Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Mosul
College of Dentistry

Evaluation of the Mandibular Sagittal Split Ramus Osteotomy by Cone Beam Computed Tomography

A Project Submitted to
The College of Dentistry, University of Mosul, Department of Oral and Maxillofacial Surgery in Partial Fulfillment for the Bachelor of Dental Surgery

By

Hiba Jasem Muhammed Amen

Supervised by:

Dr.Sufyan Hammadi Ahmed

B.D.S,F.I.B.M.S

2025

Certification of the Supervisor

I certify that this project entitled "Evaluation of the Mandibular Sagittal Split Ramus Osteotomy by Cone Beam Computed Tomography" was prepared by the fifth-year student Hiba Jasem Muhammed Amen under my supervision at the College of Dentistry/University of Mosul in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Supervisor: Dr.Sufyan Hammadi Ahmed

Date:

Dedication

I would like to dedicate this project to those who were the reason for my existence (My Parents), to my soul (My Sister and My Brother), to the everyone who taught me a litter throughout my life, to that difficult times that made me who I am now.

Acknowledgment

First and foremost, praises and thanks to Allah Almighty for helping me in my difficult times, for his blessings throughout my work to complete it successfully.

I would like to extend my deepest respect and gratitude to the Dean of College of Dentistry, University of Mosul, Prof. Dr. Rayan Salim Hamed.

My sincere thanks to all professors and seniors in the department of Oral and Maxillofacial Surgery for them pleasant cooperation.

I would like to show my deep and sincere gratitude to my research supervisor, Dr.Sufyan Hammadi Ahmed for her advice, encouragement, and guidance in planning and conducting this project.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATION

2D	Two-dimensional
3D	Three dimensional
BSSO	Bilateral sagittal split osteotomy
CBCT	Cone beam computed tomography
CT	Conventional computed tomography
IAN	Inferior alveolar nerve
LBCE	Lateral bone cut end
NSD	Neurosensory disturbance
TMD	Temporomandibular dysfunction
TMJ	Temporomandibular joint
VOR	Virtual operating room

Introduction

Orthognathic surgery involves the surgical correction of the components of the facial skeleton to restore the proper anatomical and functional relationship in patients with dentofacial skeletal abnormalities. An important component of orthognathic surgery is the bilateral sagittal split osteotomy (BSSO), which is the most commonly performed jaw surgery, either with or without upper jaw surgery. Indications for a BSSO include horizontal mandibular excess, deficiency, and/or asymmetry. It is the most commonly performed procedure for mandibular advancement and can also be utilized for a mandibular setback of small to moderate magnitude. (1) Asymmetry cases require careful workup and planning, but can be easily addressed with a BSSO. (2)

Difficulty in accessing the medial region of the ramus can lead to inadequate osteotomies and split patterns, which can create complications, such as permanent damage to the IAN, facial asymmetry, bone resorption or infection, and relapse. (3) Thus, classifications have been suggested to better understand the possible split patterns generated by BSSO and how they affect postsurgical results by means of cone beam computed tomography (CBCT) which has enabled a clear view of the buccal and lingual surfaces of the mandible, especially those previously hidden lingual fracture lines. (4-6) Cone beam computed tomography (CBCT) is a medical image acquisition technique based on a cone shaped x-ray beam centered on a two-dimensional (2D) detector. (7)

CBCT coupled with a 3D reconstruction software provide effective means for evaluation of the facial skeleton and are currently used in large-scale studies of the maxillofacial region. (8,9,10)

An unfavorable and unanticipated pattern of the mandibular osteotomy fracture is generally referred to as a 'bad split'. Incidences of 0.2% up to 14.6% per split site have been reported. (11,12)

Bad splits may cause mechanical instability, a disturbance in bony union, and lead to bone sequestration with subsequent infection. (3)

Hu et al. (2020) described **six** types of lingual split and three types of lateral bone cut end (LBCE) were defined based on three-dimensional images. Fig. (1.1-1.2) (13)

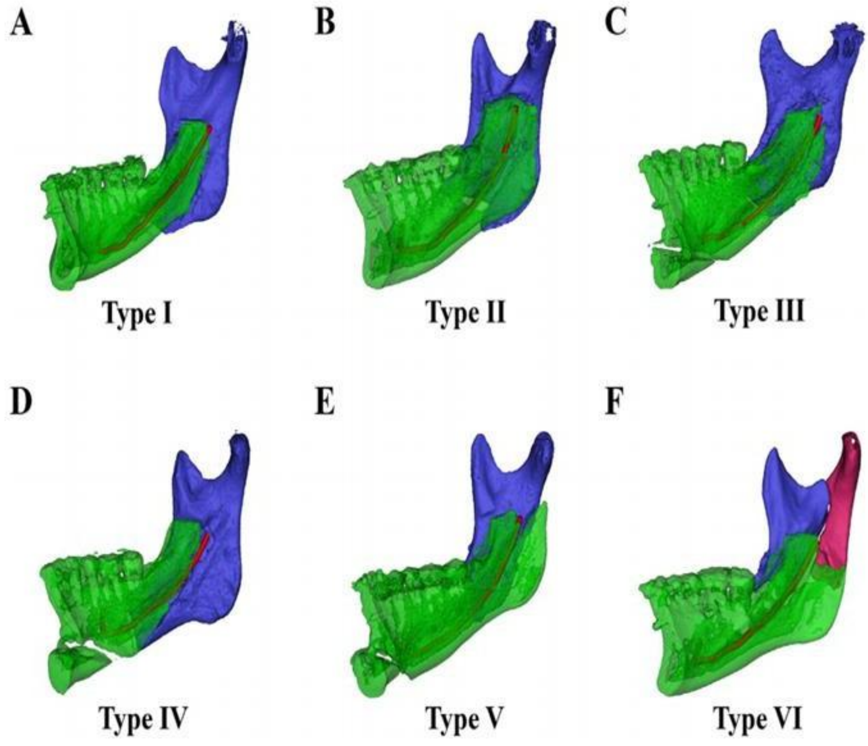

Fig. (1.1) Patterns of mandibular lingual split after bilateral sagittal split osteotomy. (A) Type I: fracture line running as a vertical fracture-line pattern to the inferior mandibular border. (B) Type II: fracture line running with the medial bone cut above the lingula and extending towards the posterior border. (C) Type III: fracture line running through the mandibular foramen and obliquely extending towards the mandibular angle. (D) Type IV: fracture line running through the mandibular canal to the inferior border of the mandible. (E) Type V: fracture with the medial bone cut extending through the mandibular foramen towards the posterior border of ramus and mandibular angle remaining in the distal fragment. (F) Type VI: other unexpected fractures, i.e., bad split. (13)

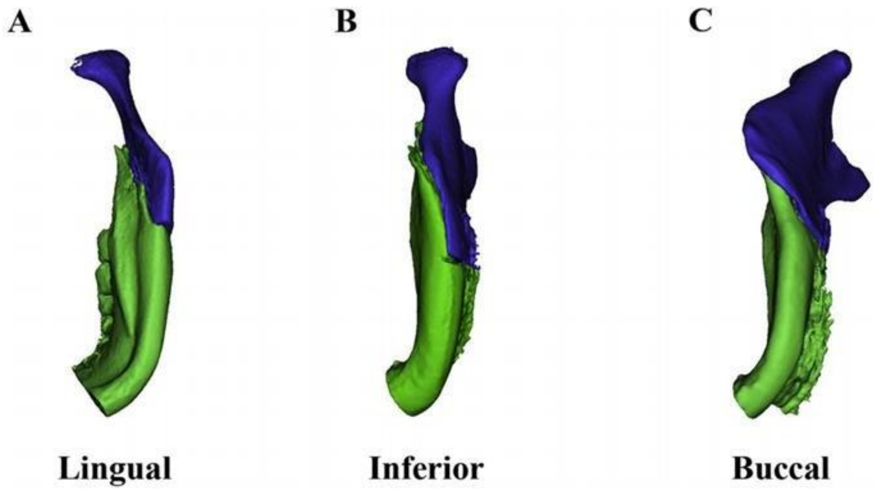

Fig. (1.2): Types of lateral bone cut end after bilateral sagittal split osteotomy. Three types of mandibular buccal split were categorized as a more lingual bone cut end (A), a central bone cut end (B), or a more buccal bone cut end (C). [13]

The aims of the study

The aims of this study are to:

1- Characterize the patterns of lingual split and lateral bone cut end (LBCE) after Bilateral sagittal split osteotomy (BSSO).
2- Measure the ramus thickness and its possible relation to the splitting pattern.
3- Evaluate the possible relation between the presence of impacted mandibular 3^{rd} molars and the occurrence of bad splitting.
4- Define and monitor the condylar position both pre and post operatively using CBCT-based 3D evaluation.

Chapter One: Review of Literature

1.1 Evolution of BSSO

The history of orthognathic surgery of the mandible started with Hullihen in 1846, who performed an osteotomy of the mandibular body for the correction of prognathism. (14) There was little further innovation until that of Blair in the early 1900s, who performed a horizontal osteotomy of the ramus. (15) The 1920s and 1930s saw further modifications by Limberg, Wassmund, and Kazanjian of external approaches to ramal osteotomies. (16) All of these approaches had difficulties with relapse. The earliest description of the modern BSSO and the first intraoral approach to a ramal osteotomy was described in the German literature by Schuchardt in 1942.
(16) In 1954, Caldwell and Letterman described a vertical ramus osteotomy technique, which was shown to preserve the inferior alveolar neurovascular bundle. (17) Trauner and Obwegeser in 1957 modified Schuchardt's procedure and described what would become today's BSSO. (18) The next several decades would see improvements and modifications to the procedure with the focus on decreasing relapse, improving healing, and decreasing complications. (1)

The main contributors to these improvements included Dal Pont (1961), Hunsuck (1968), and Epker (1977). In 1961, Dal Pont modified the lower horizontal cut to a vertical osteotomy on the buccal cortex between the first and the second molars. Fig. (1.3). Which allowed for greater contact surfaces and required minimal muscular displacement. (19)

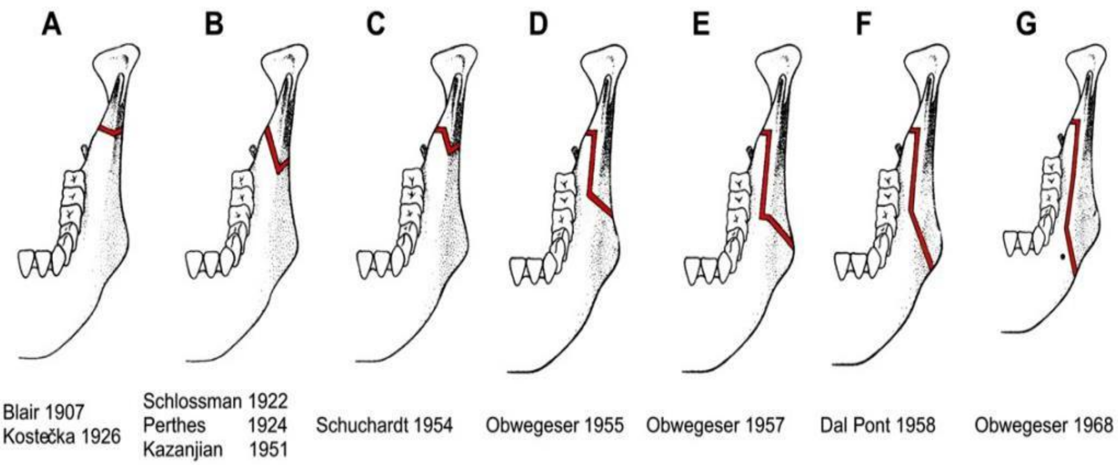

Fig. (1.3): Evolution of vertical and lateral cuts in BSSO. [16]

In 1968, Hunsuck modified the technique, advocating a shorter horizontal medial cut just past the lingula to minimize the soft tissue dissection. His anterior vertical cut was similar to Dal Pont's. [20]

In 1977, Epker proposed several refinements. These included less stripping of the masseter muscle as well as limited medial dissection, all of which led to decreased postoperative swelling, hemorrhage, and manipulation of the neurovascular bundle. The decreased stripping of the masticatory muscles increased the vascular pedicle to the proximal segment, which diminished bone resorption and loss of the gonial angle. [21]

Rigid internal fixation was introduced in 1976 by Spiessel to promote healing, restore early function, and decrease relapse. [22]

The introduction of an internal rigid fixation method, instead of 5- to 6-week intermaxillary fixation, had the added benefit of improved patient convenience. [1]

Posnick described a modification of BSSO that places the medial horizontal osteotomy cut below the lingula. This modification is particularly useful in situations in which the lingula is located in close proximity to the condylar neck or the ascending ramus is thin near the lingula, with no appreciable marrow space between the outer and inner cortices, such as in congenital mandibular deformities, or in which the nerve has a more cephalad entrance into the mandible. medial horizontal osteotomy below the lingula allows for more favorable propagation of the proximal osteotomy into the retrolingular fossa but comes at the expense of a greater likelihood of the inferior alveolar nerve (IAN) being contained within the proximal segment. Fig. (1.4) ([23]

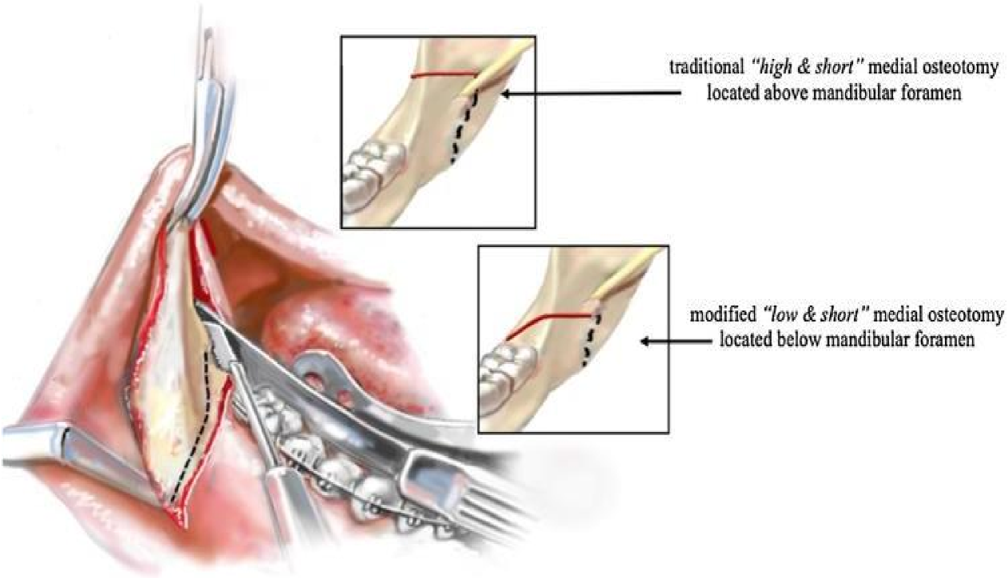

Fig. (1.4): Posnick's modification, low and short medial cut below the lingula. [23]

In 2015, Verweij et al. suggested further alterations, angled lateral osteotomy design to increase the amount of bone contact between the segments, allow better stability, facilitate the installation of internal fixation, obtain better control of the condyle position, and possibly reduce postoperative complications, such as bad splitting and dysesthesia or permanent hypoesthesia of the inferior alveolar nerve (IAN). Fig. (1.5) [24]

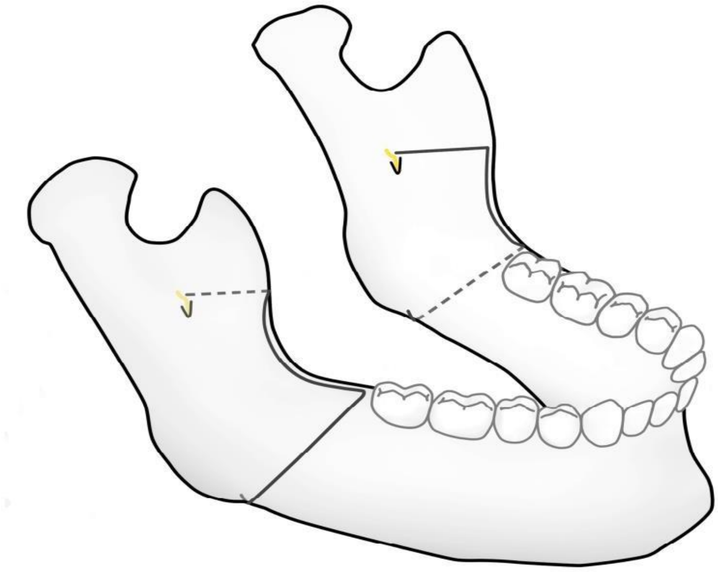

Fig. (1.5): Angled lateral osteotomy suggested by Verweij et al. [24]

1.2 Indications of BSSO

BSSO is a versatile surgical procedure that can be used to treat mandibular excess, deficit, mandibular asymmetry, open bite and crossbite, J. Beukes et al proposed the following indications:

1. **Mandibular deficiencies:**

- Mandibular deficiencies with normal or short face
- Mandibular deficiencies with long face: increase maxillary vertical dimension
- Mandibular deficiencies with long face: excessive chin height
- Sleep apnea.

2. **Mandibular excess:**
    - Short face
    - Long face
    - For the treatment of these abnormalities, the limitation of the BSSO is
        - Large setbacks of ≥7–8 mm need an intraoral vertical ramus osteotomy/inverted “L” osteotomy.
3. **Mandibular asymmetries:**
    - Hemi-mandibular hypertrophy
    - Hemi-mandibular elongation.
4. **Open bite**
5. **Crossbite.**

1.3 Limitations

The limitations of the BSSO are [25]:

1. For advancements beyond 10–12 mm, an extraoral approach needs consideration
2. Additional surgery is required for most dentofacial deformities.

1.4 Contraindications

Contraindications for the BSSO are as follows [25]:

1. Severe decreased posterior mandibular body height.
2. Extremely thin medial-lateral width of ramus.
3. Severe ramus hypoplasia.
4. Severe asymmetries.

1.5 Advantages

1. Healing is enhanced because of a good bony interface.
2. The surgery can advance or set back the mandible, correct most asymmetries, and alter the occlusal plane.
3. Rigid fixation can be used, eliminating the need for maxillomandibular fixation. Rigid fixation when properly applied, significantly improves the stability and predictability of results.
4. Modifications can maintain the angle of the mandible in the original spatial position, even in large advancements.
5. Major muscles of mastication remain in the original spatial position.
6. Minimal or no scar extraorally. (26)

1.6 Disadvantages

1. The incidence of nerve damage is increased, although this is usually temporary.
2. Unfavorable splits may occur.
3. Surgery must create a fracture on the lingual aspect of the ramus.
4. Severe asymmetries are difficult to correct. (26) (27)

1.7 Complications associated with BSSO

1.7.1 Infection

Postoperative infection was reported in studies of patients undergoing BSSO in a period ranging from 5 days to up to a year after surgery. Infections requires antibiotic therapy, and in some cases, the patients underwent surgical drainage. Osteomyelitis in BSSO was reported. (28)

The rate of infection after BSSO is up to 11.3% which is within the normal range of clean-contaminated procedures. Rigid fixation of the osteotomy may decrease the need for hardware removal. [29]

1.7.2 Hemorrhage

Intraoperative serious hemorrhage is a rare complication during a BSSO. Maintaining the surgical dissection subperiosteally and adequate retraction of soft tissue prevent minor intraoperative oozing and most cases of major hemorrhage. Minor hemorrhage from tearing of the periosteum can be controlled with electrocautery, pressure, or additional vasoconstrictive agents. [1]

1.7.3 Neurosensory disturbance (NSD)

The risk of injury to the inferior alveolar nerve is a significant consideration when performing a BSSO. The incidence of transection of the inferior alveolar nerve (IAN) is reported between 2 to 3.5% and the incidence of some form of long-term neurologic deficit is reported in 10 to 30% of patients, whether symptomatic or not. [30] When the sagittal split osteotomy is performed with an osseous genioplasty, nearly 70% of patients have some degree of neurosensory deficit at 1 year. [31]

Even with careful surgery, injury to the IAN appears unpredictable. Multiple factors are considered responsible for the development of NSD after BSSO, including fixation methods, patient age and surgical procedures, improper splinting, magnitude of mandibular movement, experience of the surgeon, and timing of the postoperative neurosensory evaluation. [32] Injury to the IAN may happen with direct and indirect intraoperative trauma and results in change of sensibility or altered sensation of the lower lip and/or mental region. It may lead the negative effect on patients' normal functions such as eating, drinking, speech, and social interaction. NSD may affect patients' everyday lives and can have social or psychological problems. [33] The position of the canal is important in NSD following SSO because the canal position is impacted by osteotomy design and fixation techniques. [34] Nowadays, technologies and software help to evaluate the canal by using CBCT data. An increased distance between the canal and cortical bone presurgically decreased the incidence of postoperative NSD, and high bone density increased of the risk of postoperative NSD. [35]

Since the modern era of screw fixation, the incidence of lingual nerve injury has declined and become an uncommon complication following a BSSO. In most instances, lingual nerve paresthesia spontaneously resolves. [1] But Pepersack and Chausse reported a 3% neurosensory deficit at 5 years. Most cases were due to wire or bicortical screw placement near the superior border of the mandible in the region of the third molar. [36]

1.7.4 Unfavorable split (Bad split)

An unfavorable fracture, may be called a "bad split" occasionally occurs and can lead to intraoperative difficulties as well as postoperative relapse.
[37]

Frequently cited reasons for bad split include [12]:

1- Incomplete osteotomies.
2- Using osteotomes that are too large.
3- Attempting to split the segments too rapidly.
4- Misdirecting the medial osteotomy upward toward the condyle.
5- Placement of the medial osteotomy too far superior to the lingula.

The incidence of bad split is low (0.7% of all BSSOs) and patients sometimes have uneventful healing. Neither technical progress nor the surgeon's experience further decreased the frequency of bad splits. [38] It was reported that older patients experienced more bad splits than younger patients. [39]

The bone thickness of the ramus may affect the type of fracture pattern on the medial side of the ramus. [40] It is clear that certain mandibular anatomic differences can increase the risk of a bad split during SSO. [12] The use of splitters and separators instead of chisels does not increase the risk of a bad split and is therefore safe with predictable results. [41]

The split is considered undesirable when the fracture line incorrectly divides the ascending ramus, if it does not separate the mandibular base, if the angle stays in the distal segment, and when bone fragmentation occurs. [5,6]

Types of bad split:

1- Fracture of the buccal cortex of the body of the mandible. Fig. (1.6).
2- Fracture of the buccal cortex involving the body and ramus of the mandible. Fig. (1.7).
3- Fracture of the vertical osteotomy on the medial aspect of the mandibular ramus anterior to the inferior alveolar foramen. Fig. (1.8).
4- Fracture of the retromolar segment of the mandible distal to the second molar. Fig. (1.9) [42]

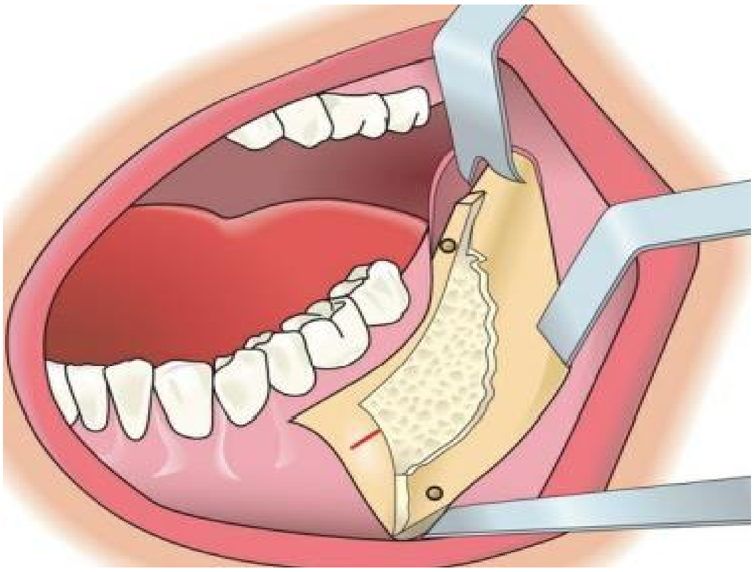

Fig. (1.6): Bad splitting: fracture in buccal cortex of the mandibular body. (42)

Fig. (1.7): Bad splitting: fracture in buccal cortex of the mandibular body and ascending ramus. (42)

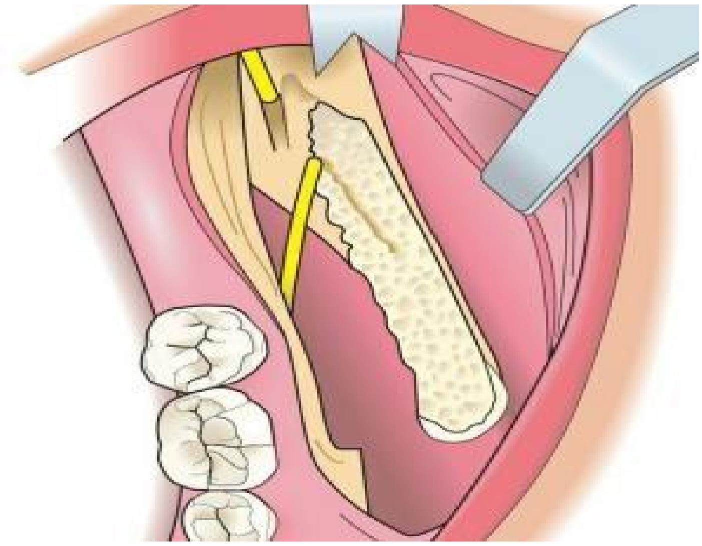

Fig. (1.8): Bad splitting: fracture in the medial aspect of the mandibular ramus. [42]

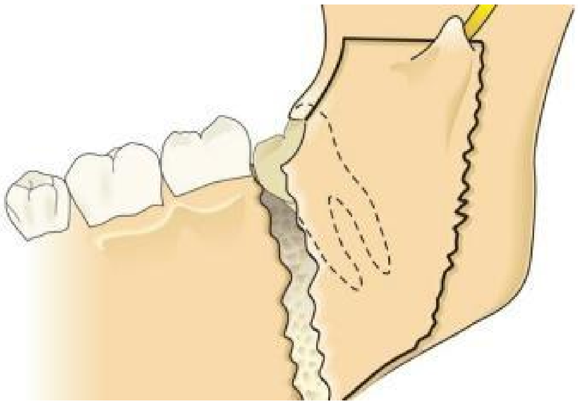

Fig. (1.9): Bad splitting: fracture in the retromolar segment of the mandible. [42]

Muto et al. reported that splits can occur on the buccal side at a rate of 15% with the short lingual cut method and that the factor responsible for this effect is the position of the end of the lateral bone cut. [5]

Bad splits may cause mechanical instability, a disturbance in bony union, and lead to bone sequestration with subsequent infection. [3] In addition, it has been proposed that temporomandibular joint (TMJ) dysfunction and inferior alveolar nerve damage may arise due to excessive intraoperative manipulation in an attempt to reposition the fractured segments, and that subsequent difficulty in positioning the condyle in the glenoid fossa may increase the risk of relapse.

In order to reduce the risk of postoperative functional deficits, fractured split segments are best fixated and reconsolidated. [43-47]

Impacted mandibular 3rd molars are thought to be another cause of unfavorable fractures and should ideally be removed 6 months to 1 year prior to mandibular surgery. However, recent research suggests that there is no statistical significance between the time of removal and incidence of unfavorable fractures. [39]

The split patterns may then become variable and communication between professionals can become confusing and ineffective. For this reason, classifications of possible fracture patterns are necessary [5,6,10]

1.7.5 Temporomandibular dysfunction (TMD) and Condylar resorption

The incidence of preoperative TMD in the orthognathic population is reported to be between 16 and 50%. The most frequent symptoms identified are pain and clicking of the TMJ. [2]

Most studies have shown that the majority of patients has improvement in their symptoms with only a small percentage experiencing worsening of symptoms. [2]

Decreased mobility after a BSSO is not an uncommon postoperative problem. It is most frequently attributable to prolonged immobility that results in fibrosis and atrophy of the muscle and connective tissue of the masticatory system. The incidence of hypomobility after a BSSO has declined with the use of rigid fixation, as prolonged periods of maxillomandibular fixation are not necessary. With the institution of a program of active rehabilitation, most patients return to preoperative interincisal opening within 3 months. [1]

Condylar displacement is one of the common complications of SSO. It can induce relapse and temporomandibular joint dysfunction symptoms. [48]

The need to accurately position the condyle in the glenoid fossa has been underlined by the increasingly common application of rigid fixation in bilateral sagittal split ramus osteotomies. However, there is no consensus as to what constitutes an ideal functional and stable relationship between the condyle, meniscus, and glenoid fossa. [42]

The location of mandibular condyle in the fossa can be changed by surgeons during fixation. Rigid fixation is considered one of the major etiologies of temporomandibular disorder (TMD). [49]

Knowing the condylar movement after orthognathic surgery is important to prevent postoperative instabilities. [50] However, condylar displacement within the physiologic capability of the adaptive mechanism does not lead to morphologic changes and dysfunction of temporomandibular joint (TMJ). [50] The postoperative condylar position is known to be affected by various factors such as rotational movement of the distal segment, tensional balance of the surrounding muscles, fixation method, and the surgeon's experience. [51]

Relapse due to a change in the condylar position may occur immediately after removal of the maxillomandibular fixation or later during the postoperative course. Avoiding an unfavorable condylar position intraoperatively is obviously highly desirable and therefore the subject of ongoing research that has focused primarily on two management philosophies: (1) maintaining the condyle in its preoperative position (by means of a device recording the relationship of the proximal segments to a skeletal structure that will remain constant and not be repositioned during surgery) prior to BSSOs and (2) using sophisticated imaging modalities or computer-assisted navigation to replace the condyle in its preoperative position. Condylar sag can be defined as an immediate or late caudal movement of the condyle in the glenoid fossa after surgical establishment of a preplanned occlusion and rigid fixation of the bone fragments, leading to a change in the occlusion.

Two types of condylar sag may occur: central and peripheral.

In central condylar sag, the condyle is positioned inferiorly in the glenoid fossa and makes no contact with any part of the fossa. In the absence of intracapsular edema or hemarthrosis (causing hydraulic pressure), the condyle will move superiorly after removal of maxillomandibular fixation, leading to a malocclusion. Fig. (1.10 a,b). [42]

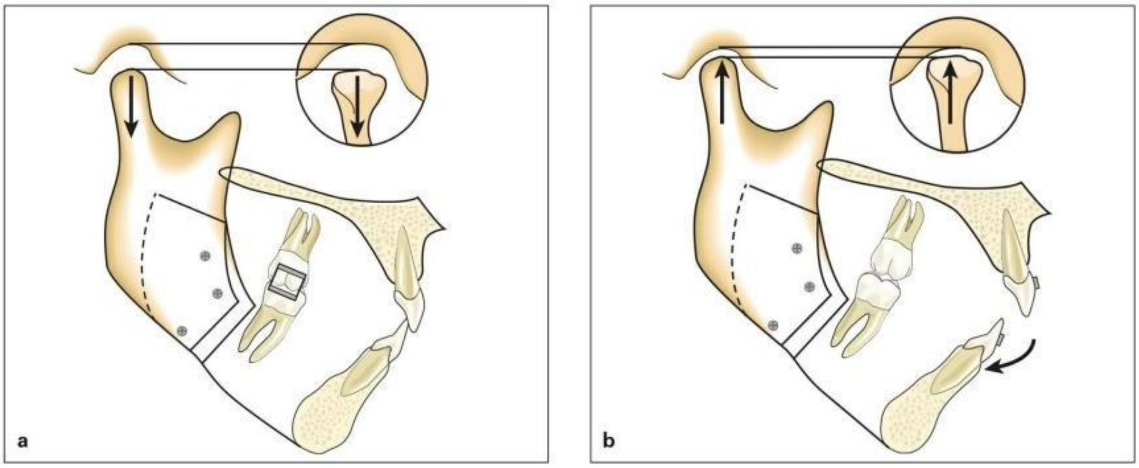

Fig. (1.10): (a) Central condylar sag. The condyle is positioned inferiorly in the glenoid fossa with no bone contact while the teeth are in occlusion (maxillomandibular fixation) and rigid fixation is placed. (b) After removal of maxillomandibular fixation, the condyle will move superiorly, causing immediate relapse. [42]

Two types of peripheral condylar sag may occur. In type I, the condyle is positioned inferiorly, with some fossa contact (lateral, medial, posterior, or anterior) with the maxillomandibular fixation in position (teeth in occlusion) and rigid fixation placed. Postoperative resorption or a change in condylar shape will lead to late relapse. Fig. (1.11 a,b). [42]

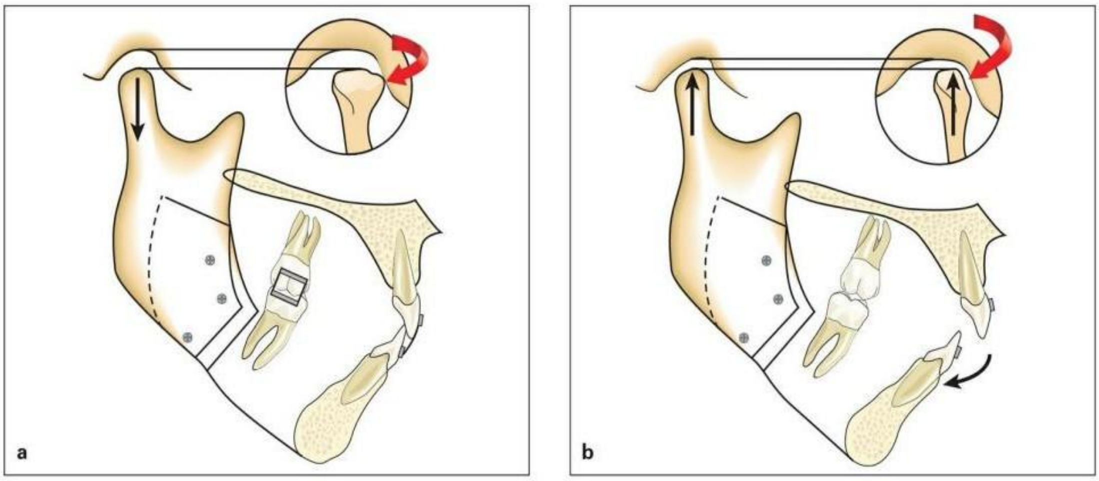

Fig. (1.11): (a) Type I peripheral condylar sag. The condyle is displaced inferiorly with (in this case) medial fossa contact. After removal of the maxillomandibular fixation, the condyle-fossa contact provides physical support to the occlusion. **(b)** Postoperative condylar resorption will lead to superior positioning of the condyle, which will later cause relapse. [42]

In type II, the condyle is positioned correctly in the fossa with the maxillomandibular fixation in position (teeth in occlusion); however, with the placement of rigid fixation, a torquing force is applied to the condyle and ramus of the mandible. The tension on the ramus is released when the maxillomandibular fixation is removed, and the condyle will move either laterally or medially and slide inferiorly in the fossa. Fig. (1.12 a,b,c) [42]

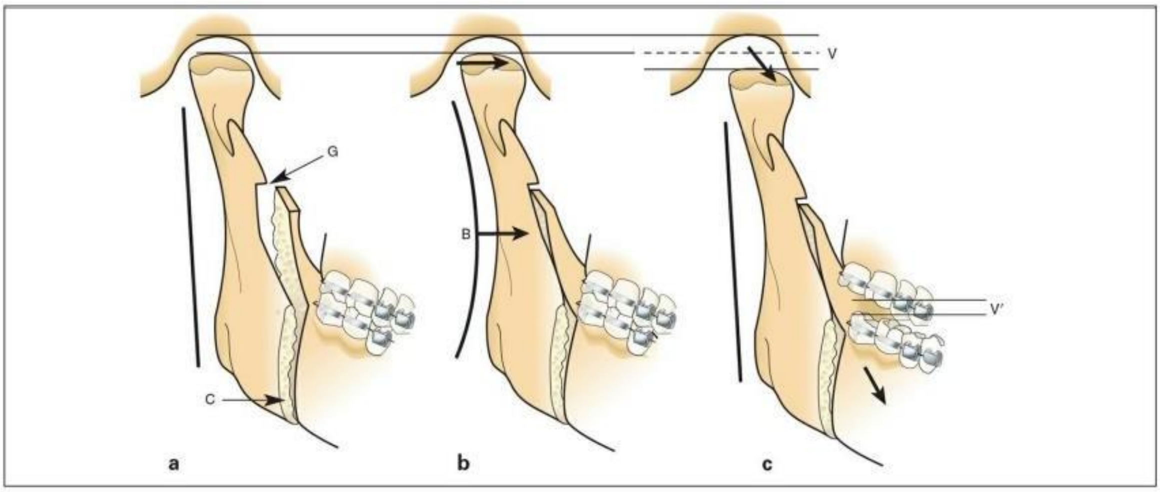

Fig. (1.12): Frontolateral view of the glenoid fossa, condyle, and proximal and distal bone segments. **(a)** The condyle is in the correct relationship to the glenoid fossa. Note, however, the gap (G) and the contact area (C) between the bone segments. **(b)** The placement of rigid fixation forces the bone segments together, which applies tension on the condyle and ramus, causing a bowing effect (B). **(c)** Once the maxillomandibular fixation is removed, the tension on the ramus is released, causing the condyle to move medially and slide inferiorly on the medial wall of the fossa; this creates a posterior open bite. The vertical change in condylar position (V) is equal to the posterior open bite (V'). (42)

It is possible to diagnose central condylar sag and type II peripheral condylar sag intraoperatively immediately after removal of the maxillomandibular fixation. With type I, however, where condyle–glenoid fossa contact supports the occlusion, the condylar sag will become apparent only when resorption of the condyle has taken place. (42)

1.8 Bone thickness

The anatomy, represented by bone quality or bone thickness (6,12,52), has been associated with bad splits. The bone pattern with the greater amount of medullary bone between the buccal and lingual cortex facilitates separation and increases the chances of a correct split, possibly due to the lower resistance attributed to the cancellous bone. (53)

Regarding bone thickness, studies have argued that a thinner ramus and body are more prone to bad splits. However, recent studies comparing bone thickness and bad splits have not covered the entire BSSO area and some have not classified the fracture patterns. (54)

Hou et al. (6) found that the ramus shape can generate different fracture lines. When the ramus presented in ‘half-moon’ or triangular form (thicker anterior region), the pattern was ideal (type I). Whereas when the ramus was ‘well distributed’, i.e., had similar thickness in the anterior and posterior regions, the split line occurred more posteriorly (type II), possibly due to the reduced resistance created by the considerable and even amount of medullary bone.

Aarabi et al. (12) and Wang et al. (52) quantitatively evaluated the anatomy by performing measurements in the ramus, lingula, retromolar area, oblique line, and mandibular canal, the latter in relation to the inferior border. Although these studies did not use a bone split classification,

they found that thinner mandibles and/or lower height rami presented higher rates of bad split.

1.9 The use of CBCT in assessing split patterns and condylar position

When performing a BSSO, there is no visual control of the lingual split pattern that occurs during the split procedure. Postoperative nerve damage in a BSSO, might be a result of the fact that the exact split pattern is unknown during the surgery. The surgical result of a BSSO is mainly evaluated using conventional X-rays, such as an orthopantomogram. This method does not allow a precise analysis of the split pattern. Recently, software platforms have been introduced to reconstruct a 3D model from (cone-beam) CT data to analyze 3D data in a virtual operating room (VOR). With these 3D models, a clear view of the lingual surface of the mandible can be achieved, enabling observation of the previously hidden lingual aspect of the fracture line. (4) The advantages of vertical CBCT scanning in contrast to conventional computed tomography (CT) are the lower radiation dose, lower cost, and the possibility to scan patients in natural head position. (55)

The true nature of 3D information lies in segmenting the desired volume out of the CBCT data and comparing 3D models. (56)

Orthognathic surgery can induce structural changes to the temporomandibular joint (TMJ). (57) Intraoperative and postoperative forces such as the mandibular split, mobilization of the proximal segment, condylar torque, an altered postoperative condylar position, and soft tissue tension exert their effects on the TMJ. These can all culminate in a remodeling process altering the shape of the condyle. (58)

CBCT is the best modality for evaluation of bony and positional condylar changes in temporomandibular joints. It provides better information about glenoid fossa and its remodeling. Therefore, 3D CBCT can be a better modality in evaluation of the postoperative stability and changes of glenoid fossa. (51)

The 3D evaluation of the lingual split line pattern in a BSSO procedure was first reported by Plooij et al. (4) They categorized the lingual split line pattern of 40 consecutive patients with symmetric mandibular hypoplasia who underwent advanced BSSO into four groups. Only 51% of the splits coursed as described by Hunsuck(20) ; 13% extended to the posterior border, 33% coursed along the outer side of the mandibular canal, and 2.5% had an unfavorable split pattern. The length and position of the medial bone cut during horizontal osteotomy showed that the likelihood of splitting according to Hunsuck's description increases when the bone cut end lies behind the mandibular foramen; however, it decreases if the bone cut end extends through the mandibular canal.

Nowadays, CBCT is an essential part of the orthognathic work-up and follow-up. The preoperative data are used for 3D virtual surgical planning and the postoperative data can be utilized to study the accuracy of the transfer, postoperative remodeling, and stability. (59,60)

Chapter Two: Discussion

2. Discussion

BSSO is the most popular orthognathic surgery used to correct different deformities of the mandible. (1)(61) It has evolved over the years to decrease the complications associated with it. Many of these have been mentioned in the literature, bad splitting is one of the most deleterious complications encountered in this surgery which can significantly affect its result. (62) So, attempts have been made to classify the lingual splitting patterns and study the association of various risk factors with unfavorable splits using CBCT. (10)(13) In This study, CBCT was used to assess the splitting pattern and LBCE in addition to monitoring the condylar changes after BSSO. Furthermore, the study investigated the relationship between the presence of impacted mandibular 3rd molar, as a risk factor for bad splitting.

Reference

1. Aarabi M, Tabrizi R, Hekmat M, Shahidi S, Puzesh A. Relationship between mandibular anatomy and the occurrence of a bad split upon sagittal split osteotomy. J Oral Maxillofac Surg 2014;72:2508–13.
2. Akhtar S, Tuinzing DB. Unfavorable splits in sagittal split osteotomy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999;87: 267–8.
3. August M, Marchena J, Donady J, Kaban L. Neurosensory deficit and functional impairment after sagittal ramus osteotomy: a long-term follow-up study. J Oral Maxillofac Surg 1998;56:1231–5.
4. Aziz S R. Simon P. Hullihen and the origin of orthognathic surgery. J Oral Maxillofac Surg. 2004;62(10):1303–1307.
5. Beukes J, Reyneke JP, Damstra J. Unilateral sagittal split mandibular ramus osteotomy: Indications and geometry. Br J Oral Maxillofac Surg. 2016;54:219–23.
6. Borstlap WA, Stoelinga PJ, Hoppenreijs TJ, van't Hof MA. Stabilisation of sagittal split advancement osteotomies with miniplates: a prospective, multicentre study with two-year follow-up. Part I. Clinical parameters. Int J Oral Maxillofac Surg. 2004 Jul;33(5):433-41.
7. Bouchard, C. and M. Lalancette, Infections after sagittal split osteotomy: a retrospective analysis of 336 patients. Journal of Oral and Maxillofacial Surgery, 2015. 73(1): p. 158–161.
8. Bruckmoser, E., et al., Factors influencing neurosensory disturbance after bilateral sagittal split osteotomy: retrospective analysis after 6 and 12 months. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology, 2013. 115(4): p. 473–482.
9. Caldwell J B, Letterman G S. Vertical osteotomy in the mandibular raml for correction of prognathism. J Oral Surg (Chic) 1954;12(3):185– 202.
10. Carter JB, Stone JD, Clark RS, Mercer JE. Applications of Cone-Beam

Computed Tomography in Oral and Maxillofacial Surgery: An Overview of Published Indications and Clinical Usage in United States Academic Centers and Oral and Maxillofacial Surgery Practices. J Oral Maxillofac Surg. 2016 Apr;74(4):668-79.

11. Cevidanes LH, Styner MA, Proffit WR. Image analysis and superimposition of 3-dimensional cone-beam computed tomography models. Am J Orthod Dentofacial Orthop. 2006 May;129(5):611-8.
12. Chrcanovic BR, Freire-Maia B. Risk factors and prevention of bad splits during sagittal split osteotomy. Oral Maxillofac Surg. 2012 Mar;16(1):19-27.
13. Cunha G., M. R. Oliveira, F. S. Salmen, M. F. R. Gabrielli, M. A. C. Gabrielli: How does bone thickness affect the split pattern of sagittal ramus osteotomy. Int. J. Oral Maxillofac. Surg. 2020; 49: 218–223.
14. D'Agostino A, Trevisiol L, Gugole F, Bondí V, Nocini P F. Complications of orthognathic surgery: the inferior alveolar nerve. J Craniofac Surg. 2010;21(4):1189–1195.
15. Dal Pont G. Retromolar osteotomy for the correction of prognathism. J Oral Surg Anesth Hosp Dent Serv. 1961;19:42–47.
16. De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg. 2009; 38: 609-625.
17. Epker B N. Modifications in the sagittal osteotomy of the mandible. J Oral Surg. 1977;35(2):157–159.
18. Falter B, Schepers S, Vrielinck L, Lambrichts I, Thijs H, Politis C. Occurrence of bad splits during sagittal split osteotomy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010 Oct;110(4):430-5.
19. Hou M, Yu TP, Wang JG. Evaluation of the mandibular split patterns in sagittal split ramus osteotomy. J Oral Maxillofac Surg 2015;73:985– 93.

20. Hu J, Song Y, Wang D, Yuan H, Jiang H, Cheng J. Patterns of lingual split and lateral bone cut end and their associations with neurosensory disturbance after bilateral sagittal split osteotomy. Int J Oral Maxillofac Surg. 2020 May;49(5):595-601.
21. Hunsuck E E. A modified intraoral sagittal splitting technic for correction of mandibular prognathism. J Oral Surg. 1968;26(4):250– 253.
22. Jung HD, Kim SY, Park HS, Jung YS. Orthognathic surgery and temporomandibular joint symptoms. Maxillofac Plast Reconstr Surg. 2015 May 28;37(1):14.
23. Kerstens HC, Tuinzing DB, van der Kwast WA. Temporomandibular joint symptoms in orthognathic surgery. J Craniomaxillofac Surg 1989;17:215–8.
24. Kim YJ, Oh KM, Hong JS, Lee JH, Kim HM, Reyes M, et al. Do patients treated with bimaxillary surgery have more stable condylar positions than those who have undergone single-jaw surgery? J Oral Maxillofac Surg. 2012; 70: 2143-2152.
25. Kim YK, Yun PY, Ahn JY, Kim JW, Kim SG. Changes in the temporomandibular joint disc position after orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Ra-diol Endod. 2009; 108: 15-21.
26. Klinge B, Petersson A, Maly P. Location of the mandibular canal: comparison of macroscopic findings, conventional radiography, and computed tomography. Int J Oral Maxillofac Implants. 1989; 4:327– 332.
27. Kondo T, Ong SH, Foong KW. Computer-based extraction of the inferior alveolar nerve canal in 3-D space. Comput Methods Programs Biomed. 2004; 76:181–191.
28. Kriwalsky, M.S., et al., Risk factors for a bad split during sagittal split osteotomy. British Journal of Oral and Maxillofacial Surgery, 2008. 46(3): p. 177–179.
29. Kuroyanagi N, Miyachi H, Ochiai S, Kamiya N, Kanazawa T, Nagao T,

Shimozato K. Prediction of neurosensory alterations after sagittal split ramus osteotomy. Int J Oral Maxillofac Surg. 2013 Jul;42(7):814- 22.

30. Larry MW, Joao RG. Surgical planning in orthognathic Surgery and outcome stability. In: Peter AB, Henning S, Ghali GE, Luke C. (eds.) *Maxillofacial Surgery.* 3rd edition. Missouri: Elsevier; 2017. p. 1071- 1074.
31. Mensink, G., et al., Bad split during bilateral sagittal split osteotomy of the mandible with separators: a retrospective study of 427 patients. British Journal of Oral and Maxillofacial Surgery, 2013. 51(6): p. 525– 529.
32. Monson LA. Bilateral sagittal split osteotomy. Semin Plast Surg. 2013;27(3):145-148.
33. Muto T, Shigeo K, Yamamoto K, Kawakami J. Computed tomography morphology of the mandibular ramus in prognathism: effect on the medial osteotomy of the sagittal split ramus osteotomy. J Oral Maxillofac Surg 2003;61:89–93.
34. Muto T, Takahashi M, Akizuki K. Evaluation of the mandibular ramus fracture line after sagittal split ramus osteotomy using 3-dimensional computed tomography. J Oral Maxillofac Surg 2012;70:e648–52.
35. Obwegeser H L. Orthognathic surgery and a tale of how three procedures came to be: a letter to the next generations of surgeons. Clin Plast Surg. 2007;34(3):331–355.
36. Ow A, Cheung LK. Skeletal stability and complications of bilateral sagittal split osteotomies and mandibular distraction osteogenesis: an evidence-based review. J Oral Maxillofac Surg. 2009 Nov;67(11):2344-53.
37. Panula K, Finne K, Oikarinen K. Incidence of complications and problems related to orthognathic surgery: a review of 655 patients. J Oral Maxillofac Surg 2001;59:1128–36. discussion 1137.
38. Park SB, Yang YM, Kim YI, Cho BH, Jung YH, Hwang DS. Effect of bimaxillary surgery on adaptive condylar head remodeling: metric

analysis and image interpretation using cone-beam computed tomography volume superim-position. J Oral Maxillofac Surg. 2012; 70: 1951- 1959.

39. Pepersack W J, Chausse J M. Long term follow-up of the sagittal splitting technique for correction of mandibular prognathism. *J Maxillofac Surg.* 1978;6(2):117–140.

40. Plooij M, Naphausen MT, Maal TJ, Xi T, Rangel FA, Swennnen G, de Koning M, Borstlap WA, Berge´ SJ. 3D evaluation of the lingual fracture line after a bilateral sagittal split osteotomy of the mandible. Int J Oral Maxillofac Surg 2009;38:1244–9.

41. Posnick JC, Kinard BE. Use of a 'low and short' medial cut limits sagittal ramus osteotomy interferences. Int J Oral Maxillofac Surg. 2021 Dec;50(12):1583-1587.

42. Prasad V, Kumar S, Pradhan H, Siddiqui R, Ali I. Bilateral sagittal split osteotomy a versatile approach for correction of facial deformity: A review literature. Natl J Maxillofac Surg. 2021 Jan-Apr;12(1):8-12.

43. Reyneke JP. Surgical technique. In Essentials of Orthognathic Surgery, 2nd Edition. Hanover: Quintessence Publishing Co Inc; 2010. p. 500- 512, p. 412-442.

44. Reza Tabrizi 1, Shoaleh Shahidi 2, Emad Bahramnejad 3, Hamidreza Arabion 4 Evaluation of Condylar Position after Orthognathic Surgery for Treatment of Class II Vertical Maxillary Excess and Mandibular Deficiency by Using ConeBeam Computed Tomograph J Dent Shiraz Univ Med Sci., 2016 December; 17(4): 318-325.

45. Rich, J., B.A. Golden, and C. Phillips, Systematic review of preoperative mandibular canal position as it relates to postoperative neurosensory disturbance following the sagittal split ramus osteotomy. International Journal of Oral and Maxillofacial Surgery, 2014. 43(9): p. 1076–1081.

46. Schmoker R, Spiessl B, Tschopp H M, Prein J, Jaques W A. [Functionally stable osteosynthesis of the mandible by means of an excentric-dynamic

compression plate. Results of a follow-up of 25 cases] SSO Schweiz Monatsschr Zahnheilkd. 1976;86(2):167–185.

47. Shaheen E, Shujaat S, Saeed T, Jacobs R, Politis C. Three-dimensional planning accuracy and follow-up protocol in orthognathic surgery: a validation study. Int J Oral Maxillofac Surg. 2019 Jan;48(1):71-76.
48. Smith, B.R., et al., Mandibular ramus anatomy as it relates to the medial osteotomy of the sagittal split ramus osteotomy. Journal of Oral and Maxillofacial Surgery, 1991. 49(2): p. 112–116.
49. Song JM, Kim YD. Three-dimensional evaluation of lingual split line after bilateral sagittal split osteotomy in asymmetric prognathism. J Korean Assoc Oral Maxillofac Surg. 2014 Feb;40(1):11-6.
50. Sousa, C.S., and R.N.T. Turrini, Complications in orthognathic surgery: a comprehensive review. Journal of Oral and Maxillofacial Surgery, Medicine, and Pathology, 2012. 24(2): p. 67–74.
51. Steinhäuser E W. Historical development of orthognathic surgery. J Craniomaxillofacial Surg. 1996;24(4):195–204.
52. Stokbro K, Aagaard E, Torkov P, Bell RB, Thygesen T. Virtual planning in orthognathic surgery. Int J Oral Maxillofac Surg. 2014 Aug;43(8):957-6
53. Tabrizi, R., Sadeghi, H. M. M. Complications of Orthognathic Surgery. In: Motamedi, M. H. K., editor. A Textbook of Advanced Oral and Maxillofacial Surgery Volume 3. London: IntechOpen; 2016.
54. Trauner R, Obwegeser H. The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. I. Surgical procedures to correct mandibular prognathism and reshaping of the chin. Oral Surg Oral Med Oral Pathol. 1957;10(7):677–689.
55. Turvey TA. Intraoperative complications of sagittal osteotomy of the mandibular ramus: incidence and management. J Oral Maxillofac Surg 1985;43:504–9.

56. Van Sickels J E, Hatch J P, Dolce C, Bays R A, Rugh J D. Effects of age, amount of advancement, and genioplasty on neurosensory disturbance after a bilateral sagittal split osteotomy. J Oral Maxillofac Surg. 2002;60(9):1012–1017
57. Veras RB, Kriwalsky MS, Hoffmann S, Maurer P, Schubert J. Functional and radiographic long-term results after bad split in orthognathic surgery. Int J Oral Maxillofac Surg 2008;37:606–11.
58. Verweij JP, Mensink G, Houppermans PNWJ, van Merkesteyn JPR. Angled osteotomy design aimed to influence the lingual fracture line in bilateral sagittal split osteotomy: a human cadaveric study. J Oral Maxillofac Surg 2015;73:1983–93.
59. Wang T, Han JJ, Oh HK, Park HJ, Jung S, Park YJ, Kook MS. Evaluation of mandibular anatomy associated with bad splits in sagittal split ramus osteotomy of mandible. J Craniofac Surg 2016;27:e500–4.
60. Wolford LM, Bennett MA, Rafferty CG. Modification of the mandibular ramus sagittal split osteotomy. Oral Surg Oral Med Oral Pathol. 1987 Aug;64(2):146-55.
61. Zamiri B., et al., Medial cortex fracture patterns after sagittal split osteotomy using short versus long medial cuts: can we obviate bad splits? International Journal of Oral and Maxillofacial Surgery, 2015.44(7): p. 809–15.