Unconventional osteotomies in orthognathic surgery: a narrative review

Dani Stanbouly[1], Alexander V. Besmer[1], Kevin C. Lee[2], Sung-Kiang Chuang[3,4,5,6]

[1]College of Dental Medicine, Columbia University, New York, NY, USA; [2]Division of Oral and Maxillofacial Surgery, NewYork-Presbyterian/Columbia University Irving Medical Center, New York, NY, USA; [3]Department of Oral and Maxillofacial Surgery, School of Dental Medicine, University of Pennsylvania, Philadelphia, PA, USA; [4]Brockton Oral and Maxillofacial Surgery Inc., Brockton, MA, USA; [5]Department of Oral and Maxillofacial Surgery, Good Samaritan Medical Center, Brockton, MA, USA; [6]Department of Oral and Maxillofacial Surgery, School of Dentistry, Kaohsiung Medical University, Kaohsiung

Contributions: (I) Conception and design: SK Chuang; (II) Administrative support: SK Chuang; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: D Stanbouly, AV Besmer; (V) Data analysis and interpretation: D Stanbouly, AV Besmer; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Sung-Kiang Chuang, DMD, MD, DMScc. Clinical Professor, Department of Oral and Maxillofacial Surgery, School of Dental Medicine, University of Pennsylvania, Philadelphia, PA, USA; Private Practice, Brockton Oral and Maxillofacial Surgery Inc., Brockton, MA, USA; Attending, Department of Oral and Maxillofacial Surgery, Good Samaritan Medical Center, Brockton, MA, USA; Visiting Professor, Department of Oral and Maxillofacial Surgery, School of Dentistry, Kaohsiung Medical University, Kaohsiung. Email: sungkiangchuang@gmail.com.

Background and Objective: The bilateral sagittal split osteotomy (BSSO) and Le Fort variants dominate orthognathic surgery, being the most common osteotomies. Yet, these procedures carry their risks in terms of patient safety and outcomes. Common issues with the BSSO include permanent neurosensory deficits in patients relating to damage of the inferior alveolar nerve. Hence, there is a need to evaluate the efficacy of alternative osteotomy designs that may improve safety and patient outcomes. Indeed, there are multiple alternative osteotomies that may be better indicated for certain patients with specific maxillofacial features.

Methods: The literature was reviewed in order to all relevant studies across PubMed, regardless of study design, using certain key words related to unconventional orthognathic surgery.

Key Content and Findings: Alternative orthognathic surgery may range from different osteotomy techniques to using new technology. Examples of unconventional maxillary osteotomies include, but are not limited to, the quadrangular Le Fort I osteotomy to simultaneously address transverse and vertical issues of the maxilla and the horseshoe osteotomy to reposition the maxilla superiorly at great distances while protecting the descending palatine artery. Unconventional mandibular osteotomies include the high oblique sagittal split osteotomy to preserve the inferior alveolar nerve and the inverted L osteotomy for large mandibular advancements that preserve the airway length. Finally, the use of piezoelectric tools in orthognathic surgery, compared to traditional surgical instruments, is also of note. Many of the techniques involve case reports which suggest increased patient safety. However, more research is needed before mass adoption of these techniques in orthognathic surgery.

Conclusions: Many traditional orthognathic surgery techniques are commonly performed today with fantastic outcomes. That said, the scientific literature is beginning to note alternative and unconventional osteotomy techniques that may be better suited for certain patients.

Keywords: Unconventional; osteotomy; orthognathic; surgery

Received: 28 May 2022; Accepted: 25 July 2022; Published online: 11 August 2022.

doi: 10.21037/fomm-21-69

View this article at: https://dx.doi.org/10.21037/fomm-21-69

Introduction

In 1849, the first osteotomy of the craniomaxillofacial complex was chronicled by Dr. Hullihen (1). Since then, traditional osteotomies in orthognathic surgery have included the bilateral sagittal split osteotomy (BSSO), osteotomies of the oblique ramus of the mandible, Le Fort I osteotomies, and osteotomies of the genial tubercles (2). There are many instances in which an alternative approach to orthognathic surgery may be warranted. Some cases may require surgery that entails drilling around the inferior alveolar nerve and canal, placing the anatomical structure at risk of injury. Damaging the inferior alveolar nerve may lead to paresthesia in the chin, lower lip, and lack of motor function to the mylohyoid muscle.

A pilot study by Gruber *et al.* explores the use of ultrasonic bone cutting devices in orthognathic surgery to avoid potential injury to the inferior alveolar nerve (3). Further efforts to protect the inferior alveolar nerve involve using different tools and performing the osteotomy in a different position than the traditional BSSO. A BSSO consists of a cut "*medial to the ascending ramus*" and then continued "*anteriorly down the external oblique ridge to the level of the second molar*" (4). Kashani and Rasmusson echo this sentiment by stating similarly that the osteotomy in a BSSO occurs "*on the lateral aspect of the anterior border of the ramus midway up to the ascending ramus and downwards into the depth of the vestibule ending mesial to the second molar*" (2). These examples suggest that the osteotomy takes place around the lingula, an essential landmark for where the inferior alveolar nerve enters the mandibular foramen.

An alternative method studied by Seeberger *et al.* involves the high oblique sagittal split osteotomy (HSSO) (5). This method was implemented to avoid areas of danger in terms of the inferior alveolar nerve. Finally, there may be adjuncts to traditional orthognathic surgeries that involve additional corticotomies, which then become alternative and unconventional approaches. Fariña *et al.* write about using buccal alveolar corticotomies in combination with a traditional Le Fort I osteotomy as an "*alternative to segmentation of the maxilla in Le Fort I osteotomy*" (6). Many unique surgical techniques and technologies have been written about this in the literature. Still, they are not used widely due to insufficient evidence suggesting efficacy or because of technological or financial barriers to adoption. Regardless, when a complicated case may place a patient in harm's way, it is vital to be aware that there may be safer, more efficacious surgical techniques to minimize intra-surgical and post-surgical complications. In this chapter, the authors shall discuss the variety of alternative osteotomies that are outside conventional orthognathic surgery procedures. We present this article in accordance with the Narrative Review reporting checklist (available at https://fomm.amegroups.com/article/view/10.21037/fomm-21-69/rc).

Methods

The authors conducted a narrative review to achieve the aims of the following study (*Table 1*). To enable a more comprehensive review of the current literature, the study search was limited to a particular study design. Consistent with others (7), the authors also did not deem it necessary to critique the selected articles in completing this narrative review. The titles for all studies that appeared for the designated key words were screened for suitability to the current topic. Additionally, the references for all selected articles were screened to identify other potential studies that could supplement the narrative review. The selection process was executed by author D Stanbouly and AV Besmer using the following terms: unconventional osteotomies; unconventional orthognathic surgery; alternative osteotomies; alternative orthognathic surgery; modified osteotomy; modified orthognathic surgery.

Quadrangular Le Fort I osteotomy

Dr. Eugene E. Keller utilized the quadrangular Le Fort I, or the "high modified Le Fort I", in 1981. The technique involves making a bone cut "*as high as possible*, *from the tuberosity around the whole maxilla*, *staying just beneath the infraorbital foramen*" (8). For maxillary advancement, this technique alteration provides increased esthetic results stability post-operation. Bennett and Wolford continued to raise the level of the bone cut by placing the osteotomy "*at the level of the floor of the nose*" (8). Multiple graft types have been used in conjunction with the quadrangular Le Fort I to facilitate healing. The literature notes both autogenous iliac crest and porous block hydroxyapatite grafts. Grafts are placed "*from the piriform aperture medially to the zygoma laterally*" and "*the infraorbital rim superiorly and extend inferiorly to lie posterior to the anterior antral wall on the floor of the antrum*" (8). The procedure above is another form of surgery used to correct a Class III skeletal malocclusion, but one caveat is that patients must have normal nasal-

Table 1 The search strategy summary

Items	Specification
Date of search	03/01/2021–05/01/2021
Databases and other sources searched	PubMed
Search terms used	Unconventional osteotomies; unconventional orthognathic surgery; alternative osteotomies; alternative orthognathic surgery; modified osteotomy; modified orthognathic surgery
Timeframe	1849–2021
Inclusion and exclusion criteria	Inclusion criteria entailed studies were relevant to the topic of unconventional orthognathic surgery. No specific study design was preferred
Selection process	The selection process was independently conducted by Dani Stanbouly and Alexander V. Besmer

ethmoidal position and proportions. The quadrangular Le Fort I also assists with transverse and vertical issues of the maxilla. The transverse indications are maxillary midline shifts greater than 2 mm and general maxillary transverse deficiencies. The vertical indications are deficiencies or excess greater than 5 mm. The most interesting indication can be established mid-surgery. Suppose a patient is scheduled for a quadrangular Le Fort II but lacks piriform aperture bone strength. In that case, the surgeon may audible to a quadrangular Le Fort I, as the preparations and post-operative care are identical in both surgeries.

Keller summarizes 54 patients who received a quadrangular Le Fort I, with most patients receiving maxillary advancements between 6–10 mm, vertical alterations between 4–10 mm, and transverse alterations between 3–10 mm. Only 4 of the 54 patients had swellings of noticeable proportion and were treated with incision and drainage and antibiotic prescription. All four cases were resolved with no following consequences. Three patients had sequestra form, but the patients all had previous maxillary alveolar cleft deformities. Therefore, there is a confounding variable behind the sequestra. All other sites in all patients healed without complications. Only one patient had any neurosensory disturbances associated with the inferior alveolar nerve, yet this subsided within six months of surgery completion. Lacking significant complications, the quadrangular Le Fort I is a practical, versatile surgery for maxillary advancement. In addition, it is possible to fix transverse and vertical issues simultaneously with the mandibular advancement.

Anterior segmental maxillary osteotomy

The anterior maxillary osteotomy (AMO) is often indicated for anterior vertical maxillary excess in cases with normal posterior occlusion, sagittal maxillary excess with normal posterior occlusion, maxillary anterior protrusion of anterior teeth with normal incisor axial inclination to bone and normal posterior occlusion, excessive proclination of anterior teeth, anterior open bite, and normal posterior occlusion (9). In 1921, Günther Cohn-stock was the first surgeon who executed this technique in an attempt to surgically correct an exaggerated overjet and overbite of central maxillary teeth (9). Subsequent variations to the procedure were developed by Wassmund, Wunderer, and Cupar (10). These variations were geared towards maintaining sufficient blood supply to the maxilla while giving adequate access for instrumentation. Wassmund, in particular, approached the labial premaxillary cortex using three vertical incisions and subperiosteal tunneling to complete the labial osteotomy without reflection of labial or palatal flaps. In this way, both the labial and palatal blood supply are maintained. However, the disadvantage with Wassmund's technique is that the osteotomy is made in a relatively blind fashion (10).

In 2011, a pilot study was conducted with 15 patients who underwent a modified form of the anterior segmental maxillary osteotomy, one that spares the nasal floor. The horizontal osteotomy cut was at a minimum of 4 mm apical to the root tips of the maxillary canines, which were used as a guide since they have the longest roots. You see, involvement of the nasal floor in conventional AMO results in changes in the nasal soft tissue architecture post-surgery. A cosmetic problem ensues, with the widening of the alar base and anti - tip rotation of the nasal tip explicitly. Thus, the advantage of this modified technique in this pilot study is that the osteotomy line is well below the nasal floor and walls, resulting in negligible alar widening (11).

Posterior segmental maxillary osteotomy

The posterior maxillary osteotomy (PMO) has several indications: maxillary hyperplasia, distal replacement of the posterior maxillary alveolar fragment to provide space for proper eruption of an impacted canine or bicuspid posterior open bite, posterior crossbite, or scissor bite, and anterior open bite (2). A case report illustrated the efficacy of PMO as a surgical procedure for an anterior skeletal open bite. There was a stable occlusion and improvement of tongue posture at a 5-year follow-up with the patient after the maxillary posteriorly segmental osteotomy, shifting posteriorly and inferiorly (12). PMO has also been utilized to enhance the posterior maxilla, especially when atrophied, for easy prosthodontic rehabilitation with implants. For instance, after the extraction of several posterior teeth, a patient had a significant vertical deficit of the maxillary crest that could not support any implants. A trapezoidal-shaped osteotomy was executed, and the liberated segment was then rigidly fixed with a standard osteosynthesis plate at the desired location. The resulting bone gap was filled with the particulate cadaveric bone. After bone consolidation, implants were successfully placed (13). In another case that entailed the utility of PMO for optimal implant placement, the problem was the opposite: vertical excess at the left posterior maxillary ridge. The patient was edentulous at the left second premolar and beyond distally. Hence, the treatment plan was to mobilize the segment superiorly and stabilize it at the ideal position with a titanium miniplate and screws. After a 2-week healing period, implants were placed to achieve a successful relationship (14).

Horseshoe osteotomy

Hall and Roddy first described the horseshoe osteotomy, which they called '*total maxillary alveolar osteotomy*' (15). In 1977, Bell combined the horseshoe osteotomy with the Le Fort I osteotomy. To correct a retrodisplaced edentulous maxilla with consequent retrusion of the upper lip, Bell repositioned the atrophic maxillary alveolar ridge anteriorly and inferiorly through the horseshoe osteotomy and filled the gap with bone grafts (16). The technique was modified by Obwegeser and Farmand, where the horseshoe sandwich osteotomy was followed up with a submucosal vestibuloplasty. This approach was geared towards increasing the vestibular and palatal height since the hard palate remains pedicled on the nasal septum and vomer after the horseshoe-shaped alveolar ridge is moved inferiorly and anteriorly following the original horseshoe osteotomy proposed by Bell. This new technique could also change the intermaxillary relationship and often provided mucosal relief (17).

Recently, the horseshoe osteotomy, in conjunction with the Le Fort I osteotomy, was used to reposition the maxilla superiorly at great distances. Furthermore, unlike the traditional Le Fort I osteotomy, the horseshoe osteotomy enabled maxillary repositioning while safeguarding the descending palatine artery (DPA) because there is no need for bone trimming around the vessel, thereby maintaining the nasal chamber volume. Yoshioka allocated patients to two different treatment arms according to the extent of superior impaction: 9 patients underwent Le Fort I osteotomy alone where preoperative planned superior movement <3.5 mm. Ten patients underwent Le Fort I and horseshoe osteotomy where the preoperative planned superior movement >3.5 mm. The resulting discrepancy between the planned and measured superior movement of the maxilla in the Le Fort I group was 0.30 mm, while that for the combination (i.e., horseshoe) group was 0.23 mm. Hence, the maxillae in both groups were repositioned close to their planned positions during surgery. Both groups showed skeletal stability without any significant post-operative changes at follow-up 1 year later. Hence, Yoshioka *et al.* demonstrated that the horseshoe-fort I osteotomy combination can be a valuable technique for reliable, superior repositioning of the maxilla (18). Yoshioka *et al.* also showed the efficacy of the horseshoe-fort I osteotomy combination for posterior repositioning of the maxilla. The discrepancy between the planned and actual posterior movement was minuscule, and there were no post-operative complications. Hence, the horseshoe-fort I osteotomy combination can be a safe and accurate treatment option for adults with the dentofacial class II deformity (19).

Corticotomy-assisted Le Fort I osteotomy

Tooth-related issues can be seen with the Le Fort I osteotomies, involving but not limited to pulpal necrosis and tooth loss after surgery. If the teeth happen to be safe during the procedure, there is still a chance that interdental structures may be affected, especially between the roots of teeth. An effort to combat this misfortune is by implementing corticotomies in addition to a traditional Le Fort I osteotomy. Fariña suggests the use of "*maxillary selective alveolar decortication (SAD)*" in combination with Le Fort I osteotomies to decrease the likelihood of adverse events (6). At the end of the study involving six subjects, Fariña reports that no patients had any issues with tooth vitality. This study appears to be the first of its kind, and more studies are needed to validate the results of this study. However, it seems as though when there is limited interradicular space and damage to dental structures, it may be advised to add corticotomies while performing a Le Fort I surgery to promote patient safety.

High oblique sagittal split osteotomy

An alteration in orthognathic surgery may come from the location of the osteotomy rather than the tool that executes the osteotomy. BSSO has become the gold standard in terms of split osteotomies for orthognathic surgeries; however, several studies have made use of the alternative HSSO. Similar to using piezoelectric tools, the HSSO aims to preserve the inferior alveolar nerve and surrounding tissues from damage. The HSSO contains an oblique bone section starting from an area superior to the lingula and traveling downward and laterally above the angle of the ramus (20). Seeberger *et al.* studied 50 patients undergoing HSSO to understand neurosensory alterations and function of the temporomandibular joint (TMJ) after surgery (5). No patient had sensory alterations in the lip or chin 6 weeks after the operation, which is evidence of not harming the inferior alveolar nerve. Similarly, none of the patients noted abnormal or decreased function of the TMJ after the surgery. Compared to other studies that suggest up to 24% of patients having sensory alterations in the lip and chin after BSSO, the HSSO becomes an interesting and possibly safer alternative (21). Yet, Seeberger states that more studies are needed to confirm fewer neurosensory deviations after HSSO as this study only tested a few patients at a maximum of six months after their procedures. Herrera-Vizcaino *et al.* did just this and reviewed 116 patients who received HSSO (22). This study confirms the findings by Seeberger *et al.* that there was greater preservation of the inferior alveolar nerve than BSSO. During the long-term follow-up, there were no sensory alterations noted by patients. There is conflicting evidence between Seeberger and Herrera-Vizcaino about rates of TMJ dysfunction after HSSO. However, Herrera-Vizcaino states that different plates were used and that it was the plates that contributed to TMJ issues. Therefore, more studies involving several plate configurations in conjunction with HSSO could be carried out to elucidate whether the surgery or the plates contribute to TMJ dysfunction after HSSO.

Inverted L osteotomy (ILO)

The first mention of the ILO occurs in 1968 in the *Journal of Oral Surgery*, written by Dr. Caldwell (23). Wu *et al.* compared the ILO with a conventional bilateral split sagittal osteotomy in treating obstructive sleep apnea (OSA) patients. A total of 28 patients were split into two separate groups, nine receiving an ILO and 19 receiving the sagittal split ramus osteotomy (SSRO). Both groups saw significant apnea hypopnea index decreases, with a 90.2% decrease in the ILO group and an 85.6% decrease in the SSRO group (24). Differences came between groups in physical airway changes. The ILO group saw no statistically significant change in airway length, and the hyoid didn't move. In the SSRO group, the airway length decreased, and the hyoid moved upward and forward. Therefore, if deciding between these two procedures for OSA treatment, depending on desired airway changes, airway length and hyoid position could be two indications for ILO instead of SSRO. In terms of patient satisfaction, 88.9% of patients in the ILO group were satisfied, while 84.3% of the SSRO patients were satisfied. Therefore, there is no significant difference in patient satisfaction in both groups. Unfortunately, six patients in the SSRO group had mild inferior alveolar nerve injuries, and three subjects had major inferior alveolar nerve injuries. Therefore, safety may be of concern for SSRO, and ILO may appear as a safer alternative for surgical treatment of OSA.

ILO combined with iliac crest bone grafts was used in 11 patients from 2008 to 2010, and follow-ups were chronicled by Zhu *et al.* No patient had severe complications. Horizontal changes ranged from 5.4 to 12.5 mm, and vertical changes ranged from 8.6 to 15.5 mm. Therefore, the bilateral ILO can be used for large magnitude mandibular advancements and corrections. Zhu *et al.* state that "*all of the patients involved had significant improvements in occlusion and aesthetic appearances postoperatively*" (25). One benefit of ILO is that the procedure can be completed via an extraoral or intraoral approach. Zhu *et al.* stated that ILO was chosen in some patients because the typical SSRO was too tricky, so ILO presents as a more straightforward procedure in terms of technique. This ease and versatility of use allow for safety benefits for both the patient and surgeon. Greaney *et al.* describe alterations to the typical ILO which improve cosmetic outcomes. Since the ILO used to be completed via an extraoral incision, there is skepticism about the esthetic outcome of the surgery. Instead, the ILO is conducted using a "*standard intraoral incision along the external oblique* *ridge*", and the osteotomy is completed with a "Lindeman bur and right-angled saw" (26). The primary benefit of the ILO written by Greaney is its safety, suggesting a lower rate of inferior alveolar nerve injury. Reporting on seven patients who underwent ILO, Greaney *et al.* noted that sensation to the lower lip returned to baseline after 1 year in all patients (26).

Mandibular subapical osteotomy

Initially written about by Hofer in 1942, the mandibular subapical osteotomy was refined by MacIntosh in 1974 (27). Yet, the indication for this procedure as described in 1974 was extremely specific, with MacIntosh stating that the primary indication of the mandibular subapical osteotomy was to treat infantile apertognathia. A more recent paper by Jeong *et al.* studied 33 patients undergoing four premolar extraction combined with mandibular anterior subapical osteotomies under local anesthesia. Firstly, it must be noted that an anterior mandibular subapical osteotomy was completed under local, and not general, anesthesia. Therefore, there may be benefits for patients if they require procedures to be less intensive. Yet, the author noted a decrease in "*inferior pharyngeal airway space*", suggesting that caution must be used in patients with high risk for OSA (28). There was no mention of neurosensory disturbances in patients, nor was anything mentioned about complications after surgery. Therefore, no conclusions about the safety of a mandibular anterior subapical osteotomy may be drawn from this study. Yet, for patients not at risk of OSA, this procedure may be an adequate treatment for skeletal and dentoalveolar class II patients requiring combined orthodontic and surgical treatment. Konopnicki *et al.* add to the evidence that total mandibular subapical osteotomy may be used to correct inferior alveolar retrusion. Eight patients were analyzed, and the results after surgery suggest "*mandibular subapical osteotomy may be considered as a stable, safe and ideal procedure for patients having a class II deformity*" (29).

Piezoostomy/ultrasonic tools in orthognathic surgery

Traditional osteotomies are non-specific in terms of the tissues that are involved in cutting during surgery. The benefit of ultrasonic technology is the specificity of tissue destruction. Variables are changed, which leads to the cutting device only lysing specific tissues. Medicine has shown use for removing hard tissue only via renal calculus and gallbladder stone removal (30,31). There may be a niche for ultrasonic and piezoelectric tools in orthognathic surgery in cases that involve complicated anatomy involving the inferior alveolar nerve. Gruber *et al.* summarize seven orthognathic surgery cases involving ultrasonic technology. The surgeries were all completed by the same team; therefore, the quality of surgery is consistent between each patient. However, six surgeries involved patients with Class II occlusion. Consequently, this pilot study may be more applicable only for BSSO involving Class II correction. This study states that the lack of need for applying "high pressure" during surgery could be an advantage when precision is required around anatomic landmarks (3). Seven months after completing the surgeries, only one patient reported nerve disturbance, and the qualitative description can be described as mild. This is in comparison to a study involving 25 patients undergoing traditional BSSO without ultrasonic technology where, after six months, 26% of patients reported neurosensory disturbances (32). More research comparing traditional BSSO with BSSO using piezoelectric surgical devices is needed to compare the risks and benefits of ultrasonic surgery.

A more extensive study involving 180 total surgeries attempted to discern differences in several variables between piezoostomy and saw and chisel osteotomy. Landes *et al.* collected 90 data from 90 piezoelectric surgeries with the following distribution: 34 monosegment osteotomies, 47 Le Fort I osteotomies, 94 sagittal split osteotomies, 11 symphyseal, and four mandibular body osteotomies (33). This data was compared to the following distribution of conventional surgeries: 58 monosegment osteotomies, 27 segmented Le Fort I osteotomies, 130 sagittal split, and four symphyseal osteotomies. Although the control group (traditional osteotomy) does not perfectly align with the ultrasonic group in terms of surgery selection, this extensive array provides a broader analysis of the benefits and risks of piezoostomy compared to saw and bur osteotomies. Landes *et al.* state that piezoelectric operating tools may salvage soft tissues while the device cuts hard tissues, even in the event of an accident. This ability may be an advantage provided by selective tissue selection during osteotomy via alternative osteotomy methods. Wallace *et al.* showed that perforation of the soft tissue Schneiderian membrane, an unwanted sequela during a sinus lift, was reduced from 30% to 7% when switching from conventional osteotomy methods to a piezoelectric tool (34). Landes *et al.* (33) also compared the complications after 1,000 Le Fort I surgeries through conventional means with piezoelectric means. The paper reports a 6.4% complication rate after a traditional osteotomy compared with no complications in the piezoostomy group. Yet, the one caveat is that osteotomies through ultrasonic means require more diligent irrigation, as the ultrasonic group was noted to create more heat during the procedure. The heat generated could lead to loss of vitality of the bone after surgery and future bone necrosis. Like the Le Fort I comparison, the piezoelectric sagittal split osteotomy group showed remarkable decreases in complications. Landes *et al.* chronicled half the percentage of "bad splits" in the piezoostomy group compared with the traditional group, and additionally, the piezoelectric group had no other complications (33). This magnitude of change shows promise for the use of ultrasonic tools for osteotomies as the standard of care where it is warranted. One possible disadvantage of a piezoostomy is the potential for vascular thrombosis. However, Landes cites several papers that do not find vascular complications after ultrasonic osteotomy.

The findings presented by Landes *et al.* have been corroborated by a meta-analysis published later. Pagotto *et al.* confirm the decreased rate of neurosensory complications and "severe blood loss" during orthognathic surgery using piezoelectric techniques (35). More importantly, the benefits did not come at the expense of increased operation time, which may have been seen as a possible disadvantage of ultrasonic tools. Yet, the meta-analysis involved several randomized controlled trials (RCTs) which contained several surgical teams. Contradictory findings were suggested by a study conducted by Rossi *et al.* where the piezoelectric osteotomy group had significantly longer operation times (36). This study targeted specific bimaxillary orthognathic surgery and contained only 25 patients, with 14 patients receiving piezoelectric surgery. Therefore, increased operating time may only apply to these particular bimaxillary orthognathic surgeries because other studies contradict this result. Jenkins *et al.* showed no difference in operation time by a single surgeon who completed 48 cases, 24 of which were through traditional means and 24 of which were met with piezoelectric cutters (37). This study involved bimaxillary surgery, similar to that in the paper by Rossi *et al.*, in addition to BSSO. Both groups involved 10 BSSO and 14 bimaxillary surgery cases, with no differences in operating time between both methods. Piezoostomy seems like a safer alternative to conventional bur osteotomy for orthognathic surgery. As more studies are published, one can confidently say whether piezoelectric tools may replace conventional burs for complicated anatomical cases where neurosensory and vascular considerations must be made.

Robot-assisted mandibular osteotomies

The advancement of dental technology improves operational success and safety of complex treatment. Sun *et al.* write about an automatic mandibular osteotomy done after programming coordinates and information for a robot to assist a provider in craniofacial surgery (38). There were no post-operative complications associated with this study. Wu *et al.* completed an error analysis of robot-assisted orthognathic surgeries to reveal more information about the safety of similar procedures (39). The study was very limited, with a robot completing three osteotomies on skull models compared to a surgeon performing the same osteotomy on three skull models. There was no statistical significance in osteotomy errors. Nevertheless, more research is needed before this data can be extrapolated to other robot-assisted surgeries. Further studies have been completed on animal models to determine whether robot-assisted osteotomies can be implemented in the future. Zhou *et al.* had a robot system drill completed tunnels for mandibular angle split osteotomies in dog mandibles (40). This surgery typically carries substantial risk and is notorious for causing neurosensory disturbances in patients afterward. Zhou recorded the entrance and exit positions of the tunnels created by the robot in addition to complications with the dogs after the procedures (40). None of the dogs had complications. Zhou states that this method can train doctors for future mandibular angle split osteotomy (MASO) surgeries to decrease the risk of complications (40). Similar results are represented by the study completed by Lin *et al.* on surgeries completed with augmented reality while being assisted by robots (41). Patient faces were reconstructed and used as references and self-contained controls in surgery. Surgeries on the left side of a patient's face were robot-assisted, while surgeries on the right side of the patient's face were completed without robot assistance. Both sides of a patient's face were successfully treated; however, the robot-assisted surgeries suggested greater accuracy and stability. The summation of robot-assisted craniofacial surgery is sparse and limited. Still, at the moment, the majority of the research is suggesting that the implementation of robots may decrease the risk of complication and neurosensory disturbance for patients in complicated surgeries. It is exciting to see how advances in robot and surgical technology can be brought into the operating room.

Conclusions

Many traditional and dependable oral surgery techniques exist with fantastic outcomes. The scientific literature is beginning to note alternative and unconventional osteotomy techniques that may rival, and eventually perform better than, current gold standards in oral surgery. This review summarized a few of the unconventional osteotomy techniques in orthognathic surgery to increase their recognition in the surgical community.

Acknowledgments

I, Dani Stanbouly, want to express my sincere gratitude and appreciation to Dr. Sung-Kiang Chuang for serving as my mentor. I aspire to continue contributing to the literature under his guidance.

Funding: None.

Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://fomm.amegroups.com/article/view/10.21037/fomm-21-69/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://fomm.amegroups.com/article/view/10.21037/fomm-21-69/coif). SKC serves as an unpaid editorial board member of *Frontiers of Oral and Maxillofacial Medicine* from July 2020 to June 2024. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Hullihen SP. Case of Elongation of the under Jaw and Distortion of the Face and Neck, Caused by a Burn, Successfully Treated. Am J Dent Sci 1849;9:157-65.
2. Kashani H, Rasmusson L. Osteotomies in Orthognathic Surgery. In: Hosein M, Motamedi K. editors. A Textbook of Advanced Oral and Maxillofacial Surgery Volume 3. London: IntechOpen, 2016.
3. Gruber RM, Kramer FJ, Merten HA, et al. Ultrasonic surgery--an alternative way in orthognathic surgery of the mandible. A pilot study. Int J Oral Maxillofac Surg 2005;34:590-3.
4. Monson LA. Bilateral sagittal split osteotomy. Semin Plast Surg 2013;27:145-8.
5. Seeberger R, Asi Y, Thiele OC, et al. Neurosensory alterations and function of the temporomandibular joint after high oblique sagittal split osteotomy: an alternative technique in orthognathic surgery. Br J Oral Maxillofac Surg 2013;51:536-40.
6. Fariña R, Salinas F, Zurbuchen A, et al. Corticotomy-Assisted Le Fort I Osteotomy: An Alternative to Segmentation of the Maxilla in Orthognathic Surgery. J Craniofac Surg 2015;26:1316-20.
7. Helewa A, Walker JM. Critical evaluation of research in physical rehabilitation: toward evidence-based practice. 1st edition. Philadelphia: W.B. Saunders Co., 2000.
8. Keller EE, Sather AH. Quadrangular Le Fort I osteotomy: surgical technique and review of 54 patients. J Oral Maxillofac Surg 1990;48:2-11; discussion 12-3.
9. Cohn-Stock G. Die chirurgische Immediatregulierung der Kiefer, speziell die chirurgische Behandlung der Prognathie. Vjschr Zahnheilk Berlin 1921;37:320.
10. Wassmund M. Frakturen und Luxationen des Gesichtsschädels. Leipzig: Meusser, 1927.
11. Pasupathy S, Yuvaraj V. Modified anterior maxillary segmental osteotomy – a pilot study. Oral Surgery 2011;4:149-52.
12. Sugahara T, Mori Y, Minami K, et al. Maxillary Posterior Segmental Osteotomy for Correction of Skeletal Open Bite. Jpn J Jaw Deform 1992;2:70-8.
13. Papaspyridakos P, Ostuni A, Han C, et al. Posterior maxillary segmental osteotomy for the implant reconstruction of a vertically deficient ridge: a 3-year clinical report. J Prosthet Dent 2013;110:69-75.
14. Basa S, Varol A, Sener ID, et al. Posterior maxillary segmental osteotomy for restoring the mandible with dental implants: a clinical report. J Prosthet Dent

2008;99:340-3.
15. Hall HD, Roddy SC Jr. Treatment of maxillary alveolar hyperplasia by total maxillary alveolar osteotomy. J Oral Surg 1975;33:180-8.
16. Bell WH, Buche WA, Kennedy JW 3rd, et al. Surgical correction of the atrophic alveolar ridge. A preliminary report on a new concept of treatment. Oral Surg Oral Med Oral Pathol 1977;43:485-98.
17. Obwegeser HL, Farmand M. Die hufeisen-sandwich-osteotomie des zahnlosen oberkiefers mit gleichzeitiger submuköser vestibulumplastik. Schweiz Monatsschr Zahnmed 1984;94:390-8.
18. Yoshioka I, Khanal A, Kodama M, et al. Postoperative skeletal stability and accuracy of a new combined Le Fort I and horseshoe osteotomy for superior repositioning of the maxilla. Int J Oral Maxillofac Surg 2009;38:1250-5.
19. Yoshioka I, Khanal A, Kodama M, et al. A novel modification in combined Le Fort I and horseshoe osteotomy for posterior repositioning of the maxilla. Asian Journal of Oral and Maxillofacial Surgery 2011;23:172-6.
20. Paulus C, Kater W. High oblique sagittal split osteotomy. Rev Stomatol Chir Maxillofac Chir Orale 2013;114:166-9.
21. D'Agostino A, Trevisiol L, Gugole F, et al. Complications of orthognathic surgery: the inferior alveolar nerve. J Craniofac Surg 2010;21:1189-95.
22. Herrera-Vizcaino C, Seifert L, Berdan M, et al. Revision of 116 orthognathic surgery patients operated on with the high-oblique sagittal osteotomy (HOSO): a retrospective case series (PROCESS-compliant article). Clin Oral Investig 2021;25:3229-36.
23. Caldwell JB, Hayward JR, Lister RL. Correction of mandibular retrognathia by vertical L osteotomy: a new technic. J Oral Surg 1968;26:259-64.
24. Wu Q, Wang Y, Wang P, et al. The inverted-L ramus osteotomy versus sagittal split ramus osteotomy in maxillomandibular advancement for the treatment of obstructive sleep apnea patients: A retrospective study. J Craniomaxillofac Surg 2019;47:1839-47.
25. Zhu SS, Feng G, Li JH, et al. Correction of mandibular deficiency by inverted-L osteotomy of ramus and iliac crest bone grafting. Int J Oral Sci 2012;4:214-7.
26. Greaney L, Bhamrah G, Sneddon K, et al. Reinventing the wheel: a modern perspective on the bilateral inverted 'L' osteotomy. Int J Oral Maxillofac Surg 2015;44:1325-9.
27. MacIntosh RB. Total mandibular alveolar osteotomy. Encouraging experiences with an infrequently indicated procedure. J Maxillofac Surg 1974;2:210-8.
28. Jeong HJ, Kim SH, Choi BJ, et al. The Envelope of Segmental Movement and Airway Changes After Mandibular Anterior Subapical Osteotomy in Skeletal Class II Protrusion Patients. J Craniofac Surg 2020;31:668-72.
29. Konopnicki S, Nicot R, Schlund M, et al. Total Mandibular subapical osteotomy to correct Class II with inferior alveolar retrusion. Int Orthod 2019;17:114-22.
30. Delius M, Brendel W, Heine G. A mechanism of gallstone destruction by extracorporeal shock waves. Naturwissenschaften 1988;75:200-1.
31. Gelet A, Chapelon JY, Bouvier R, et al. Transrectal high intensity focused ultrasound for the treatment of localized prostate cancer: factors influencing the outcome. Eur Urol 2001;40:124-9.
32. Leira JI, Gilhuus-Moe OT. Sensory impairment following sagittal split osteotomy for correction of mandibular retrognathism. Int J Adult Orthodon Orthognath Surg 1991;6:161-7.
33. Landes CA, Stübinger S, Ballon A, et al. Piezoosteotomy in orthognathic surgery versus conventional saw and chisel osteotomy. Oral Maxillofac Surg 2008;12:139-47.
34. Wallace SS, Mazor Z, Froum SJ, et al. Schneiderian membrane perforation rate during sinus elevation using piezosurgery: clinical results of 100 consecutive cases. Int J Periodontics Restorative Dent 2007;27:413-9.
35. Pagotto LEC, de Santana Santos T, de Vasconcellos SJA, et al. Piezoelectric versus conventional techniques for orthognathic surgery: Systematic review and meta-analysis. J Craniomaxillofac Surg 2017;45:1607-13.
36. Rossi D, Romano M, Karanxha L, et al. Bimaxillary orthognathic surgery with a conventional saw compared with the piezoelectric technique: a longitudinal clinical study. Br J Oral Maxillofac Surg 2018;56:698-704.
37. Jenkins GW, Langford RJ. Comparison of the piezoelectric cutter with a conventional cutting technique in orthognathic surgery. Br J Oral Maxillofac Surg 2019;57:1058-62.
38. Sun M, Chai Y, Chai G, et al. Fully Automatic Robot-Assisted Surgery for Mandibular Angle Split Osteotomy. J Craniofac Surg 2020;31:336-9.
39. Wu J, Hui W, Chen S, et al. Error Analysis of Robot-Assisted Orthognathic Surgery. J Craniofac Surg 2020;31:2324-8.
40. Zhou C, Zhu M, Shi Y, et al. Robot-Assisted Surgery for Mandibular Angle Split Osteotomy Using Augmented

Reality: Preliminary Results on Clinical Animal Experiment. Aesthetic Plast Surg 2017;41:1228-36.
41. Lin L, Shi Y, Tan A, et al. Mandibular angle split osteotomy based on a novel augmented reality navigation using specialized robot-assisted arms--A feasibility study. J Craniomaxillofac Surg 2016;44:215-23.

doi: 10.21037/fomm-21-69
Cite this article as: Stanbouly D, Besmer AV, Lee KC, Chuang SK. Unconventional osteotomies in orthognathic surgery: a narrative review. Front Oral Maxillofac Med 2024;6:6.