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Surgical procedures for correcting vertical maxillary excess: A review

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ABSTRACT

Introduction: Vertical maxillary excess, a common orthodontic problem that leads to long faces and open bites, can be repositioned with a Le Fort I osteotomy. However, the Le Fort I osteotomy poses the risk of a variety of complications including descending palatine artery (DPA) injury. Although several Le Fort I osteotomy modifications were reported to avoid complications associated with this osteotomy, only a few of such studies were conducted in Japan, and details remain scarce.

Patients and methods: We performed a literature review regarding modifications of Le Fort I osteotomies, including Le Fort I with a horseshoe osteotomy, modified horseshoe osteotomy, unilateral horseshoe osteotomy, pyramidal osteotomy, and U-shaped osteotomy. We identified eight relevant studies conducted in Japan; one study did not provide the number of patients examined. The 77 patients (seven studies) with vertical maxillary excess who underwent orthognathic surgery were ≥17 years old.

Discussion: There were no severe complications after the modified Le Fort I osteotomies. The postoperative maxillary changes obtained by the conventional horseshoe, modified horseshoe, unilateral type of horseshoe, pyramidal, and U-shaped osteotomies were nearly repositioned to the planned position and remained stable for ≥12 months post-surgery.

Conclusion: Our review indicates that preserving the DPA can lower the incidence of intra- and post-operative complications. Each modification of the Le Fort I osteotomy (i.e., conventional horseshoe, modified horseshoe, unilateral horseshoe, pyramidal, and U-shaped osteotomy) has its respective advantages and indications.

1. Introduction

'Vertical maxillary excess' is defined as excessive growth of the maxilla and associated dentoalveolar structures in an inferior direction, which can occur in the total maxilla, posteriorly, and/or anteriorly [1]. This clinical condition can lead to a long face, a gummy smile, and occasionally an open bite. Shortening a long face of an individual with vertical maxillary excess has been challenging. Generally, adult patients with skeletal malocclusion require treatment with a combination of orthodontic and orthognathic surgery, such as a Le Fort I osteotomy [2]. However, the Le Fort I osteotomy poses the risk of a variety of complications including descending palatine artery (DPA) injury. Some modifications have been made to the Le Fort I technique in efforts to avoid complications associated with the Le Fort I osteotomy, i.e., Le Fort I with a horseshoe osteotomy or a conventional horseshoe, a modified horseshoe, a unilateral type of horseshoe, a pyramidal osteotomy, and a U-shaped osteotomy. Only a few studies of these modifications have been conducted in Japan and the precise details and outcomes of the cases of Japanese patients who have undergone these procedures are not yet established.

The total Le Fort I osteotomy has a wide range of applications, and segmental osteotomies can also play an important role. The anatomical structures of the maxilla are characterized by a thin bone layer in between facial buttresses, the nasal cavity, maxillary sinuses, and bones with a variety of thicknesses that require special handling in planning, soft tissue access, osteotomy techniques, fixation, and tissue handling [3]. As is the case for many surgical procedures, the Le Fort I osteotomy carries the risk of various complications. The most common complication after a Le Fort I osteotomy is hemorrhagic complications. The high occurrence of hemorrhaging arises from the use of incorrect

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instrumentation at the operation area, specifically when cutting the bone or placing the osteotome too high into the pterygopalatine, damaging the internal maxillary artery; the sphenopalatine artery, and/or the DPA [4].

A widely decreased blood supply to the maxilla will result in aseptic necrosis. In 1990, Laningan et al. provided the first report of several cases of aseptic necrosis following a Le Fort I osteotomy [5]. They proposed that preserving the DPA, dividing the maxilla into a few segments, and avoiding palatal mucosa compression may reduce the possibility of aseptic necrosis [5]. Based on these suggestions, researchers, as well as clinicians, have made attempts to modify the Le Fort I technique, devising a Le Fort I with a horseshoe osteotomy (i.e., the conventional horseshoe), a modified horseshoe, a unilateral type of horseshoe, a pyramidal osteotomy, or a U-shaped osteotomy (Fig. 1).

With the conventional horseshoe osteotomy technique, the maxilla is divided into two segments [6]. With the modified horseshoe, the palatal parts are divided into three segment through two parallel osteotomies in the superior aspect [7]. Shimo et al. made alterations to this technique by devising a unilateral type of horseshoe osteotomy after a down-fracture of the maxilla in a Le Fort I osteotomy [8]. The pyramidal osteotomy technique is an improved form of the Le Fort I that involves the use of minimally invasive rotating instruments to eliminate bone interference over the DPA through a V-shaped osteotomy [9,10]. The U-shaped osteotomy is described as a technique that preserves the DPA to prevent posterior interference for the repositioning of the maxilla in a Le Fort I osteotomy [11].

In 1975, Hall and Roddy were the first to report the design of a horseshoe osteotomy; it was initially known as a 'total maxillary alveolar osteotomy'. [12] Various researchers subsequently described a similar maxillary osteotomy with various modifications, but these were not yet combined with the Le fort I osteotomy [13,14]. In 1977, Bell and McBride later introduced the 'Le Fort I with horseshoe osteotomy' as a technique that increases the versatility of the procedure and eliminates several clinical problems that might occur [15]. The horseshoe-shaped osteotomy is performed to separate the palatal and dentoalveolar segments of the maxilla to preserve the DPA and maintain the height of the nasal septum [15].

We conducted a review of relevant literature and identified eight studies of the Le Fort I with horseshoe osteotomy and its modifications that were conducted in Japan. In 2002, Harada et al. introduced the conventional horseshoe for the superior repositioning of the maxilla (Figs. 1 and 2A, B) [6]. Yoshioka et al. followed with investigation published in 2009 and 2011 [7,16]: they conducted the modified horseshoe by dividing the palatal portion into three sections and reducing the maxillary tuberosity, which is useful for repositioning the maxilla [16]; they noted that doing so provided skeletal stability after the surgery [7,16]. Preserving the DPA — especially in cases of high maxillary impaction and to maintain the height of the nasal chamber — was the greatest advantage of this technique modification [6,7,16,17]. Preserving the DPA also helps the surgeon to remove the maxillary tuberosity for the posterior movement of the maxilla without incurring a fracture or cutting the pterygoid process [18]. The remainder of this literature review summarizes the surgical procedures for correcting vertical maxillary excess.

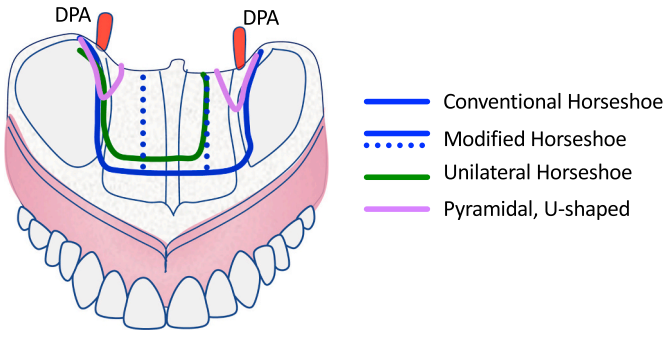

Fig. 1. Types of modification of the Le Fort I osteotomy for vertical maxillary excess. The conventional horseshoe procedure (*blue*) is a combination of Le Fort I with a horseshoe osteotomy. The modified horseshoe (*blue with dotted line*) is a conventional modification. The unilateral horseshoe procedure (*green*) combines Le Fort I with a unilateral horseshoe osteotomy. The pyramidal and U-shaped procedures (*purple*) are modifications technique of Le Fort I in which are the bone around the palatine is removed in a V- or U-shape to preserve the descending palatine artery (DPA). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2. Literature search results

We used the U.S. National Center for Biotechnology Information database 'PubMed' and conducted a manual search for publications in Japan concerning modifications of Le Fort I osteotomies, such as Le Fort I with a horseshoe (conventional horseshoe), modified horseshoe, unilateral type of horseshoe, pyramidal osteotomy, and U-shaped osteotomy for patients with vertical maxillary excess undergoing orthognathic surgery. The orthognathic surgery was done by several oral surgeons from Japan. The patient selection criteria were patients ≥17 years old with a chief complaint of forwardly placed upper front teeth. The patients presented vertical maxillary excess treated with orthognathic surgery. The exclusion criteria were patients who had undergone previous orthognathic surgery, had any drug allergies and had any history of maxillofacial trauma. Randomized clinical trials as well as case report studies were selected from the period 2000–2020. We conducted this review of the case series according to the Surgical Case Report (SCARE) guidelines [19].

As summarized in Table 1, our literature search identified eight relevant studies conducted in Japan: conventional horseshoe (n = 3), modified horseshoe (n = 2), unilateral type of horseshoe (n = 1), pyramidal osteotomy (n = 1), and U-shaped osteotomy (n = 1). One study did not provide the number of patients examined. A total of 77 patients' cases were described in the other seven studies.

2.1. Horseshoe osteotomies

All procedures were performed under general anesthesia. There were 44 cases in which a horseshoe osteotomy was performed after a Le Fort I osteotomy of the down-fractured maxilla. In this surgical procedure, at first, we used a vestibular incision is first performed on the first maxillary molar. Guiding holes are then created using a round burr or piezo cutting device in the superior nasal cavity and the antral side of the maxilla; the holes are then connected with the use of a chisel and mallet or a piezo cutting device to separate the alveolar process from the palate in order to allow free movement of the alveolar bone to achieve better maxillary impaction [7,16]. This technique is called a 'horseshoe' because the holes are drilled in the shape of a horseshoe (∩) to divide the maxilla into two different parts, i.e., the dentoalveolar and the palatal parts. After a horseshoe osteotomy, the fracture of the bone between the bone and the alveolar component usually makes it difficult to reduce the maxilla. This is due to the proximity of the palatal root of upper molar and DPA or nasal floor, making further cutting of the dentoalveolar or palatal components difficult and occasionally impossible [17].

When performing a conventional horseshoe, it is important to check the positional relationship between the palatal root apex of the maxillary molars and the maxillary sinus and nasal floor by preoperative computed tomography (CT) to avoid the risk of damaging the palatal root apex (Fig. 2A, B) [20]. Yoshioka et al. developed a modification of the conventional horseshoe in which the palatal part is divided into three segments (Fig. 2C, D) [16]. The advantage of this technique is that the horseshoe line is placed in the nasal floor on the side without impaction, thus reducing the risk of damage to the palatal root apex of the maxillary molars. In contrast, for cases of the unilateral impaction of

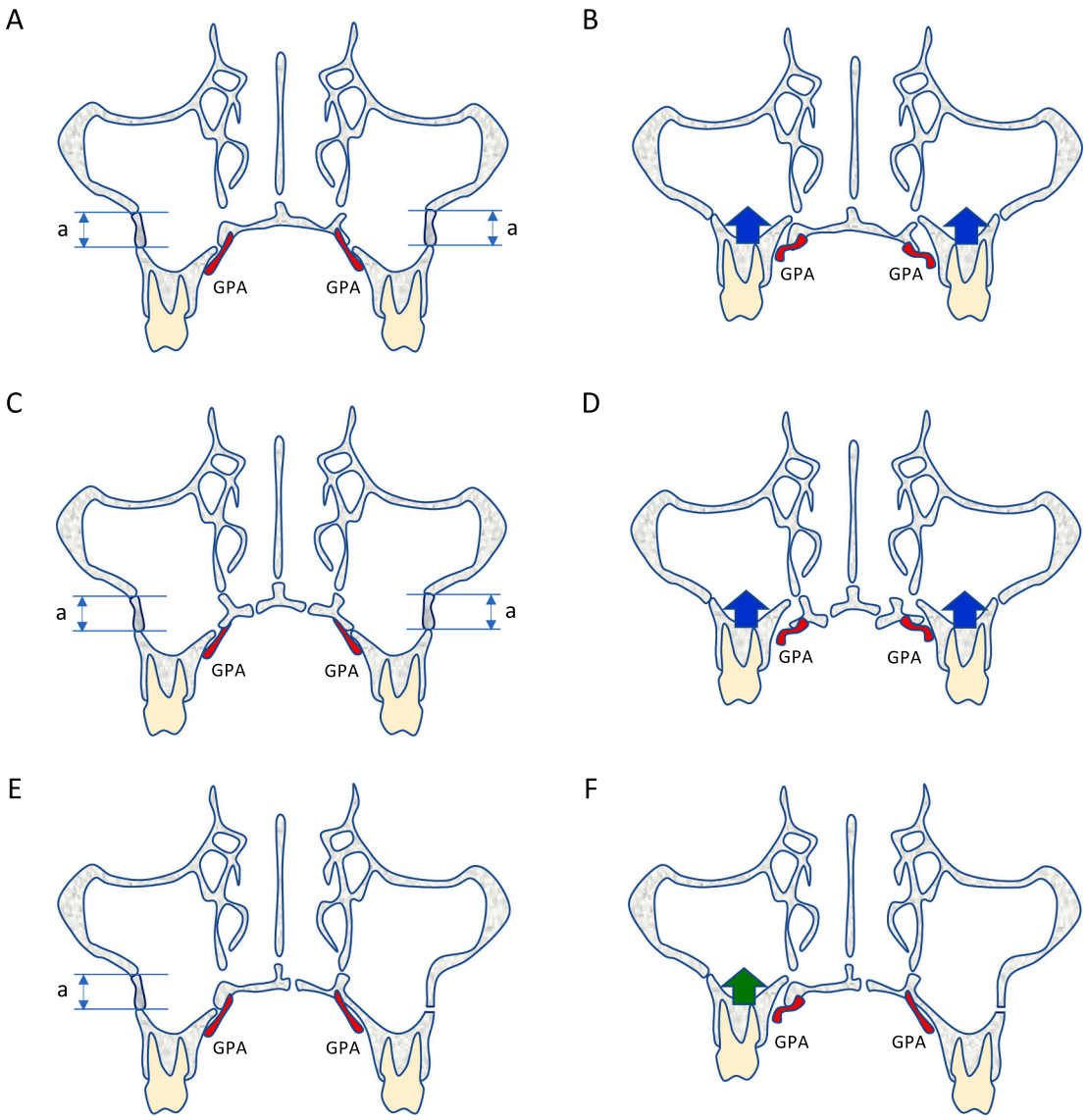

Fig. 2. The relationship between the amount of maxillary impaction of the first molar and the type of Le Fort I modification. A, B: Conventional horseshoe: Le Fort I with horseshoe osteotomy. C, D: Modified horseshoe: Le Fort I with modified horseshoe osteotomy. E, F: Unilateral horseshoe: Le Fort I with the unilateral type of horseshoe osteotomy. GPA: greater palatine artery. a: impaction length.

Table 1
Modification of Le Fort I osteotomy for vertical maxillary excess.

Author [ref.]	Year	Age, yrs Mean (range)	Gender: no. of patients	Type of osteotomy	Impaction of the nasal base	Skeletal class	Max. amount of impaction at 1st molar, mm
Harada et al. [6]	2002	24.3 (20–31)	M: 2, F:4	Conventional horseshoe	–	n.a.	n.a.
Yoshioka et al. [16]	2009	24.77 (18–31)	M: 4, F: 15	Modified horseshoe	–	n.a.	7.6
Yoshioka et al. [7]	2011	21 (19–25)	M: 1, F: 9	Modified horseshoe	–	II	5.0
Shimo et al. [20]	2013	34	F: 1	Conventional horseshoe	–	II	5.0
Omura et al. [11]	2015	n.a.	n.a.	U-shaped	+	n.a.	n.a.
Tominaga et al. [17]	2016	26.4 (21–35)	F: 8	Modified horseshoe	–	II	7.0
Shimo et al. [8]	2019	22.5 (21–24)	M: 1, F: 1	Unilateral horseshoe Conventional horseshoe	–	II, III	6.0
Yamauchi et al. [10]	2020	23,76 (17–42)	M: 11, F: 20	Pyramidal	+	I, II, III	7.0

Conventional horseshoe: Le Fort I with horseshoe osteotomy. Modified horseshoe: Le Fort I with modified horseshoe osteotomy. Unilateral horseshoe: Le Fort I with unilateral type of horseshoe osteotomy. n.a.: no data provided by the authors. M: male, F: female.

the maxilla, a unilateral modified horseshoe Le Fort I osteotomy was shown to be effective (Fig. 2E, F) [8]. After a maxillary osteotomy, the fixation was applied with absorbable plates and a 1.2-mm titanium miniplate at the anterior and posterior regions, respectively. The patient later receives postoperative guidance for post-discharge management, and follow-up examinations are conducted at 1, 3, 6, and 12 months to evaluate the accuracy of the maxillary reduction and check for post-operative complications. Fig. 3A-D provides pre-and post-operative photographs of a typical case of a Le Fort I with a unilateral type of horseshoe osteotomy.

The use of ultrasonic scalpels to perform these steps to prevent damage to blood vessels and palatal mucosa is a recent development. The osteotomy palatal segment provides flexibility and aids in the impaction of alveolar components [17]. First, the same small round drill as that mentioned above is used to make a pilot hole on the two parallel osteotomy lines of the target, and then the line is connected with an osteotome, and the palatal part is divided into three equal parts. The periosteum and the palatal mucosa are preserved. This technique can maintain the back volume of the nasal cavity, and the use of a round drill can easily scrape the front part of the nasal base in the alveolar bone assembly to maintain the airway volume in the front part of the nasal cavity as well as achieve a greater amount of posterior repositioning of the maxilla and maxillary impaction.

2.2. Pyramidal osteotomy

In the pyramidal osteotomy technique, two bone grooves are made in a triangular pattern by using an ultrasonic bone-cutting device, and a triangular-shaped piece of the bone is cut from the posteromedial sinus and the posterolateral nasal base. A straight raspatory or forceps is used to separate the segments at the base of the bone. The free pyramid-shaped part can then be slowly removed to avoid damaging the blood vessel with forceps. Then vascular bundle (including the soft palate) is then identified, and after the part of the posterior bone below the DPA bundle is identified, long swing tip of the ultrasonic bone cutting device is used to create a horizontal cutting groove, including the palatal bone. A curved raspatory is used to free the posterior bony segments [10].

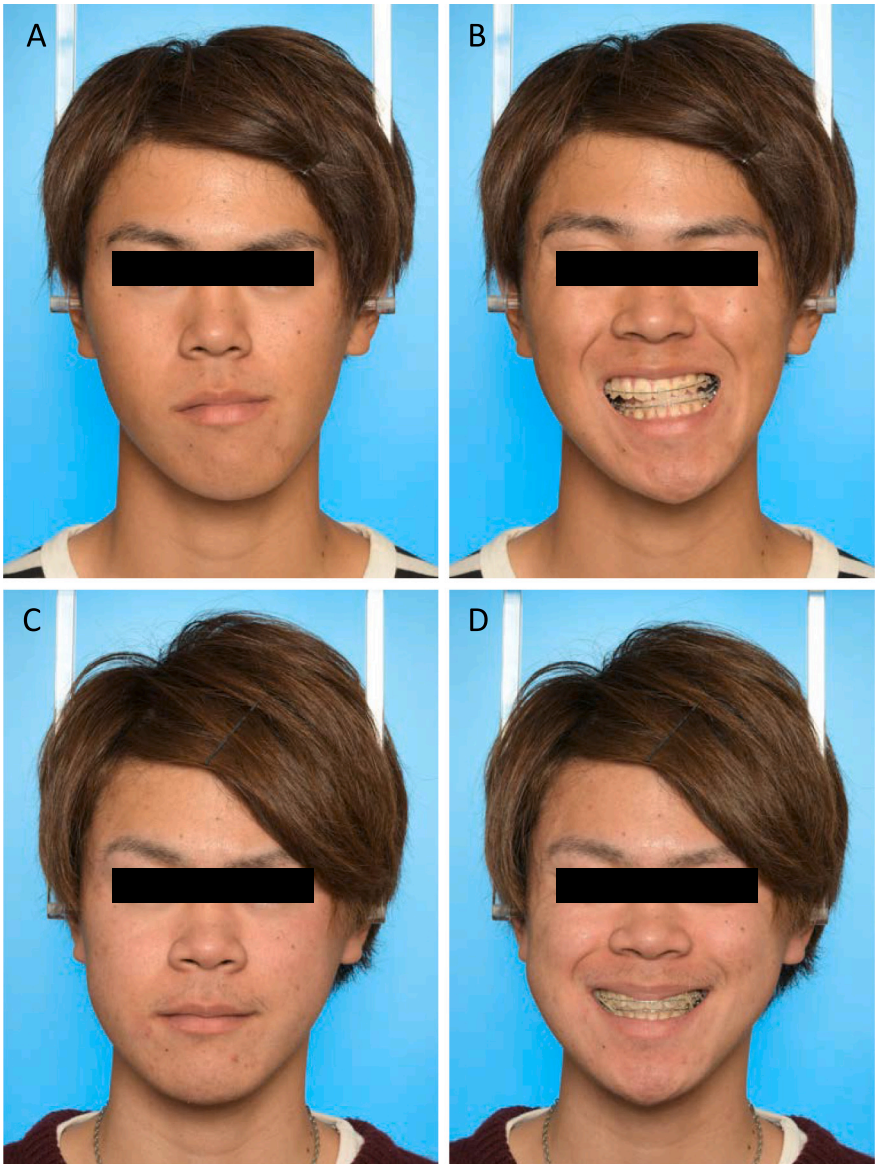

Fig. 3. Pre- and post-operative photographs of a case in which a Le Fort I with the unilateral type of horseshoe osteotomy was performed. A, B: Pre-operative photo of the patient with facial asymmetry. C, D: Post-operative photo; the facial asymmetry was corrected with Le Fort I with the unilateral type of horseshoe osteotomy.

2.3. U-shaped osteotomy

The U-shaped osteotomy technique is similar to the pyramidal osteotomy. The conventional Le Fort I osteotomy and downward fracture are performed after the injection of anesthetic around the foramen of the palate. A U-shaped osteotomy is then performed around the DPA marked with indigo blue. During the bone removal process, the blue-stained soft palate can be seen gradually observed through the remaining thin bone. A round drill or a piezoelectric bone device can be used for the osteotomy without damaging the palatal soft tissues. After a bilateral U-shaped osteotomy, the posterior bone disturbances are removed. In the case of facial asymmetry, repositioning can be easily accomplished with a unilateral U-shaped osteotomy [11].

3. Results

As shown in Table 1, orthognathic surgery was performed more often in the female patients compared to the male patients. The average age of the patients who underwent the surgery ranged from 17 to 42 years. The skeletal class ranged from class I to class III malocclusion with vertical maxillary excesses. The type of osteotomy performed is divided into a conventional horseshoe, modified horseshoe, unilateral type of horseshoe, U-shaped osteotomy, and pyramidal osteotomy. Using the eight collected studies, we next consider the postoperative outcomes of the surgeries based on the following aspects.

3.1. Presence of postoperative complications

The complication rate of a traditional or single segment of Le Fort I osteotomy was 9%. The reported postoperative complications were hemorrhage, nerve damage, bone cut, maxillary malposition, necrosis, and infection of the maxillary sinus. In some cases, hemorrhage occurred because of damage to the DPA [21]. Our review revealed that the surgical techniques (including traditional horseshoes, modified horseshoes, unilateral horseshoes, pyramidal, and U-shaped osteotomy) did not cause any complications.

Yoshioka et al. [7] and Tominaga et al. [17] reported that unlike the traditional or single-segment Le Fort I osteotomy, there were no severe complications (i.e., hemorrhage, avascular necrosis, devitalization of teeth, or oroantral/oronasal fistulas) after the conventional horseshoe and modified horseshoe techniques were used. Shimo et al. also reported that the conventional horseshoe and the unilateral type of horseshoe are useful techniques for correcting gummy smiles and facial asymmetry [8,20].

The mean blood loss in the pyramidal osteotomy technique is much less than that in the conventional Le Fort I technique [10]. The risk of intraoperative complications with the U-shape and pyramidal osteotomy techniques is low because: (1) these techniques can be performed safely away from the descending palatine canal, (2) the risk of DPA injury is less than that posed by the conventional Le Fort I method, and (3) these techniques allow safe repositioning for superior and/or posterior movement of the maxilla [10,11].

3.2. Degree of accuracy for repositioning the maxilla

The accuracy of repositioning the maxilla has been determined based on the discrepancy between the predicted and the actual horizontal and vertical movement of the upper first incisor (U1) and the upper first molar cusp tip (UMT) from the Frankfort horizontal plane. The modified Le Fort I + horseshoe osteotomy, including the conventional horseshoe, modified horseshoe, and pyramidal osteotomy, has shown good results in terms of repositioning the maxilla to the planned position. A study by Shimo et al. demonstrated that maxillary impaction up to 5.0 mm has been successfully treated with a conventional horseshoe in cases of severe gummy smiles with class II malocclusion [20]. The same result was reported by Tominaga et al.; the maxilla in cases of class II malocclusion was moved 3.0–7.0 mm superiorly with the conventional horseshoe [17]. An experiment described by Yoshioka et al. demonstrated that the vertical and horizontal differences between the planned and actual positions of the maxilla were not statistically significant [7], which indicates that the maxilla was repositioned nearly to its planned position with the modified horseshoe and the maxilla was posteriorly repositioned up to 5.0 mm [7]. In other studies, Yoshioka et al. demonstrated that the maximum impaction of the first molar can reach 7.6 mm treated with the modified horseshoe [16]. Similarly, the repositioning of the maxilla with a pyramidal osteotomy is up to 7.0 mm [10].

Harada et al. noted that the postoperative changes of the anterior nasal spine, point A, U1, and the point of maxillary tuberosity tend to increase within 6 months after surgery and remain stable at 6–12 months post-surgery [6]. The skeletal point change at any checkpoint is $<$0.5 mm. The degree of accuracy for repositioning the maxilla with either a conventional horseshoe, a modified horseshoe, or a pyramidal osteotomy was good. Nevertheless, impaction of the nasal base was reported only in cases in which a pyramidal osteotomy or U-shaped osteotomy was used [10,11].

4. Discussion

A maxillary osteotomy is a relatively safe surgical technique, with a complication rate $<$10% [21]. However, the frequent complications of this surgical procedure range from incorrect pterygomaxillary disjunction to trauma to the structure contained in the palatine canal. Injury to the DPA due to the inadvertent cutting of the surrounding bone is the most common cause of complications and leads to major bleeding [22,23]. The positioning of the maxillary segment is one of the most important procedures in bimaxillary surgery after the downward fracture. Surgery may be challenging due to the limited field of view, proximity to anatomical structures (such as the DPA), and/or the location of the pterygomaxillary are, typically in patients who require a higher maxillary posterior impaction or movement. The surgeon must carefully manage these areas to obtain the planned positioning because the surgical site varies in each case although the osteotomy line is made using a bone-cutting device or chisel [10].

The DPA is the main source of bleeding intra- and post-operatively because its anatomy is located on the posterior medial wall of the maxillary sinus [5]. However, there is disagreement in the literature regarding the importance of ligating the DPA during a Le Fort I osteotomy. Ligation of the descending palatine nerve vascular bundle (DPNB) during a Le Fort I osteotomy has been recommended to reduce the possibility of bleeding, but the sensory recovery of the palatine nerve after DPNB ligation has not been completely determined [24]. de Jongh et al. [25] and Al-Din et al. [26] concluded that neurosensory recovery, which leads to complete or partial resolution of the sensory deficit, will occur after a Le Fort I osteotomy. Surgeons thus still tend to preserve the DPNB in order to reduce the incidence of necrosis or maxillary sensory disturbances to prevent long-term neurosensory loss [10].

Many conventional Le Fort I osteotomies have been performed by many surgeons, whereas only a minority have performed a Le Fort I modification to remove the bone around the DPA. Based on the postoperative cephalometric analysis, a superiorly repositioned maxilla is not raised to its planned position with a single Le Fort I osteotomy, even if the bone around the DPA is removed [17].

The pyramidal osteotomy was introduced as an improved form of the Le Fort I, in which minimally invasive ultrasonic cutting device is used to cut the bone interference around the DPA in a V-shape. The pyramidal osteotomy is slightly different from other techniques because it involves the identification of the DPNB, and in some cases branches of the minor palatine artery can be recognized after the removal of the pyramidal bone segment. By identifying the DPNB, clinicians can reduce the risk of DPA damage and ultimately reduce the potential for blood loss [10]. In addition, with the pyramidal osteotomy's use of an ultrasonic cutting device, the operation time is shorter than that of the traditional Le Fort I

technique.

Compared to the traditional methods, the U-shaped osteotomy can be performed safely to reduce the risk of DPA injury. Compared with the Le Fort I with a horseshoe osteotomy, the U-shaped osteotomy has the advantages of a short operation time and easy identification of the easy periosteum, which can prevent damage to the DPA and soft tissue during the osteotomy [11]. The indications for a U-shaped osteotomy are posterior repositioning of the maxilla and maxillary impaction at $\geq$3 mm.

Tominaga et al. stated that the conventional horseshoe can be successfully applied to move the mobilized alveolar component up to 7.0 mm superiorly [17]. Some cases of maxillary excess with mandibular microgenia (which can theoretically be corrected by single maxillary surgery) require double jaw surgery; a Le Fort I and ramus osteotomy. This is done to avoid errors that can lead to malocclusion and relapse. By modifying the conventional horseshoe technique, the clinicians have been able to correct the maxillary excess without the intervention of the mandibular ramus and achieve sufficient mobilization of the dentoalveolar component [17].

Yoshioka et al. and Tominaga et al. presented the modified horseshoe and the conventional horseshoe respectively for repositioning the maxilla, in which the maxilla is moved superiorly [7] and posteriorly [17]. With these techniques, a greater distance for repositioning the maxilla superiorly is obtained; up to 5.0 and 7.0 mm, respectively. The modified horseshoe is performed using a small round drill or ultrasonic scalpel to form a semi-continuous pilot hole, and the bone and alveolar bone components are separated with an osteotome; in addition, the maxillary tuberosity is reduced in order to protect the DPA [17]. In contrast, Bell et al. used a Lindeman or fissure burr, which often damages blood vessels [15].

In 1960, McFall et al. were the first to introduce ultrasonic bone dissection [27]. Vercelloti et al. [28] then introduced the oblique angle piezoelectric short saw, which has many advantages; one it that this saw can be used for an osteotomy without damaging the surrounding tissues, and its safety and effectiveness have been tested by various researchers [29,30]. In 2003, Hadeishi et al. reported a non-Vercellotti ultrasonic bone curette (Sonopet; Miwata Co., Inagi, Japan) that is safely used in an anterior clinoidectomy and internal auditory canal opening without damaging adjacent structures [31]. In investigation by Yamauchi et al. of the use of an ultrasonic device to cut bone fragments and remove bony interference, the operation time was much shorter compared to traditional techniques. This may be because with the pyramidal osteotomy technique, the bone segment around the DPA area is easier to remove [10].

Harada et al. [32] compared the pulp blood flow (PBF) of patients who underwent a single-segment Le Fort osteotomy and those who underwent a Le Fort I with horseshoe osteotomy, and they reported that a maxillary osteotomy affected the changes in PBF and the recovery of pulp sensitivity. The maxillary blood flow of the patients who underwent a Le Fort I with horseshoe osteotomy was better than that of the patients with a single-segment Le Fort I osteotomy. Intraoperative and postoperative complications such as neurosensory disorders have rarely occurred.

During subperiosteal dissection, the infraorbital nerve may be compressed or retracted unintentionally, which may cause transient paresthesia and other neurosensory disturbances [4]. The results of a study by Garg et al. [33] revealed that it takes 3–6 months for the infraorbital nerve to feel normal again without any treatment.

The various modifications of Le Fort I osteotomy have different characteristics and patient indications. Yoshioka et al. noted that the modified horseshoe technique is very suitable for correcting deformities such as excessive maxillary bone, which requires repositioning of the upper and lower jaws. This modification supports rearward retraction and superior impact, providing nasal and posterior airway space capacity without interfering with the DPA. Unlike the single-segment Le Fort I osteotomy, this modification provides greater maxillary posterior movement (up to 4.77 mm) [7]. The modified horseshoe technique is also suitable for mandibles that are too small. Even with this technique, we can correct the deformity in one operation without causing bone recurrence and reducing the potential risk of progressive condyle resorption after surgery is reduced [17].

Shimo et al. also explained that the horseshoe osteotomy technique is also effective in cases of unilateral maxillary impaction [8]. The advantage of this technique is that the horseshoe-shaped line is placed on the side of the nasal floor and will not be impacted, thereby reducing the risk of damage to the palatal apex of the maxillary molar [8]. The pyramidal osteotomy technique with V-shaped cutting of superior bone interference can even be applied to patients with class III malocclusion, specifically in cases with a skeletal open bite or clockwise rotation of the maxilla. However, in patients with maxillary impaction without anterior movement or clockwise rotation, it is also necessary to remove the posterior interference to achieve maximum movement [10]. Establishing an ideal profile in cases of maxillary protrusion or asymmetry without nasal deformity is a challenging procedure. Compared to the horseshoe-shaped osteotomy technique, the U-shaped osteotomy technique enables a safe and reliable removal of mechanical bony interference and reduces the maxillary impaction in a shorter time [11].

Maxillary regression is sometimes required to obtain an ideal profile without nasal deformity in cases of maxillary protrusion or asymmetry with the maxillary normal anteroposterior position but with horizontal rotation of the maxilla. However, the application of a U-shaped osteotomy is challenging [11]. Since both U-shaped and pyramidal osteotomies affect only the posterior nasal spine (PNS), it is impossible to prevent the narrowing of the nasal cavity in cases in which the maxillary impaction is large. Yoshioka et al. reported that the combination of Le Fort I and a horseshoe osteotomy is a safe technique for posterior maxillary reduction without the risk of DPA injury. The accuracy of superior and/or posterior reduction with this technique has been confirmed in a series of osteotomies [7,16]. The maxilla was repositioned almost to the planned position by the conventional horseshoe. The method also provides the function of removing the anterior nasal base bone, thereby allowing a safe and highly superior impaction on the maxillary anterior bone, which is the reason why this method is suitable for high-position facial reduction operations such as in cases of vertical maxillary excess [6,17].

5. Conclusion

Our review of the relevant studies led us to conclude that preserving the DPA can lower the rates of intra- and post-operative complications. Modifications of Le Fort I osteotomy, including the conventional horseshoe, modified horseshoe, unilateral type of horseshoe, pyramidal osteotomy, and U-shaped each osteotomy, have their advantages and indications. The precision of the Le Fort I with a horseshoe osteotomy resulted in good skeletal stability and nasal cavity function by preventing narrowing of the nasal cavity. We suggested that the combination of the Le Fort I with a horseshoe osteotomy and its modifications are safe and reliable techniques for treating cases of vertical maxillary excess. In light of many surgical method options, the method chosen will depend on the number of maxillary movements and facilities. A further accumulation of cases and studies of the impact of surgical methods on nasal function are necessary.

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Ethical approval

Ethical approval was exempted by our institution.

Consent

Written informed consent was obtained from the patients for publication of this study.

Registration of research studies

Not applicable.

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Provenance and peer review

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Authors' contributions

Nisrina Ekayani Nasrun: Writing of original draft.
Shigehiro Takeda: Surgeon involved in care of patient of Fig. 3.
Yasuhito Minamida: Surgeon involved in care of patient of Fig. 3.
Daichi Hiraki: Collection of data and analysis.
Naohiro Horie: Collection of data and analysis.
Hiroki Nagayasu: Contributed in critical reading.
Tsuyoshi Shimo: Surgeon involved in care of patient of references no. 8, 20 and Fig. 3 conceptualising and writing of the paper.

Declaration of competing interest

None to declare.

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