Original Article

Lingual Fracture Pattern Evaluation in the Mandible after the Bilateral Sagittal Split Osteotomy

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Abstract

Aim: The aim of the study was to evaluate the pattern of lingual split line when performing a bilateral sagittal split osteotomy (BSSRO) with different osteotomy methods. **Materials and Methods:** A total of 30 dry cadaveric mandibles were taken for the study. The classical Obwegeser and Dal Pont technique in the left side and additional inferior border osteotomy cut in the right side of BSSRO were compared based on modified lingual split scale. The maximum torque force that was needed to split the mandible was recorded and the fracture pattern was observed. Similar osteotomies were performed in 30 goat mandible which acted as control group. **Results:** The cadaveric dry mandible recorded an average torque of 14.8 +4.6 Nm with a maximum of 1.0 Nm and a minimum of 10.0 Nm in the left side. About 80% of the mandibles were Type I fracture pattern and 20% had Type III fracture pattern. In contrast with the modified BSSRO technique with an additional inferior border, osteotomy required a maximal torque of 14.0 N and a minimal torque of 7.0 with an average required torque of 10.9 + 4.2 N on the right side of the mandible. About 93% of the cases split by Type II fracture pattern in the modified BSSRO technique. In goat mandible, Obwegeser and Dal Pont recorded an average torque of 18.7 N + 4.10N and modified BSSRO technique in the right side recorded an average torque of 10.4 N + 4.10 N. **Conclusion:** The new technique resulted in predictable splitting of the mandible along the lower border away from the mandibular canal (Type II) and also decreased the force needed to complete the osteotomy by 31% when compared to the Obwegeser and Dal Pont BSSRO technique.

Keywords: Bilateral sagittal split osteotomy, Cadaveric mandible, Inferior alveolar nerve, Modified lingual split scale.

Introduction

The evolution of the specialty of oral and maxillofacial surgery has paralleled the evolution of medical science in general. In reflecting on this process, an event that may have marked the beginning of this evolution, for oral surgery, was the introduction of the sagittal split osteotomy. An osteotomy of the mandible is one of the most common surgical procedures used in orthognathic surgery.[1] At the beginning of the last century, extraoral approaches were used to achieve this goal which frequently resulted in visible scarring, pseudarthrosis, lip numbness, and even facial nerve palsy.[2,3]

A milestone was set by Trauner and Obwegeser who introduced the technique of the bilateral sagittal split osteotomy (BSSRO), then conducted through an intraoral approach. This new technique led to a significant reduction in all complications. Furthermore, esthetic results improved, as the proximal mandibular segment remained in its original position. Since its introduction, many modifications of the original technique have been described to decrease the risk of bad splits, to avoid bony non-union and to prevent trauma to the alveolar nerve.[4]

A procedure evolved that could be accomplished intraorally, without facial scars, and did not require the inconvenience of prolonged intermaxillary fixation. Schuchardt modified the previously highly problematic horizontal mandibular osteotomy by introducing a technique in which a horizontal cut was made above the lingula just through the medial cortical

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plate and extended to the posterior border of the ramus.[1,5] This cut was then connected to a horizontal cortical cut in the lateral cortical plate 1 cm below. The modification could be accomplished intraorally and afforded a larger medullary approximation. The procedure resulted in a minor decrease in complications but was far from being an acceptable approach.

Obwegeser[6] expanded on Schuchardt's technique by increasing the separation between the horizontal cuts to 25 mm. The horizontal cuts were connected with a cut along the medial aspect of the lateral oblique ridge. Obwegeser advocated incising the "periosteal band." The increase in the distance between the horizontal cuts greatly increased the amount of approximated bone and also the stability of the procedure.

Dal Pont gave a modification such that he advanced the lower horizontal cut to the buccal cortex of the mandibular body as a vertical cut between the first and second molars that he called the "oblique retromolar osteotomy." In this technique, the lingual horizontal cut was stopped just past the lingula.[7] A vertical cortical cut was made in the area between the first and second molars, just as it was in his first method. These two cuts were connected by a cut passing from the lateral oblique ridge through to the mylohyoid groove on the lingual. This cut left both the medial pterygoid and the masseter muscles attached to the proximal fragment.[8-10]

Hunsuck (1968) found that it was not necessary to make an actual cut through to the lingual as Dal Pont had done in his connecting cut. The Dal Pont lingual split would occur naturally as chisels were used to split the mandible. Hunsuck's superior cut was the same as the cut that Dal Pont used in his oblique retromolar osteotomy.[11] Hunsuck's anterior vertical cut was made in the area that he referred to as the "union of the ascending ramus and the body of the mandible in the tooth stabilization." This technique, like Dal Pont's, required only minimal muscle and periosteal stripping. With Hunsuck's modifications of the basic Obwegeser technique, all of the major components of the contemporary design for the sagittal split technique were in place.

When performing a BSSRO, with Dal Pont and Hunsuck modification, there is no visual control of the lingual split pattern that occurs during the split procedure. Post-operative nerve damage in a BSSRO might be a result of the fact that the exact split pattern is unknown during the surgery. Furthermore, Plooij *et al*. emphasized that the possible influence of the lingual fracture line (and its absence of control and visualization) could be a possible factor in damaging the IAN and influencing the fracture line due to the placement of the (medial) bone cuts. Plooij *et al*. investigated the lingual fracture line using 3D-CT after BSSRO performed by the Hunsuck the fracture modification and reported that only 51% of lines ran according to Hunsuck's description, whereas 33% ran through the mandibular canal.[12-14]

It seems that the lingual fracture lines after BSSRO were influenced by the positions of the end, of the medial and lateral bone cuts. In modified Wolford technique, the inferior border of mandible is weekend by an osteotomy, thus creating a new line of minor resistance. In this way, it was hoped to reduce the osteotomy depth and additionally reduce the torque necessary for the splitting process. This should make the splitting maneuver more controllable and lead to fewer complications in repositioning the mandible. Hence, the aim of the present study was to evaluate: Whether the characteristics of the fracture line are influenced or can be controlled, by adaptation of the length or direction of the medial and buccal bone cuts or whether the fracture line simply seeks the path at least resistance.

Materials and Methods

This study was conducted at the department of oral and maxillofacial surgery. The study was done to evaluate the influence of additional osteotomy at the inferior border of the mandible in addition to the classical Obwegeser and Dal Pont technique of BSSRO. The physioelastic properties of the dry mandible would be different from that of fresh or alive mandible. Hence, we included fresh goat mandible in the study as a control group. Ethical clearance was obtained from the Institutional Review Board before commencing the study.

Inclusion and exclusion criteria

A total of 30 adult dry human cadaveric mandibles without an impacted third molar were included and 15 fresh goat mandibles (sacrificed for the food) which acted as control group were also included. The mandibles with pathological condition or damaged condition were excluded from the study.

The clipper is fixed with load cell of 1 kg capacity and tightened with M3 screws. The handle where pressure is applied is fixed with load cell of one capacity. These load cells can measure force applied on it up to 10 N force or 10 Kgf. From the load cell, the values are taken to Wheatstone bridge circuit or HX711 circuit for converting analog signals or resistance received from the load cell and converts it to digital signal. These digital signals are taken to the controller unit. The purpose of the controller unit is to send the signal to the display interface.

The signal received from the HX711 is sent to computer/laptop using USB Ethernet data cable. Arduino software (IDE) is used to detect the readings and program is done in this software for the load cell force calculation. Then, standard weights are taken to calibrate the load the cell using the software and adjust the readings. After calibrating the load cell, it is fixed in the tool handle.

The two halves of the mandible articulate by a moveable cartilaginous symphysis well into advanced age. The ventral border of the body is convex and the notch for the facial vessels is indistinct. The short incisive part bears the alveoli for the incisor teeth (three on each side) which is followed immediately by one for the canine tooth. The interdental space has particularly sharp border. This is succeeded by the molar part which carries six alveoli for the cheek teeth.

The mental foramen can be palpated through the skin of the lower lip on the lateral surface of the mandible, a fingers breadth behind and below the canine tooth. The mandibular foramen which is the entrance to the mandibular canal lies on the medial surface of the ramus at the point of intersection between a vertical line drawn from the lateral canthus of the eye and one drawn caudally for the palpable edge of the maxillary cheek teeth. The mandibular head of the condylar process is transversely concave while the coronoid process is curved backward.

The mean distance from the mandibular foramen to inferior, anterior, and posterior border of ramus and to the sigmoid notch was evaluated and recorded. The mean parallel distance between the mandibular foramen and mental foramen was also measured.

Surgical technique

The BSSRO was performed in each mandible according to Obwegeser-Dal Pont technique on the left side and with an additional inferior border osteotomy in the right side.

Obwegeser and dal pont technique

The horizontal medial osteotomy was made just above the mandibular foramen through the cortical bone of the ramus. The vertical osteotomy was done at the lateral cortical bone mesial to the second molar tooth from the lower border of the mandible to the external oblique ridge. The horizontal medial cut and vertical lateral osteotomy cuts were connected by the oblique osteotomy cut running along the external oblique ridge.

The lateral vertical osteotomy cut was extended as J cut at the inferior border to extend till the lingual side. In the goat mandible, the lateral vertical bony cut was performed at two-thirds of the total length distal to the mental foramen to mandibular foramen. A 703 or 702 surgical carbide bur was used for all of the osteotomies. After the osteotomy cuts were completed, an osteotome with an 18 mm width was inserted distal to the second molar at an angle of 45 degrees which was driven into the mandibular body in the craniocaudal direction no deeper than 2/3 of that length, and the entire osteotomy was deepened and gradual separation of the buccal cortical plate from the distal segment was done. Then, proximal and distal segments were splitted using smith's spreader attached with a torque gauge. The maximum torque force that was needed to split the mandible was recorded in computer and the fracture pattern was observed.

The right side of each mandible was operated in a modified manner by an additional osteotomy at the inferior border of the mandible from the anterior vertical cut to the mandibular angle region in addition to the classical Obwegeser-Dal Pont technique. The osteotome was applied in a similar manner and the fracture pattern and force required to split the mandible were observed and recorded.

Modified lingual split scale (LSS)

To categorize the different split patterns, a LSS was developed. The LSS consisted of five categories based on the path of the fracture line on the lingual side of the ramus. In all cases, the split began at the distal end of the medial bone cut and followed one of the following paths:

- Type 1: The lingual fracture line started above and just behind the mandibular foramen and remained posterior and inferior to the mandibular canal but without the involvement of the lower border of materials and methods 34 the mandible. The lingual plate sagittally split above the level of the lower border of the mandible.
- Type 2: The lingual fracture line started above and just behind the mandibular foramen and extended to the lower border and connected with the inferior border osteotomy resulting in sagittal splitting of the mandible through the middle of the inferior border of the mandible. The fracture line was posterior and inferior to the mandibular canal.
- Type 3: The lingual fracture line extended to the posterior border of the mandible and splitted the entire ramus of the mandible and extended anteriorly above or along the lower border of the mandible.
- Type 4: The posterior fracture line started above and just behind the mandibular foramen and extended anteriorly in the mylohyoid groove or through the mandibular canal.
- Type 5: The unfavorable split resulting in fracturing of the ramus, angle, or buccal cortex of the mandible. The digital torque gauge was used to record the force necessary to split the mandible.

Results

The present study aimed at evaluating the lingual fracture pattern after bilateral lateral sagittal split osteotomy (BSSRO). The study included a total of 60 mandibles, out of which 30 were cadaveric dry mandibles and 30 were goat mandibles. The goat mandibles were included in the study because the physioelastic properties of dry mandible would be different from that of fresh alive human mandible; so fresh goat mandibles were included in the study as control group to evaluate whether the outcome was due to the influence additional inferior body osteotomy cut or due to the changes in the mechanical properties of the mandible.

BSSO was performed in both the groups. The mandibles from both groups (cadaveric and goat mandible) were assigned for two types of BSSRO techniques. The right side was assigned with "BSSRO with Inferior Border cut" (Modified Technique) and the left side was assigned with "BSSRO with J cut" (Obwegeser-Dal Pont's technique) as described in the methodology. Statistical analysis of the data obtained was done using SPSS 22 software. The frequency of distribution of fracture patterns was calculated in both the groups. Furthermore, descriptive statistics such as mean and standard deviations were calculated for the torque force observed in both the groups.

We used Mann–Whitney U-test to observe the significance in the frequency of distribution of fracture patterns in both the groups and $P < 0.05$ was considered statistically significant. We use independent t-test to analyze the significance between torque forces measured in both the techniques (Obwegeser-

Dal Pont's and modified technique) in both the groups and $P < 0.05$ was considered statistically significant. The mean distance from the mandibular foramen to anterior border, posterior border, sigmoid notch, inferior border, and parallel distance with mental foramen was evaluated and measured. We observed that there was no significant difference in the descriptive data between the right side and left side in both goat and human cadaveric mandible.

All the mandibles were symmetric in nature. With the Obwegeser-Dal Pont technique in the cadaveric dry mandible, we recorded an average torque of 14.8 + 4.6 Nm with a maximum of 18.0 Nm and a minimum of 10.0 Nm. When using the modified technique with an additional osteotomy at the inferior border, we recorded a maximal torque of 14.0 Nm and a minimal torque of 7.0 with an average required torque of 10.9 + 4.2 Nm. The new technique decreased the torque needed to split the jaw by 31% when compared to the classical BSSO technique. The decrease in the torque required to complete the split with the additional lower rim osteotomy was statistically significant.

With the Obwegeser-Dal Pont technique in the cadaveric dry mandible, 80% of the mandibles were Type I fracture pattern and 20% had Type III fracture pattern. In contrast with the modified technique with an additional osteotomy at the inferior border of the mandible, 93% of the cases split by Type II fracture. The creation of a new osteotomy at the lower border of the mandible improved the ability to control the splitting process in a more predictable manner with reduced force. The use of the Obwegeser-Dal Pont BSSRO technique frequently causes a fracture line near the mandibular canal predisposing to higher risk of nerve injury.

The average force required to complete the split after the completion of osteotomy was 18.7 N + 4.10N in Obwegeser-Dal Pont technique in comparison to 10.4 N + 4.10 N for BSSRO cut with inferior body osteotomy. The new technique decreased the torque needed to split the jaw by 40 percent when compared to the Obwegeser-Dal Pont BSSO technique. The decrease in the torque required to complete the split with the additional lower border osteotomy was statistically significant. The same trends were noted with the splitting patterns. Most of the hemi-mandibles (80%) split by Type I fracture pattern in the Obwegeser-Dal Pont technique surgical protocol. By adding the inferior border osteotomy, the mandibular split was more predictable and 100% the hemi-mandibles split by Type II fracture pattern. The study outcome in the dry mandible correlates with that of the goat mandible indicating the influence of the modified osteotomy in the fracture pattern of the mandible.

Discussion

Sagittal split osteotomy is considered to be the most established surgical technique used in orthognathic surgeries. Even though numerous modifications have been made, the conventional technique remains unchallenged as the sort out technique in orthognathic surgical procedure.[15] The modifications applied to this technique have been done to reduce or overcome complications associated with the surgical procedure. Some of the modifications have been associated in improving the esthetic outcome of the surgery. Verweij *et al*.[16] conducted a human cadaveric study on angled osteotomy design aimed to influence the lingual fracture line in BSSRO. In the angled osteotomy group, the modified osteotomy design was used, which included the horizontal lingual and connecting sagittal bone cuts.

The modification was the use of an angled vertical-buccal bone cut making an angle of approximately 45 degree with the inferior border of the mandible. This angled buccal bone cut originated from the second molar, extending toward the mandibular angle and ending near the masseteric tuberosity. Therefore, the inferior border cut was positioned near the masseteric tuberosity and subsequently aimed in a posterior direction.[17] The advantages of the angled osteotomy design promote a more posterior lingual fracture originating from the inferior border cut and a trend was apparent that this also might decrease the incidence of bad splits and inferior alveolar nerve entrapment.[18]

Common surgical complications during the surgery are damage to inferior alveolar nerve and unfavorable splits, the complications which are suggested to be related to each other. In theory, the more a technique facilitates to weaken the mandible in proportion to the depth of the osteotomy performed, the better it improves the outcome of the splitting process. Modifications in this approach may only allow adding osteotomies of the inferior and posterior borders to the classic Obwegeser procedure.[19]

The suggested modifications itself may be difficult mainly due to lack of ease in access to those regions with an intraoral approach; however, an osteotomy in the inferior border is achievable and is easily accessible than the posterior border of the mandible. There are not many studies that address the biomechanics of BSSRO to optimize the technique and in prevention of surgical complications.

Several investigators have described the influence of the osteotomy design on the lingual fracture line. Plooij *et al*. showed that a longer horizontal lingual bone cut ending behind the anterior border of the mandibular foramen resulted in more LSS1 splits (i.e., a more posterior splitting pattern). Plooij *et al*.[22] investigated mandibular ramus split patterns using three-dimensional computed tomography (3D-CT) and reported that in 83.75% splits at the lingual side of the mandibular ramus, only 51.25% of the split lines ran according to Hunsuck's description, whereas 32.5% ran through the mandibular canal. About 13.75% splits were at the posterior border of the mandibular ramus, and 2.5% were other fracture patterns (including buccal plate fracture or a bad split).

We were able to observe the frequency of distribution of splitting patterns in both the groups and also their significance. In our study, we observed that by adding osteotomy in the inferior border, the mandibles fractured in a more predictable manner away from the nerve and along the inferior border of the mandible. There are two points at which there is increased risk of damage to the IAN during surgical splitting; during manipulation of the medial side of the ramus and during fracturing, splitting.

Majority of the authors have reported post-operative sensitivity deficits due to manipulation close to the IAN. A weakened mandibular body with additional osteotomy procedure could reduce the manipulation time on the lingual aspect, also preventing the need to chisel around the IAN because of the preformed splitting pattern, and it also could help to reduce the operative time. Such complications can be minimized by adding the inferior border osteotomy. We were able to achieve good splitting results with the modified technique in our study setting.[20]

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. 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. Cone-beam computed tomography (CBCT)-based evaluation of the BSSRO combined with the LSS enabled objective evaluation of the surgical result, thereby adding a new dimension to the discussion of BSSRO techniques.

On examining the split patterns of the mandibular ramus in BSSRO through CBCT, the investigators hypothesized that the thickness of the cortical bone of the ramus, the degree of the mandibular angle, and the shapes of the mandibular ramus in the axial plane could be associated with these split patterns. In our study, we also measured the torque force used in the resulting fracture patterns. The modified BSSRO technique with inferior border osteotomy resulted in 30%–40% reduction of force required to split the mandible. It was correlating with the studies of Roland Böckman.

In his study, the device HTG2-10 gauge developed by IMADA (Toyohashishi, Japan) has been used to evaluate the force required to split the mandible. Its accuracy was ±0.5%, with a measurement frequency of 33 times per second. The applied force was recorded with a PC and ZLINK 2 software, international edition, version 2.02E, obtained from IMADA. Muto *et al*.[23] evaluated the mandibular ramus BSSRO split patterns with Obwegeser and Dal Pont technique using CBCT and reported 63% splits at the lingual side, 22% splits at the posterior border, and 15% splits at the buccal side of the mandibular ramus.

Majority of the mandibular ramus split at the lingual side near the mylohyoid sulcus; while the remaining split at the posterior border of the mandibular ramus. No fracture lines were observed through the mandibular canal. In terms of the relevant anatomical features that influenced the split patterns, Plooij *et al*.[22] suggested that the split pattern was related to the end position of the medial bone cut. Reyneke *et al*. and Kriwalsky *et al*.[24] reported that the split pattern is also influenced by the presence of the third molar and the patient's age. In general, fractures or splits usually occur in a weaker region in terms of structure and biomechanics. The thinner the cortical bone, the weaker it is biomechanically, and therefore, easier to split.

Ma *et al*. reported that the lingual cortical is thinner than the buccal cortical. Hence, most of the splits (75.38%) ran as described by Hunsuck. Ma *et al*. also found that the shapes of the mandibular ramus in the axial plane varied among patients. In majority of the patients, the mandibular ramus is wider mediolaterally in the anterior border than the posterior border, but Discussion,[25] the width in the anterior and posterior border is similar in few patients.[21] Ma et al. also classified mandibular ramus into three types: The half-crescent, sim-triangle shapes (with wider anterior region as compared to the posterior region), and the well-distributed shape (with similar width of the anterior and posterior regions). The half-crescent and sim-triangle shapes have higher chances of vertical pattern of fracture line to inferior border of the mandible during BSSRO. However, the mandibular ramus usually splits at the posterior border in the well-distributed pattern.

The mandibular angle contains less cancellous bone and more cortical bone. The attachment of the medial pterygoid and the masseter muscles in the mandibular angle compacts the medial and lateral plates in the mandibular angle region. The differential distribution and transmission of stress with respect to the different shapes of the mandible could be one of the reasons for the different split patterns of the mandibular ramus. However, in our study, we have not evaluated the influence of mandibular angle on the fracture pattern.

Hou studies have shown that the distribution and transmission of stress could be altered by an additional osteotomy at the inferior border of the mandible in the BSSRO. The torque needed to split the mandible could increase if the degree of the mandibular angle is less. During the surgery, they found that the mandibular body was initially split, and then, the mandibular ramus was split gradually. When only the mandibular body is split, most of the mandibular ramus split smoothly near the mylohyoid sulcus in the hyperdivergent patients.[18] In contrast, due to the larger curvature of the mandibular angle in the hypodivergent patients, it is difficult to split the mandibular ramus at the lingual side near the mylohyoid sulcus. To split the mandible completely in the hypodivergent patients, a deeper split is needed in the region of the mandibular angle and the mandibular ramus.

Along with the decreased force required to split the bone, adding an osteotomy at the lower border of the mandible also improved the ability to control the splitting process. Although, the outcomes of our study have been found to be significant and favorable, application of the modified technique must be done careful as it may be technique sensitive. It is also necessary to consider the biomechanical characteristics of dry cadaveric human mandible would be different from that of alive human mandible. To further recommend the use of the technique in clinical operative conditions, it may be relevant to consider using instrument that could easily facilitate a safe method to make an inferior border osteotomy through intraoral approach.

A notable suggestion would be the use of piezoelectric equipment with a hooked oscillating saw to facilitate an inferior border osteotomy. A rotating or oscillating saw could be used. Wolford and Davis[26] developed a reciprocating saw to cut the inferior border of the mandible in 1990. Using this, they achieved mandible splitting without malleting. They described a more predictable split with fewer complications. The marginal branch of the facial nerve should be considered while attempting the technique in patients. According to the authors, this technique should only be used by experienced surgeons to avoid complications.

Piezosurgery does not guarantee a safe bone split and is time consuming. Another possibility is the use of the Wethington osteotomes. These were designed by Simpson to facilitate horizontal osteotomies but also aid osteotomy of the inferior border. The osteotomy was achieved using a triangular, V-shaped osteotome without soft-tissue protection provided by the instruments themselves. Application of our modified technique with such proper armamentarium may produce a better and predictable outcome. However, it should also be considered that the split patterns are also influenced by the surgical factors including the experience of the surgeon performing the procedure along with the force and direction of the split.

A randomized control trial with suggest instruments and in a standardized operating protocol will serve to be significant in establishing the technique. In our study, we found that this modified BSSRO technique resulted in more predictable pattern of lingual fracture pattern along the lower border of the mandible away from the mandibular canal and with the less required force to split the mandible. However, the drawbacks of the study include practical difficulty of achieving lower border osteotomy through intraoral approach and the nature of dry mandible may be different from that of the alive mandible which may influence the outcome of the osteotomy. We recommend that this technique should be done with fresh cadaveric mandible through intraoral approach before attempting the technique in human orthognathic surgery.

Conclusion

In the cadaveric dry mandible, 80% of the mandibular splits were Type I fracture pattern (along the mylohyoid sulcus) with the Obwegeser-Dal Pont technique. In contrast with the modified technique with an additional osteotomy at the inferior border of the mandible, 93% of the cases split by Type II fracture (along the lower border of the mandible). The mean average force required to complete the split with the Obwegeser-Dal Pont technique was 12.6 + 2.4 Nm. When using the modified technique with an additional osteotomy at the inferior border, we recorded an average required torque of 8.7 + 2.1 Nm. The new technique decreased the torque needed to split the jaw by 31% when compared to the classical BSSO technique.

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