess skeletal changes following mandibular setback surgery using the NM-low Z plasty method in patients with skeletal Class III..

1.3 Research objective

To evaluate skeletal stability in mandibular setback surgery using the NM-low Z plasty technique.

1.4 Research hypothesis

No significant difference in mean skeletal changes between immediate post-surgical changes (T1-T0) and post-surgical stability (T2-T1) using the NM-low Z plasty technique.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Bilateral sagittal split osteotomy

Skeletal Class III deformity is one of skeletal discrepancy caused by the hereditary etiology. This problem is characterized by mandibular prognathism and/or maxillary retrognathism. Skeletal Class III patients have concave facial profile and Class III malocclusion. Growing patients, who have the potency of growth, could treated by growth modification to modify the growth pattern; either to induce the maxillary growth or inhibit the mandibular growth. On the other hand, if patients met the completed growth, growth may rarely be modified. To correct skeletal problem in adults can divided into two ways. The first is dental camouflage to accept the skeletal discrepancy and conceal that problem by only dental movement with orthodontic treatment. But if patients need facial improvement, proper treatment to solve skeletal problem is orthognathic surgery (OGS) combined with orthodontic treatment.

Before mandibular setback osteotomy becomes popular in which procedure to treat skeletal Class III patients nowadays. The first mandibular osteotomy procedure was done by Hullihen [(14)] since 1849 to correct the protruded alveolar mandibular segment. Blair conducted the first osteotomy of the mandible's whole body in 1897 to treat a prognathism. Blair published the horizontal subcondylar osteotomy in 1907 to treat Class II dysgnathia using a technique that advances the mandibular body.[(15)] This method requires prolonged intermaxillary fixation due to insufficient bone contact between the osteotomized segments. Hagensil et al.[(16)]overcame this limitation by using an overlapping segmentation and osteosynthesis plates to promote healing. Schuchardt developed an oblique osteotomy method that allowed him to cut from just above the lingula and reach the buccal cortex 10 mm further caudally without disturbing the inferior alveolar nerve (IAN). This operation might be carried out intraorally and result in increased medullary bone contact. [(17)] Trauner and Obwegeser introduced previously mentioned technique in 1957 by extending the distance between two horizontal incisions from 10 to 25 millimeters, which caused the surgeon to touch the IAN.

Following osteotomy, the fracture was created by chiseling through the mandible's lateral cortex. Bilateral Sagittal Split Osteotomy was the name of this surgery (BSSO). The greater distance between the buccal and lingual horizontal incisions allowed for better bone segment overlap, which enhanced stability. Obwegeser's BSSO was designated as the world's first standardized and safe method. [(18)]

Thereafter, various modifications were performed by many surgeon in order to reduce the unwanted complications such as decreasing relapse and improving healing. Dalpant changed the horizontal incision on the buccal cortex of the jaw between the first and second molars to a vertical cut in 1961; this resulted in greater bone contacts and needed less muscle movement.[(19)] In 1968, Hunsuck reduced the length of the cut through the mandible's medial cortex to the mandibular foramen in order to minimize damage to surrounding soft tissues.[(20)] Epker's 1977 modification featured less masseter muscle stripping and minimal medial dissection. This method intended to minimize postoperative edema, bleeding, and neurovascular bundle manipulation. Less stripping of the masticatory muscles resulted in increased vascularization of the proximal region, lowering the risk of bone resorption.[(21)]

The new BSSO modification, called Low Z Plasty technique or Prasan's modification [(4)] , was released in 2016. This new procedure facilitated severe skeletal Class III correction by a large amount of the mandibular set back which could achieved by modified vertical or slightly oblique osteotomy on the lingual retromolar region. Hence, this method allows the center of rotation of the mandible to shifted to retromolar area as the surgeon can easily rotate the distal segment with minimal muscle interference as a result of decreasing the chance of skeletal relapse. By reposition the lingual vertical cut to the retromolar region, mandibular set back can go further without interfering the facial nerve that usually occurred in the classical Obwegeser's technique. This reduces a chance of the facial paralysis. The novel modification technique is one of the procedures for surgical correction of mandibular discrepancy, including the severe prognathism. This procedure allows advantages over previous modifications by means of easier and increasing success for correction of the severe deformity.

2.1.1 Technical note : Surgical procedure of the NM-low Z plasty technique (modified from Low Z plasty technique or Prasan's modification [4])

Following standard exposure of the mandibular ramus and body, a horizontal osteotomy is done 5-10 mm higher in the retromolar region using a fissure bur and a round bur. The posterior horizontal cut is modified using oblique osteotomy in the retromolar region. Sagittal and vertical osteotomies are performed in the same manner as the Low Z plasty procedure, which involves a continuous incision from the buccal side of the external oblique ridge to the distal aspect of the mandibular second molar. In some cases that surgery was planned to advance the mandible, the vertical cut may extend to the buccal side between the mandibular first and second molar region. Following completion of the osteotomy, a sagittal split of the mandible's body is done as normal. The occlusal splint is used to guide the mandible into its final position. Bony interference on the proximal segment is reduced and internal fixation is conducted by titanium plated and screws.

2.1.2 Advantages of NM-low Z plasty technique

Due to the horizontal osteotomy in the retromolar region, the amount of mandibular setback is greater than with traditional method, and the posterior border of the distal segment may extend into the gonial region following mandibular setback. Additionally, the surplus setback may interrupt the vital structures , like styloid process and facial nerve, and possibly shortening the pharyngeal airway space. With this new surgical technique would reduce the chance to skeletal relapse.

With NM-low Z plasty technique, the bony interference on internal surface of the proximal segment is trimmed. This procedure provides not only the lessen torque through the proximal segment when fixation is performed, but also the possible to proceed the counterclockwise/clockwise rotation of the mandible. Without the bony interference, surgeon can perform a differential setback in such a case of facial asymmetry which impossible to do so if the bony interference impeded the asymmetrical setback, cause torque of the proximal segment and finally produce the skeletal relapse. Moreover, surgeon can move the maxillomandibular complex freely. Thus this would enhance surgical process when performed with the Surgery First Approach (SFA) cases.

When perform a conventional mandibular setback, osteotomy is conducted just posterior and superior to the lingula. This procedure requires a muscular detachment of the temporalis tendon which is the main cause of the muscular injury. Unlike conventional approach, the NM-low Z plasty technique offer the little chance to do a muscular detachment. With this technique can reduce the surgical time and provides less intra-operative and postoperative swelling that would please satisfaction of both surgeon and patients.

The sagittal osteotomy of the NM-low Z plasty technique provides the possible intra-operative surgical removal of the third molar impacted teeth. Because the horizontal cut is located in the retromolar area, surgeon can easily remove the impacted teeth. This would save at least one appointment that patient came to visit the surgeon.

Lastly, patient's satisfaction would enhance not only the less swelling, but also the improved facial appearance by decreased larger mandibular angle width. This wide angle is esthetic problem that would occur in the traditional mandibular setback which is performed only setback in anteroposterior direction but has no further osteotomy reduction of the internal surface of the proximal segment.

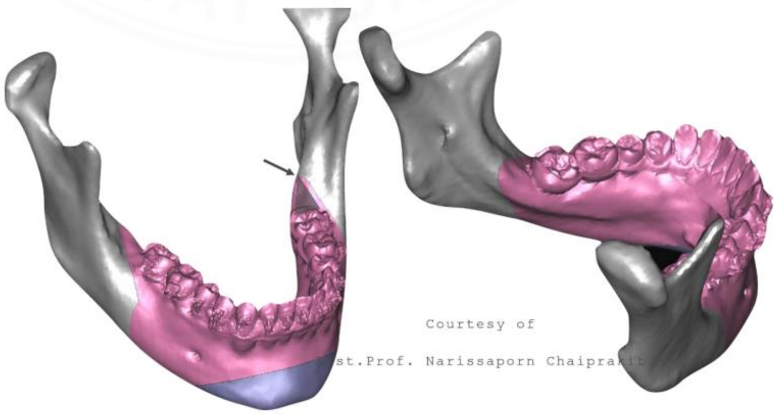

Figure 1 NM-low Z plasty's osteotomy design
(from Chaiprakit et al.[5])

2.2 Factors related to skeletal relapse

The skeletal instability, or skeletal relapse, is considered as an undesired result of the orthognathic treatment for both surgeons and patients. Many causes take responsibility to this relapse and thought this is multifactorial. By any step of the treatment can be the etiology of relapse, presurgical orthodontic treatment [(22)], surgical technique [(23)] by which means that surgeon use to perform the mandibular setback indicates amount of bony interference between proximal and distal mandibular segments, type of the fixation or amount of the mandibular setback [(24)]. Disruption of the pterygomasseteric sling and inability of the masticatory muscles to adjust to the segments' altered position appear to lead to relapse[(25)]. Additionally, continued growth of the mandibular condyles and changed condylar posture as a result of the proximal segment becoming distracted during fixation have also been reported. [(26)] In contrast, no significant connection was observed between tongue position alterations during mandibular setback and postoperative skeletal relapse.. [(27)]

One of the multifactorial contributed to the skeletal relapse is the surgical technique. Kim et al[(28)] proved that combined mandibular angle resection and BSSO had a significant effect on postoperative skeletal instability. By modifying the traditional BSSO, the strain on the pterygomasseteric sling can be reduced, resulting in better clinically esthetic outcomes in mandibular prognathism patients who have squared faces and prominent mandibular angle. Kim et al [(29)] also reported the procedure in order to reduce postoperative relapse after mandibular setback using BSSO. He compared a procedure that included intended osteotomy of the distal segment's posterior portion to a standard approach. This 'distal osteotomy' technique has been used since 1994. Without this distal osteotomy technique, as the mandible is set back, the distal segment protrudes into the gonial region. Lengthening the pterygoid muscle, consequently, causes relapse and reduces the posterior pharyngeal air space.

BSSO has several advantages when compared with other surgical procedure to surgically correct mandibular deformities, such as intraoral vertical ramus osteotomy (IVRO), includes a shorter healing period, an improved viewing field during the osteotomy operation, simplicity of fixation, and a broader range of indications for usage.[(30)] However, Due to bone interference, traditional BSSO may result in proximal segmental dislocation.[26] As a consequence, this bone interference enhance the risk of temporomandibular disorders (TMDs) and skeletal relapse.

According to a previous study[23], Modification of BSSO (Hunsuck-Epker method) and IVRO produced significantly less bone interference when compared with conventional BSSO. This interference causes displacement of the proximal segment which is one of factors of the skeletal relapse after surgery. [31] Thus several modified surgical techniques of conventional BSSO have been introduced and frequently used to overcome BSSO flaws.

Since the evolution of the rigid internal fixation [32], the stabilization of BSSO have been improved. Choi et al [33] reported that rigid fixation with bicortical screws without intermaxillary fixation (IMF). Even though no IMF has used, bicortical screws provides sufficient stability in mandibular setback surgery both short term (6 weeks duration) and long term (up to 24 months) [34]. Not only means of the fixation, fixation material also takes role that influence the skeletal relapse. Harada and his colleague [35] found that apart form the metal screws, other type of material can replace to be suitable fixation screws. He paid attention to the biodegradable materials Poly-L-lactic acid (PLLA) was focused on his research. Although statistical analysis showed greater relapse tendency (with no significance compared with titanium control group), PLLA screws can be used effectively after BSSO in selected case.

One of the major complications following surgical setback procedure is neurosensory disturbance of lower lip and chin. Sensory disturbance of the IAN and its terminal branch, the mental nerve, is the most commonly reported complication since the earliest publication of describing complications after BSSO procedure. [36]

2.3 Computerized cephalometric software

Cephalometric radiography is an essential tool in orthodontics for growth and development of dentofacial skeleton, diagnosis, treatment planning and evaluating the treatment results. Traditionally, manual tracing is considered “Gold standard” for cephalometric analysis. [37] Nevertheless, it is time consuming and associate with various errors, since incorrect tracing, measurement and calculation errors. These possibly because of human fatigue.

Nowadays, in this digital era, digital system comes to facilitate in many ways. One of them is digitized cephalometric software. Digitization eliminates various error and has benefit of time-saving so numerous analyses can be done in a very short time. [38] [39] [40] It has been published that digital plotting using Dolphin imaging software had high reliability for both hard tissue and soft tissue points equivalent to those traced by manual landmark plotting. [41] [42] [43] [44]

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Study design

A retrospective study to evaluate skeletal stability in mandibular setback surgery with NM low Z plasty technique. A set of three standardized lateral cephalograms (T0: before surgery, T1: immediate after surgery, T2: 6 months to 1 year follow-up after surgery) were obtained from patients. The mean skeletal changes were defined in the variables at different stages; immediate postsurgical changes (T1-T0) and postsurgical stability (T2-T1).

3.2 Sample preparation

Skeletal Class III discrepancy patients, whom were treated by NM low Z plasty technique at Thammasat University Hospital, were included in the study. Data was collected from the dental department (2nd floor, Ratchasuda Building, Thammasat University).

3.3 Inclusion criteria

- Skeletal Class III discrepancy patients with ANB angle lower than 0
- Completion of orthognathic surgery (OGS)
- Orthognathic surgeries performed by the same surgeon
- Patients with a complete series of identifiable lateral cephalograms
- Growth completion confirmed by Cervical vertebrae maturation (CVM) status which is CS6.

3.4 Exclusion criteria

- Patients with craniofacial anomalies, facial bones fracture
- Patients with incompleted diagnostic records

3.5 Sample size

This study included 38 symmetrical skeletal Class III patients whom were treated by NM-low Z plasty technique, 29 with two jaws surgery and 9 with one jaw surgery. 14 patients had genioplasty (Table1.), and had complete cephalograms. The sample size was calculated via G*power version 3.1.9.4. α=0.05, Power=0.95, δ_1= -0.41, σ_1= 3.24, δ_2= 2.39, σ_2= 1.2

From previous study, sample size was calculated from comparison of vertical surgical changes (T0 to T1) and vertical relapse (T1 to T2) at the B point. 16 patients are for each group. We studied in two different stages; immediate postsurgical changes (T1-T0) and postsurgical stability (T2-T1).

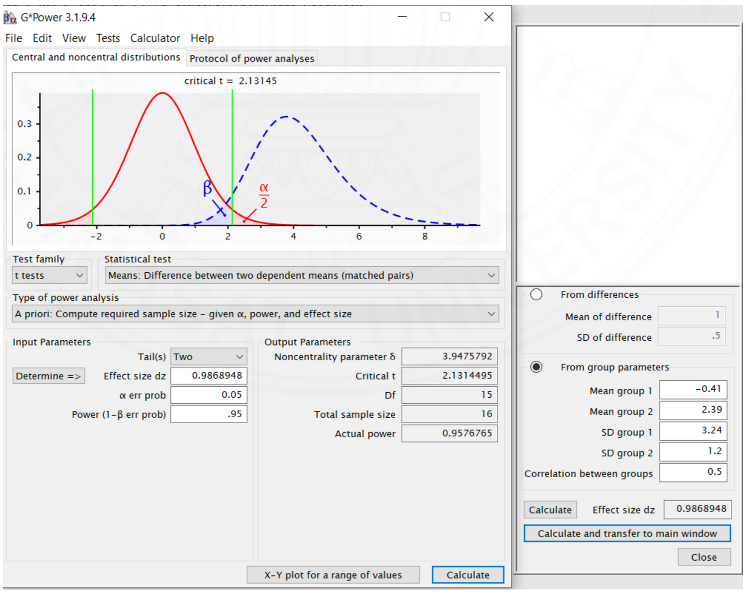

Figure 2 Sample size calculation

3.6 Statistical analysis

The distribution of horizontal and vertical skeletal changes at B point were examined. Statistic showed measurement was in a normal distribution according to the Shapiro-Wilk test and Q-Q normality plot (Figure3&4, Table 2).

Paired T-Tests were used to compare the mean skeletal changes in the variables at different stages in NM-low Z plasty technique. Two-sided p-values<0.05 was considered significant. This statistical analysis was conducted using IBM SPSS Software Version 22 (International Business Machines Corporation, Armonk, NY).

3.7 Reliability

Intraobserver reliability of investigator and interobserver reliability (between investigator and experienced researcher) were measured by all variables from 6 randomly selected subjects. The linear measurements were compared between 2 time sets using the Dahlberg formula ($D = \sqrt{\sum_{i=1}^{N} \frac{d_i^2}{2N}}$), where D is the difference between two measurements and N is the number of double determinations.[45]

3.8 Data collection

Evaluation was performed using the following three time points; T0 immediately before surgery (within 2 weeks), T1 a month after surgery (on the day that intermaxillary fixation and splints were removed) and T2 a year after surgery.

Demographic variables (n=38)	
Age (years), mean ± SD (range)	24.8 ± 4.3 (16-37)
Women,% (n)	65 (25)
With two jaws surgery, % (n)	76 (29)
With one jaw surgery, % (n)	24 (9)
With genioplasty, % (n)	36.8 (14)

Table 1 Demographic variables of the sample

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
BSN7perp T0	.100	36	.200*	.971	36	.460
BSN7perp T1	.084	36	.200*	.982	36	.817
BSN7perp T2	.107	36	.200*	.974	36	.558
BSN7T0	.082	36	.200*	.976	36	.622
BSN7T1	.090	36	.200*	.967	36	.343
BSN7T2	.090	36	.200*	.963	36	.275

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 2 Tests of Normality of horizontal and vertical measurements; B-SN7perp indicates horizontal measurement, B-SN7, vertical measurement, T0, before surgery, T1, immediate after surgery, T2, 6 months to 1 year follow-up after surgery. At 95% Confident Interval

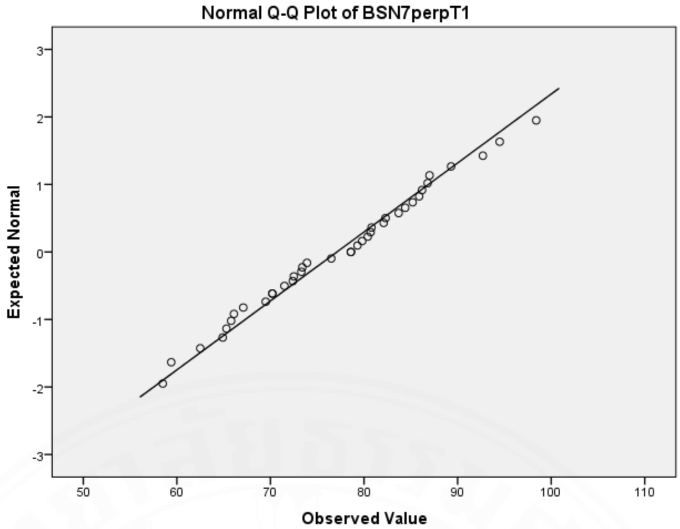

Figure 3 Normal Q-Q plot of horizontal measurement

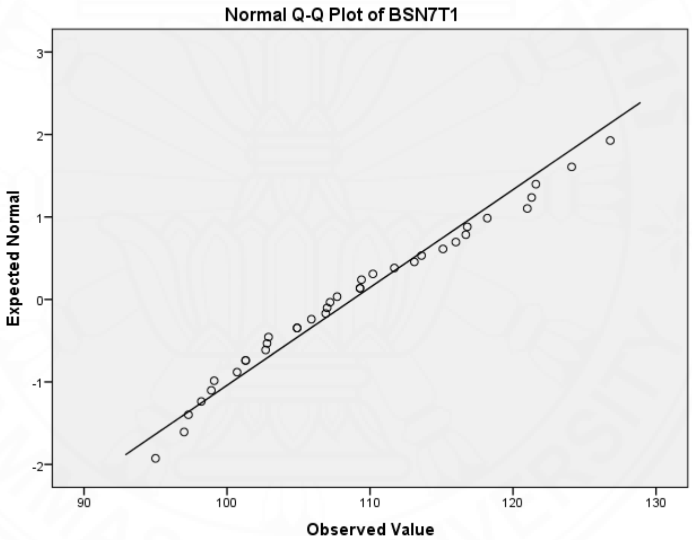

Figure 4 Normal Q-Q plot of vertical measurement

3.9 Reference points and reference lines (planes) using cephalometric analysis (46)

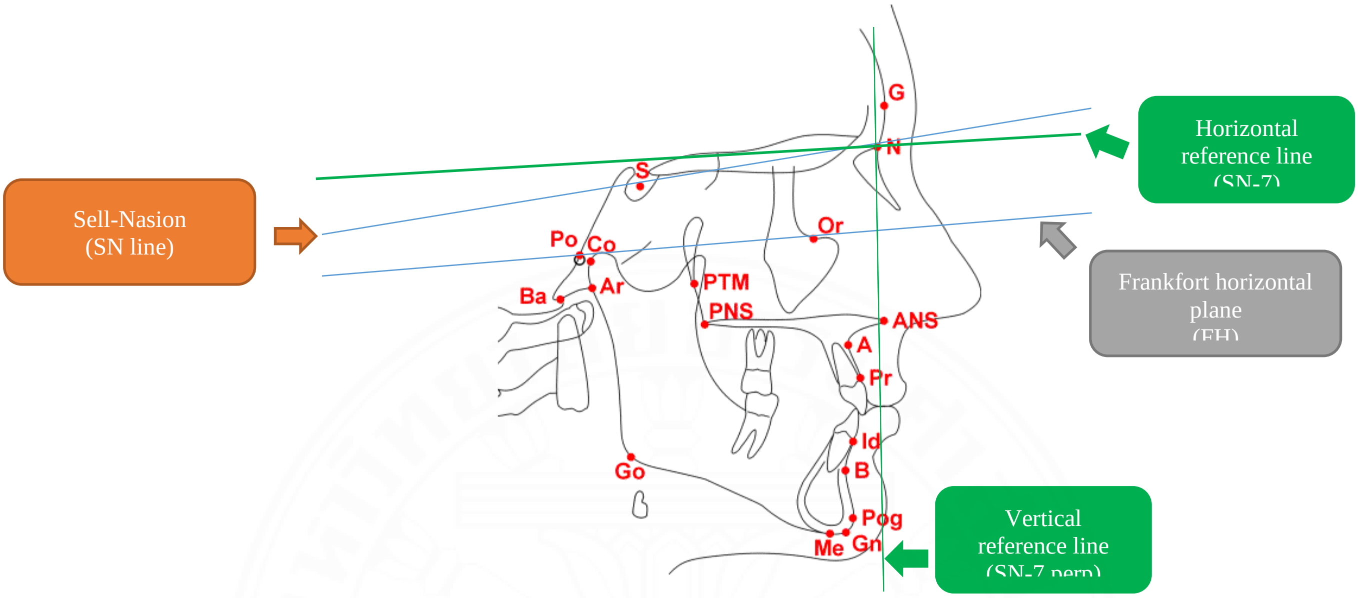

Figure 5 Reference points and reference lines used in cephalometric analysis

Reference points	Definitions
▪ **Hard tissue landmarks[46]**	
Sella (S)	The geometric center of the pituitary fossa (sella turcica), determined by inspection—a constructed point in the midsagittal plane. (midsagittal)
Nasion (N)	The intersection of the internasal and frontonasal sutures, in the midsagittal plane. (midsagittal)
Porion (Po)	The most superior point of the outline of the external auditory meatus (*anatomical porion*)
Orbitale (Or)	The lowest point on the inferior orbital margin. (bilateral)
A-point (A)	The deepest (most posterior) midline point on the curvature between the ANS and prosthion. Its vertical coordinate is unreliable and therefore this point is used mainly for anteroposterior measurements. The location of the A-point may change somewhat with root movement of the maxillary incisor teeth. (midsagittal)
B-point (B)	The deepest (most posterior) midline point on the bony curvature of the anterior mandible, between infradentale and pogonion. (midsagittal)
Pogonion (Pog)	The most anterior point on the contour of the bony chin, in the midsagittal plane. Pogonion can be located by drawing a perpendicular to mandibular plane, tangent to the chin. (midsagittal)
Gnathion (Gn)	The most anterior inferior point on the bony chin in the midsagittal plane. (midsagittal)
Menton (Me)	The most inferior point of the mandibular symphysis, in the midsagittal plane. (midsagittal)

Gonion (Go)	The most posterior inferior point on the outline of the angle of the mandible. It may be determined by inspection or it can be constructed by bisecting the angle formed by the intersection of the mandibular plane and the ramal plane and by extending the bisector through the mandibular border. (bilateral)
Anterior nasal spine (ANS)	The tip of the bony anterior nasal spine at the inferior margin of the piriform aperture, in the midsagittal plane. It corresponds to the anthropological point acanthion and often is used to define the anterior end of the palatal plane (nasal floor). (midsagittal)
Posterior nasal spine (PNS)	The most posterior point on the bony hard palate in the midsagittal plane; the meeting point between the inferior and the superior surfaces of the bony hard palate (nasal floor) at its posterior aspect. It can be located by extending the anterior wall of the pterygopalatine fossa inferiorly, until it intersects the floor of the nose. (midsagittal)
Prosthion (Pr)	The most inferior anterior point on the maxillary alveolar process, between the central incisors. (midsagittal)
Infradentale (Id)	The most superior anterior point on the mandibular alveolar process, between the central incisors. (midsagittal)

Incision inferius (Ii)	The incisal tip of the most labially placed mandibular incisor. (unilateral)
Incision superius (Is)	The incisal tip of the most labially placed maxillary central incisor. (unilateral)

▪ **Soft tissue landmarks[46]**	
Soft tissue glabella (G')	The most prominent point of the soft tissue drape of the forehead, in the midsagittal plane. (midsagittal)
Soft tissue nasion (N')	The deepest point of the concavity between the forehead and the soft tissue contour of the nose in the midsagittal plane. (midsagittal)
Soft tissue pogonion (Pg')	The most prominent point on the soft tissue contour of the chin, in the midsagittal plane. (midsagittal)
Soft tissue menton (Me')	The most inferior point of the soft tissue chin, in the midsagittal plane. (midsagittal)
Subnasale (Sn)	The point in the midsagittal plane where the base of the columella of the nose meets the upper lip. (midsagittal)
Stomion superius (Sts)	The lowest midline point of the upper lip. (midsagittal)
Stomion inferius (Sti)	The highest midline point of the lower lip. (midsagittal)
Superior labial sulcus (Sls)	The point of greatest concavity on the contour of the upper lip between subnasale and labrale superius, in the midsagittal plane. (midsagittal)
Inferior labial sulcus (Ils)	The point of the greatest concavity on the contour of the lower lip between labrale inferius and menton, in the midsagittal plane. (midsagittal)
Labrale superior (Ls)	The point denoting the vermillion border of the upper lip, in the midsagittal plane. (midsagittal)
Labrale inferior (Li)	The point denoting the vermillion border of the lower lip, in the midsagittal plane. (midsagittal)

Table 3 Reference points demonstrated hard and soft tissue landmarks used for cephalometric analysis in the study

Reference lines (planes)[46]	Definitions
Sella-Nasion line (SN)	A frequently used cephalometric reference line representing the anterior cranial base. A line joining points S and Na.
Frankfort horizontal plane (FH)	An anthropological horizontal plane described on dry skulls as passing through the lowest point in the floor of the left orbit and the highest point on the margin of the external auditory meati. On a lateral cephalometric radiograph, the Frankfort horizontal plane is represents by a line connecting the cephalometric landmarks porion and orbitale.
N-perpendicular	A line drawn perpendicular to the Frankfort horizontal from nasion. A reference line for anteroposterior measurements in the McNamara analysis.
Palatal plane (PP)	A line joining PNS and ANS.
Mandibular plane (MP)	A line representing the plane passing through the mandibular borders (bilaterally). It can be drawn into different ways: by joining points gonion and gnathion, or by drawing a tangent to the posterior aspect of the lower mandibular border from menton.
Occlusal plane (OP)	A line on the cephalometric radiograph representing an imaginary plane at the level of the occlusion. There are various different definitions. Bisected occlusal plane A line passing through the cusp tip of the maxillary and mandibular first permanent molars and midway between the incisal edges of the maxillary and mandibular central incisors (bisecting the overbite).

E-line	A line tangent to the chin and nose, introduced by R.M. Ricketts for assessment of lip fullness. According to him, the lower lip should fall slightly ahead of the upper lip when related to this line.

Table 4 Reference lines demonstrated reference lines used for cephalometric measurements in the study

3.10 Cephalometric measurements

Cephalometric measurements	Definitions
1. Hard tissue measurements[46]	
ANB angle	The difference between angles SNA and SNB, aiming at providing an evaluation of the anteroposterior relationship between the maxillary and mandibular apical bases. The measurement is not specific as to the location of the deformity.
Frankfort-mandibular plane angle (FMA)	The anterior angle formed by the intersection of the mandibular and the Frankfort horizontal planes. One of the angles of the "Tweed triangle."
Interincisal angle	A measurement of the degree of procumbency of the incisor teeth, introduced by W.B. Downs as the (posterior) angle formed by the intersection of the long axes of the maxillary and mandibular central incisors.
L1-to-AP distance	The perpendicular distance (in mm) of the incisal edge of the mandibular central incisors to the A-Pog line. A measurement of the Downs analysis, expressing the degree of protrusion of the mandibular incisors.
Mandibular plane angle	A measurement introduced by C.C. Steiner for assessment of the steepness of the mandibular plane in relation to the cranial base. The anterior angle formed by the intersection of SN and GoGn is measured. W.B. Downs defined the mandibular plane angle as the anterior angle formed by the intersection of the Frankfort horizontal plane and a tangent to the lower border of the mandible and symphysis.

SNA angle	A commonly used measurement (of the Steiner analysis) introduced by R.A. Riedel for assessment of the anteroposterior position of the maxilla with regards to the cranial base. The inferior posterior angle formed by the intersection of lines SN and NA is measured.
SNB angle	A measurement introduced by R.A. Riedel to evaluate the anteroposterior position of the mandible in relation to the cranial base (also part of the Steiner analysis). The inferior posterior angle formed by the intersection of lines NA and NB is measured.
Wits appraisal	A measurement introduced by A. Jacobson, designed to avoid the shortcomings of the ANB angle in evaluating anteroposterior jaw disharmonies. The method entails drawing perpendicular lines on a tracing of a lateral cephalogram from point A and B, onto the functional occlusal plane (which is drawn through the region of the overlapping cusps of the first premolars and molars) and subsequently measuring the distance between the two points of intersection of the two perpendicular lines with the functional occlusal planes, along the latter. The greater the deviation of this reading from 0 mm in females and -1.0 mm in males, the greater the degree of sagittal discrepancy between the maxilla and mandible.

2. <u>Soft tissue measurements[46]</u>	
H-angle (of Holdaway)	The superior angle formed by the intersection of the H-line of Holdaway and the (bony) NB line. It provides a measurement of soft tissue protrusion or retrusion and is evaluated in conjunction with the ANB angle. The amount of deviation of the ANB angle from the average (1º to 3º) is added or subtracted from the H-angle for appropriate assessment of the lip and chin projection. The H-angle takes the skeletal relationship into account, but does not consider nasal contour and projection.
Nasolabial angle (NLA)	The anterior inferior angle formed by the intersection of a line tangent to the columella of the nose and a line drawn from subnasale to the mucocutaneous border of the upper lip. It evaluates the degree of protrusion or retrusion of the upper lip, in reference to the columella of the nose.

Table 5 Cephalometric measurements hard and soft tissue measurements used in the study

3.11 Variables

3.11.1 Skeletal variables

Linear measurements	Angulation measurements
Pog - NB (mm)	ANB (º)
A-Point to SN, Perp. (mm)	MP-SN (º)
A pt Horizontal (mm)	SNA (º)
B - SN-7 Perp (mm)	SNB (º)
B pt Horizontal (mm)	SN - GoGn (º)
S Vert - Pog (mm)	FH - NB (º)
Pog Horizontal (mm)	
Pogonion - SN-7 Perp (mm)	
Menton - SN-7 (mm)	
B-N Perpendicular (mm)	
A-N Perpendicular (mm)	
Pog-N Perpendicular (mm)	
A - FH Perp (mm)	
A-FH (mm)	
B - FH Perp (mm)	
Pogonion - FH Perp (mm)	
Pog-N|FH (mm)	

Table 6 Skeletal variables hard tissue (skeletal) measurement represented in distance and angulation

3.11.2 Dental variables

Linear measurements	Angulation measurements
L1 - NB (mm) U1 - NA (mm) U1 (labial surface) to NA (mm)	Interincisal Angle (U1-L1) (º) IMPA (L1-MP) (º) U1 - SN (º) Occ Plane to SN U1 - NA (º) L1 - NB (º)

Table 7 Dental variables hard tissue (dental) measurement represented in distance and angulation

3.11.3 Soft tissue variables

Linear measurements	Angulation measurements
Lower Lip to E-Plane (mm) Upper Lip to E-Plane (mm) S Vert - Pog' (mm) S Vert - Ss (mm) S Vert - Si (mm) ST A point - FH Perp (mm) Soft Tissue A - S True Vertical (mm) STissue N Vert (N Perp) to ST Pogonion (mm) ST Pogonion - FH Perp (mm)	Soft Tissue Convexity (º)

Table 8 Soft tissue variables soft tissue measurement represented in distance and angulation

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Anteroposterior skeletal relationship

The mandibular was setback in amount of 9.78 mm at B point, and the skeletal relapse was 2.61 mm at point B, representing a skeletal relapse rate of 26.69 % (2.61/9.78) in this group of patients. The statistical analysis showed the difference between before surgery and immediate postsurgical changes to be significant (p <0.05). Obviously, the mandible was significantly setback repositioned (B-SN7 perp, Pog-SN7 perp, SNB, $p < 0.05$) and significantly relapsed forward during postsurgical period (B-SN7 perp, Pog-SN7 perp, SNB, $p > 0.05$). This means the mandible was significantly relapsed forward during the postsurgical follow-up period.

4.2 Vertical skeletal relationship

There was a trend of decreased in vertical dimension post-surgically. B point showed significant upward relapse (B-SN7, p <0.05) after surgery and follow up period. Since sagittal and vertical skeletal relationship, the mandible demonstrated a forward-upward rotation or autorotation.

4.3 Dental relationship

IMPA decreased because of autorotational counterclockwise of mandible immediately after removal of the stabilization splint (IMPA, $p<0.05$). The mandible seemed to relapse forward direction, Class III mechanics was used to prevent this situation. Consequently, lower incisors were lingually inclined. During postsurgical period, lower incisors retroclined to maintain proper overjet while mandible had tendency to relapse in anterior position.

Measurement (n=38)	T0		T1		T2		*p*		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	***T1-T0***	***T2-T1***	***T2-T0***
B-SN7 perp (mm)	81.46	13.52	71.68	12.45	74.28	12.7	.000*	.000*	.000*
Pog-SN7 perp(mm)	83.29	14.96	75.33	14.02	77.82	13.93	.000*	.000*	.000*
SNB (degrees)	86.88	4.39	83.5	4.15	84.8	4.37	.000*	.000*	.000*
ANB (degrees)	-3.65	2.65	2.09	1.68	1.17	2.04	.000*	.000*	.000*
Me-SN7 (mm)	-128.04	15.75	-124.71	13.1	-122.78	14.4	.017*	.077	.001*
B-SN7 (mm)	105.32	12.99	102.1	10.95	99.96	11.57	.009*	.041*	.000*
SN-GoGn (degrees)	31.82	5.94	32.58	6.5	32.08	7.12	.255	.228	.726
IMPA (degrees)	85.88	7.6	79.32	6.56	79.46	7.75	.000*	.839	.000*

Table 9 Comparison of skeletal and dental variables according to different stages in patients treated with NM-low Z plasty technique; Paired T-test was done. T0 indicates before surgery, T1, immediate after surgery, T2, 6 months to 1 year follow-up after surgery. ** p <0.05 by paired T test*

Measurement (n=9)	T0		T1		T2		*p*		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	***T1-T0***	***T2-T1***	***T2-T0***
B-SN7 perp (mm)	80.76	8.63	70.78	7.33	73.31	9.47	.000*	.097	.011
Pog-SN7 perp(mm)	83.31	10.44	75.59	10.34	78.04	10.12	.001*	.241	.017*
SNB (degrees)	86.19	3.71	82.54	2.94	84.58	3.7	.001*	.008*	.144
ANB (degrees)	-3.13	2.2	1.47	1.35	1.11	1.59	.000*	.078	.000*
Me-SN7 (mm)	-127.16	11.58	-124.73	9.19	-119.94	15.57	.295	.171	.099
B-SN7 (mm)	103.2	9.97	101.52	6.35	97.9	11.55	.408	.2	.148
SN-GoGn (degrees)	29.03	5.56	29.74	6.81	29.16	7.08	.458	.644	.917
IMPA (degrees)	88.19	8.29	83.24	6.09	82.52	7.38	.008*	.482	.001*

Table 10 Comparison of skeletal and dental variables according to different stages in patients treated with NM-low Z plasty technique **(one jaw surgery)**; Paired T-test was done. T0 indicates before surgery, T1, immediate after surgery, T2, 6 months to 1 year follow-up after surgery. ** p <0.05 by paired T test*

Measurement (n=29)	T0		T1		T2		*p*		
	Mean	SD	Mean	SD	Mean	SD	*T1-T0*	*T2-T1*	*T2-T0*
B-SN7 perp (mm)	81.68	14.84	71.96	13.75	74.59	13.68	.000*	.000*	.000*
Pog-SN7 perp(mm)	83.28	16.27	75.26	15.14	77.76	15.06	.000*	.000*	.000*
SNB (degrees)	87.09	4.62	83.79	4.47	84.87	4.61	.000*	.000*	.000*
ANB (degrees)	-3.81	2.79	2.29	1.74	1.18	2.18	.000*	.000*	.000*
Me-SN7 (mm)	-128.31	16.99	-124.71	14.24	-123.66	14.18	.034*	.289	.008*
B-SN7 (mm)	105.97	13.88	102.28	12.12	100.6	11.7	.013*	.126	.001*
SN-GoGn (degrees)	32.68	5.88	33.46	6.25	32.99	6.99	.353	.241	.742
IMPA (degrees)	85.17	7.37	78.1	6.31	78.5	7.74	.000*	.632	.000*

Table 11 Comparison of skeletal and dental variables according to different stages in patients treated with NM-low Z plasty technique **(two jaws surgery)**; Paired T-test was done. T0 indicates before surgery, T1, immediate after surgery, T2, 6 months to 1 year follow-up after surgery. ** p <0.05 by paired T test*

4.4 Discussion

For skeletal Class III patients, mandible was backward and superior repositioned after mandibular setback surgery (Table9). Moreover, the mandible seemed to significantly relapse in forward and superior direction.

The null hypothesis, no significant difference of mean skeletal changes between immediate postsurgical changes and postsurgical stability in BSSO NM-low Z plasty technique, was denied.

In our study, there was no significant change of vertical skeletal variable (SN-GoGn, $p>0.05$) with a significant increase of horizontal measurement (SNB, $p>0.05$) during postsurgical period. These findings would explain that an upward-forward movement of the mandible which occurred during postsurgical period. Our findings were conforming to many previous studies [47, 48], which reported a greater horizontal relapse and more forward chin projection caused by bite closed after postsurgical orthodontic treatment. Additionally, Hsu et al. reported the most sagittal relapse in postsurgical period contributed to the forward-upward rotation of mandible[49].

There was a significant decreased in vertical skeletal relationship during postsurgical period (B-SN7, $p<0.05$). According to Ko et al., it was hypothesized that vertical dimension was decreased because autorotation of the mandible with occlusal settling procedure of the posterior teeth in post-surgical orthodontic treatment; particularly in cases of severe occlusal interferences[48]. Furthermore, Imerb et al. stated that high mandibular plane angle had less stability when compared with normal mandibular plane angle[50].

Although there were benefits in performing dental decompensation before surgery in conventional approach[51, 52]. From our finding that upper incisors (U1-SN in Table 9) retroclined after decompensation and proclined after postsurgical period, there was a round-tripping tooth movement which was considered an adverse effect. It was in accordance with Capelozza and colleagues who reported a dental decompensation to obtain more amount of skeletal correction for skeletal Class III patients[52]. Conversely, the lower incisors proclined before surgery and retroclined after surgery for maintain normal overjet and compensate for the skeletal relapse after mandibular setback.

With rotational relapse (forward-upward movement of the mandible) immediately after surgery, there might be a benefit in skeletal Class III patients with hyperdivergent pattern (open-bite tendency) to decrease the facial height. In contrast, hypo-/normodivergent patients must be treated with caution. Vertical control of overbite and anterior facial height were recommended in Contemporary Orthodontics[53].

In finishing stage of comprehensive orthodontic treatment, normal overbite is one of the requirements[54] before removal of full fixed appliances. To correct excessive overbite, two factors must be addressed: 1.) the vertical relationship of upper lip and upper incisors 2.) anterior facial height. If there is an appropriate display of upper incisors while smiling, the position of upper incisors needs to be maintained and correct overbite by intruding the lower incisors instead of upper incisors. If upper incisors display is excessive, intrusion of upper incisors would be suggested. If patient has short facial height, extruding the lower posterior teeth would be acceptable. If patient has long facial height, intruding the incisors would be indicated. As with other issues, planning for impending events is critical while dealing with skeletal and dental relapses.

When compare one jaw to two jaws surgery, our results (Table 10) showed that one jaw surgery had less relapse than two jaws. Al-Delayme R et al[24] found less stability in one jaw surgery. However Rodriguez et al[55] found magnitude of 10 mm setback surgery with 2.6 mm skeletal relapse (which six from fourteen subjects were operated in 10 mm setback and the highest amount of setback in the study was 12 mm). Two jaws surgery showed significant relapse (Table 11). SFA had more high relapse cases than COS group.[56] Further investigation including SFA and COS group should be conducted.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Mandible was significant relapsed in forward and upward direction after mandibular setback surgery using NM-low Z plasty tecnique. Lower incisors was retroclined after surgery to compensate the autorotational counterclockwise of mandible. Patient selection, overcorrection and orthodontic mechanics to deal with relapse must all be considered.

5.2 Recommendations

Because NM-low Z plasty is a new procedure in surgical treatment, further studies on long-term stability, included conventional orthognathic surgery or surgery first approach will be necessary.

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