

Original Article

Treatment of sagittal maxillary fractures by an innovative method of reversing pre-activated maxillary expanders

Zhaoling Wang*, Yuhong He*, Ying Liu*, Diyan Huang, Ling Gu, Dong Wang, Lu Yang, Xiaotao Xing, Jiaojiao Zou, Guoxiong Zhu

*Department of Stomatology, General Hospital of Jinan Military Command, Shifan Road 25, Jinan 250031, China.
Equal contributors.

Received November 28, 2015; Accepted February 15, 2016; Epub March 15, 2016; Published March 30, 2016

Abstract: Aim: To introduce an innovative treatment alternative for sagittal maxillary fractures by reversing pre-activated maxillary expanders and evaluate its efficacy. Methods: A total of 18 patients with sagittal maxillary fractures were studied. According to patients' dental casts, individualized maxillary expanders were made and attached to the upper posterior teeth. By reversing pre-activated maxillary expanders, transversal force was produced to reduce fractured fragments. After reduction was confirmed, the expander was immobilized and remained in situ for 8 to 12 weeks to stabilize maxilla as an external fixator before removal. All cases were followed up for 3 months. Results: The time from injury to treatment was 3 to 24 days. All patients achieved satisfied outcomes and tolerated this technique well. No obvious complications were found. Conclusions: This method could produce enough transversal force to reduce fractured fragments and then serve as an ideal external fixator to maintain stability for bony healing. It is an innovative, safe and efficient method for sagittal maxillary fractures.

Keywords: Facial trauma, sagittal maxillary fracture, closed reduction, maxillary expander

Introduction

As a result of high energy impact to midface, sagittal maxillary fractures, which split the maxillae and palate in sagittal direction and present as isolated fractures or associated with other midfacial or panfacial fractures, are more often seen than before [1, 2]. The reported incidence rate ranged from 8 to 46.4 percent and the difference may be somehow attributed to misdiagnosis, for some sagittal maxillary fractures may be overlooked especially in those without visible mucosa injury [1-6]. A finding of buccally expanding maxillae indicates the existence of sagittal fracture. Thorough physical examinations and CT scans with thin sections are of great help for the diagnosis [2, 3, 7, 8].

As for successful reduction of sagittal maxillary fracture, the key point is to compress fractured fragments together, restore the occlusion and maintain the stability during healing [1-5, 7-9].

In literatures, many methods for sagittal maxillary fractures were introduced, including hand-pressing, intermolar wiring, "figure-of-8" wiring, intermaxillary wiring, maxillomandibular traction, forceps or ratchet clamps, internal or external fixation, and light-cured resin splint and so on [1, 4, 7-12]. Nevertheless, some inherent disadvantages are also found in the methods. For instance, open reduction and rigid internal fixation has inherent risks of surgery and anesthesia. Despite its more invasion and cost, it would also cause iatrogenic damages to soft tissues and have the potential of hardware exposure. There are always problems of oral hygiene and oral function associated with intermaxillary fixation or intermolar wiring. As for palatal splint, it has no active role for reduction of fractured fragments. Hence, though management of sagittal maxillary fractures and attempts to avoid malunion and malocclusion are evolving, displacement of fractured fragments together with some complications related to treatments are not yet rare after treatment [1,

Treating sagittal maxillary fractures by maxillary expanders

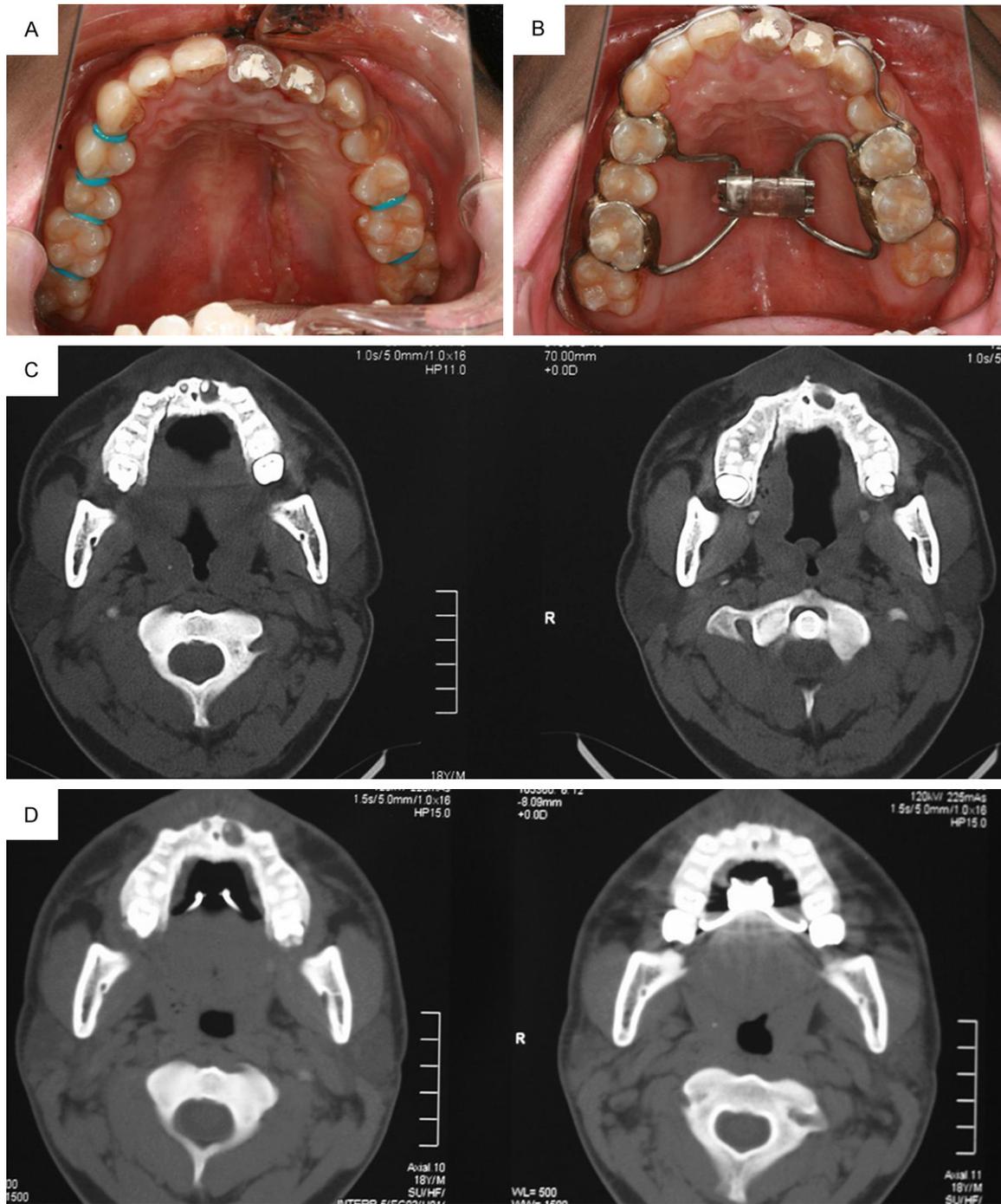


Figure 1. Photographs show a 29-year-old male patient (patient No 4) treated by reversing pre-activated maxillary expander, who suffered paramedian sagittal maxillary fracture and palatal laceration. A: Separating upper posterior teeth from their adjacent teeth. Note the laceration of palatal soft tissue; B: Intraoral view illustrating reduced maxillary fragments and healed palatal laceration without suture or palatal flap treatment. The expander was immobilized by self curing plastic resin and remained in situ as an external fixator; C: CT scans of 1.0 mm interval illustrating the paramedian sagittal maxillary fracture; D: CT scans illustrating reduced maxillary fracture. Note the disappeared palatal gap and partly visible maxillary expander.

2, 5, 6, 9-11]. In addition, since sagittal maxillary fractures induce splaying and instability of

fractured fragments, and the treatment may be sometimes delayed because of severe com-

Treating sagittal maxillary fractures by maxillary expanders

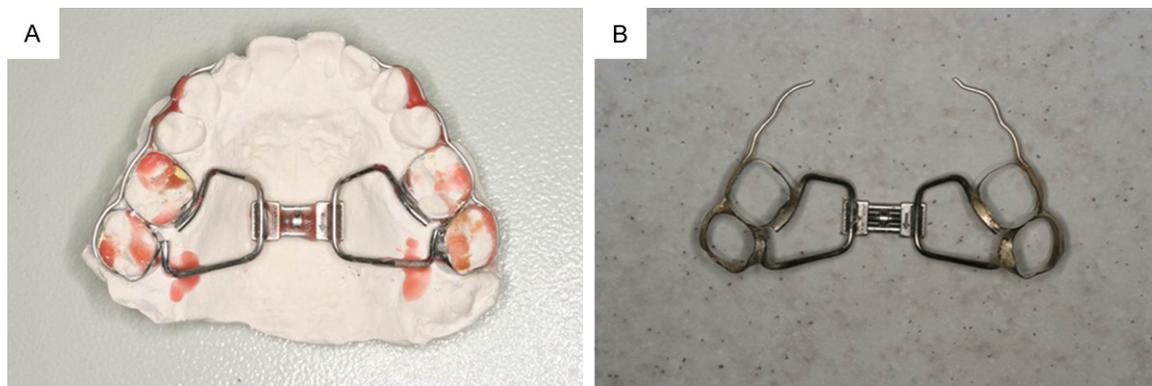


Figure 2. Individualized pre-activated maxillary expander. A: Design and manufacture on the cast; B: Composition after demolding and buffing.

bined injuries or missed diagnosis, there are still challenges for treatment of this kind of fractures.

In order to seek an efficient method for sagittal maxillary fractures with more advantages such as ensuring enough reductive forces and stability, keeping better oral hygiene and function and causing minimal invasion, an innovative application of reversing pre-activated maxillary expanders was first applied for treatment of sagittal maxillary fractures since 2009 in our department. In this article, the method was introduced and discussed.

Methods

Patients

A total of 18 patients with sagittal palatal fractures, who presented to the Department of Stomatology of General Hospital of Jinan Military Command, Jinan, China, from April 2009 to March 2015, were included in this study. The diagnosis of sagittal maxillary fractures was identified by physical examination and CT scans with thin sections of 1.0 mm interval (**Figure 1A, 1C**). The criteria of inclusion for this study were patients with at least 1 upper posterior tooth left in each side and with mouth opening of more than 2 cm. All patients provided signed informed consents and the study was reviewed and approved by the Ethics Committee of General Hospital of Jinan Military Command.

Treatment procedure

The reduction of sagittal maxillary fracture is performed by reversing an individualized pre-activated Hyrax maxillary expander. This indi-

vidualized expander includes 2 or 4 bands around bilateral upper first molars and first premolars (or other posterior teeth if these teeth are missed), stainless steel buccal bars and a pre-activated maxillary expander (**Figure 2A, 2B**). The width of pre-activated expander is a little bigger than that of the palatal gap showing on CT scans. The procedure for making individualized maxillary expanders is described as below. First, the selected upper posterior teeth are separated from their adjacent teeth by orthodontic spacers or copper wires of 0.6 mm. After that, an impression is taken and the cast is made. On the cast, stainless steel wires of 1.2 mm are bended along the upper teeth arch to form individualized buccal bars, which are used to stabilize the upper teeth arch when compressing fractured fragments. The bands are placed on the cast around prepared teeth and the pre-activated maxillary expander is adjusted to fit the cast. Finally all the parts are welded together to get the individualized maxillary expanders (**Figure 2A**). After demolding and buffing, the individualized expander is attached to upper posterior teeth by cementation and then the screw of maxillary expander is gradually reversed to compress and reduce the fractured segments. Once successful reduction is identified, the maxillary expander is immobilized by self curing plastic resin (**Figure 1B**) and afterwards rigidly remained in situ for some 8 to 12 weeks, acting as an external fixator for further stabilization of fractured fragments (**Figure 1B**), and then removed.

Physical examination of occlusion and midfacial width were regularly conducted during the treatment and follow-up. CT scans were used to confirm the results of reduction. All cases were followed up for at least 3 months.

Treating sagittal maxillary fractures by maxillary expanders



Figure 3. Photographs show a 56-year-old male patient (patient No 14), presenting oronasal fistula 2 weeks after rigid internal fixation and intermaxillary fixation, treated by reversing pre-activated maxillary expander. A: Oronasal fistula; B: Treated by reversing individualized pre-activated maxillary expander; C: Oronasal fistula successfully healed after 5-day treatment without additional surgery and the expander remained in situ for 12 weeks and then removed.

Results

In this series aged from 18 to 56 years old, 14 were males and 4 were females. There were 3 cases suffering isolated sagittal maxillary fractures and the other 15 suffering combined injuries other than maxillary Le Fort fractures. Of the 18 cases, 10 cases were first treated in other departments for combined injuries, 8 from neurosurgery department and 2 from orthopedics department. The most commonly associated injuries were other facial bone fractures (12/15) and craniocerebral injuries (8/15). As for sagittal maxillary fractures, 16 patients were not treated before while the other 2 patients, presenting oronasal fistulae, had received rigid internal fixation and intermaxillary fixation in other hospitals (**Figure 3A**). The trauma mechanisms were road accident (14/18), fall (2/18) and fist assault (2/18). The details of these patients were illustrated in **Table 1**.

The time from injury to treatment of sagittal maxillary fractures ranged from 3 to 24 days. The time for separating teeth was within 6 hours and after 1 to 7 days of reversing pre-activated maxillary expanders, all the sagittal fractures were successfully reduced, which were identified by physical examination or CT scans (**Figures 1B, 1D, 3C**). The mid-facial width and occlusion were recovered. Among these 12 cases with associated facial bone fractures, there were 7 patients who underwent this technique first and the reduced maxillae were used to guide the reduction of associated facial bone fractures. 3 patients gave up surgery because of poor system condition, economic problems and/or unwilling to undergo operation. The other 2 with oronasal fistulae second to first surgery were treated by this method. For cases with concomitant with palatal lacerations or oronasal fistulae (8/18), no

suture or elevation of palatal flaps was performed and all the palatal soft tissue lacerations and oronasal fistulae healed well (**Figures 1B, 3B, 3C**). Also, no intermaxillary fixations were conducted in this series. During the procedure, all maxillary expanders worked well and all patients tolerated the treatment well with good oral hygiene and function.

The patients were followed up for at least 3 months. All fractures unevenly healed. No alteration of dental occlusion and mobility of fractured fragments were found. No other obvious complications were found.

No statistical analysis was done because of the small sample size.

Discussion

The posterior fragments of sagittal maxillary fractures commonly tend to buccally splay [1, 2, 4]. With the goal of restoring pre-traumatic occlusion, management of this type of fracture is to push back the fragments by transversal force and maintain the stability. The purpose of this study was to seek a less invasive but efficient treatment alternative for reduction of sagittal maxillary fractures and assesses its efficacy. We innovatively introduced a technique for reduction of this kind of fractures in 18 cases by reversing pre-activated maxillary expanders and achieved successful outcomes.

Maxillary expander has been used for rapid maxillary expansion by orthodontists for a long time to correct the narrowness of maxillae [13, 14]. This appliance can produce transversal forces enough to gradually expand the maxillae and be rigidly maintained in situ after expansion for the mature of the new bone. Noticing the strong transversal force it produces and its

Treating sagittal maxillary fractures by maxillary expanders

Table 1. Data of patients with sagittal maxillary fractures reduced by maxillary expanders

Patient No.	Age (ys)	Sex	Trauma Mechanism	Time from Injury to Treatment (d)	Palatal soft tissue injury	Associated injuries other than maxillary Le Fort fractures	Other Information
1	18	M	Road accident	7	Laceration	Craniocerebral injury; Dental injuries	Transferred from Dept. of Neurosurgery
2	21	M	Assault	9			
3	32	F	Road accident	3	Laceration	Craniocerebral injury; Zygomatic fracture	Transferred from Dept. of Neurosurgery
4	29	M	Road accident	9		Craniocerebral injury	Transferred from Dept. of Neurosurgery
5	27	M	Road accident	24		Basal fracture; Mandibular fracture; Zygomatic fracture	Treated prior to surgery on associated facial fractures
6	19	F	Road accident	10	Laceration with oronasal fistula	Mandibular fracture; Zygomatic fracture	Treated prior to surgery on associated facial fractures
7	35	M	Road accident	5		Zygomatic fracture	
8	37	M	Road accident	14	Laceration with oronasal fistula	Epidural hematoma; Pan-facial fracture	Transferred from Dept. of Neurosurgery; Treated prior to surgery on associated facial fractures
9	41	M	Road accident	4		Craniocerebral injury; Pan-facial fracture; Pulmonary contusion	Transferred from Dept. of Neurosurgery. Treated prior to surgery on associated facial fractures
10	51	M	Fall	7		Zygomatic fracture	
11	38	F	Road accident	9	Laceration with oronasal fistula	Craniocerebral injury; Zygomatic fracture	Transferred from Dept. of Neurosurgery. Treated prior to surgery on associated facial fractures
12	45	M	Road accident	11	Laceration		
13	50	M	Road accident	17		Pan-facial fracture; Acetabular fracture	Transferred from Dept. of Orthopedics; Treated prior to surgery on associated facial fractures
14	56	M	Road accident	24	Oronasal fistula	Craniocerebral injury; Basal fracture; Pan-facial fracture	Transferred from Dept. of Neurosurgery. Presented with oronasal fistula posterior to rigid internal fixation and intermaxillary fixation
15	25	F	Road accident	5		Craniocerebral injury	Transferred from Dept. of Neurosurgery
16	19	M	Assault	14			
17	36	M	Fall	20		Pan-facial fracture	Treated prior to surgery on associated fractures.
18	33	M	Road accident	7	Oronasal fistula	Pan-facial fracture; femoral fracture	Transferred from Dept. of Orthopedics. Presented with oronasal fistula posterior to rigid internal fixation and intermaxillary fixation

Treating sagittal maxillary fractures by maxillary expanders

stability for bone mature, we intended to reverse this procedure to reduce sagittal maxillary fractures. In this study, maxillary expanders were individually pre-activated and then reversed on 18 cases. As expected, by reversing pre-activated maxillary expanders, splaying posterior ends of sagittal maxillary fractures were powerfully pushed back and reduced. Also, the immobilized expanders could keep fractured fragments stable for bony healing as an external fixator. The procedure could be considered as the opposite of rapid maxillary expansion.

As reported in literatures, it is relatively easy to reduce fresh sagittal maxillary fractures by whatever methods despite their inherent shortcomings [1, 3, 4, 7-12]. However, sagittal maxillary fractures are often associated with other injuries including some fatal injuries and sometimes overlooked due to lack of obvious symptoms, which would result in postponed treatment. In this series, 10 patients were first treated in other departments and when they were transferred to seek maxillofacial management, the fractures were not fresh again. Under these conditions, proliferated tissues make it much harder to push back the splaying posterior ends. Much stronger transversal force should be needed and the ever reported techniques seemed unfavorable [4, 6, 8, 10]. Also in this series, for relatively fresh fractures, the fractured segments were reduced soon, but for long-standing fractures, the speed of reduction was much slower. It is relatively difficult for not-so-fresh fractures. Nevertheless, by reversing individualized pre-activated maxillary expanders, all cases achieved satisfied reduction. Results indicated the transversal force produced by reversing the expander is strong enough for reduction of sagittal fractures and then leads to true bone union. In our opinion, this active force for reduction is much better than the passive one. Noticeably, the longest time from injury to treatment was 24 days and the fractured fragments were nearly immobile. This maybe contributes to the continuous force the expanders produced, which might squeeze out the proliferated tissue, or make the callus absorbed, and then reduced the fractured fragments. However, the mechanism should be further studied.

For posterior fractured fragments of sagittal maxillary fracture tend to flare out buccally and

thus lead to instability from side to side, the stabilization of fractured fragments is an important factor for bony healing [1, 2, 8, 9]. Although open reduction and rigid internal fixation are mainly used to achieve anatomical reduction of maxillary fractures, stabilization obtained on thin maxillary bone at pyriform apertures and the maxillary buttresses might be sometimes not strong enough to oppose the forces which would cause malrotation and disinclination of the palatoalveolar segments [1-3, 8, 10, 11, 15]. As a result, some auxiliary methods to prevent widening of the palatal vaults, such as intermaxillary fixation, transpalatal wire, dental splint, palatal plates were inevitably applied to achieve additional stability and adjustment of occlusion [2, 4, 5, 8-10]. Even so, the instability could not be entirely avoided. In our series, there were 2 patients presenting oronasal fistulae 2 weeks after rigid internal fixation of maxillary buttresses together with intermaxillary fixation. To achieve enough stability after reduction, the teeth-attached maxillary expanders were immobilized and used as a kind of external fixator in this study. The individualized buccal bars successfully prevented the unexpected movement of upper teeth. The palatal bars of maxillary expanders were adapted to follow the vaults of palates which could maintain the contour of the palates and thus prevent tilting or malrotation of fractured fragments. It ensured that there was no medial angulation or overlapping caused by over tightening. It indicates that this technique might be used for some comminuted palatal fracture instead of a splint. Besides that, the width of the palates could be precisely adjusted by rotating the screw and be maintained at expected position. In a word, all these parts work together to enhance the stability of reduced fragments and thus no additional intermaxillary fixation was needed. Based on that, the fractured palate with the dentition could be fixated as a whole part by this method, which would facilitate the management of associated facial bone fractures. In this study, 7 patients underwent this technique prior to management of associated facial bone fractures and results proved that the reduced maxillae were stable enough to guide rigid internal fixation of associated facial fractures. The surgical procedures were thus simplified.

Complications should also be considered when treatment modality is applied. Maxillary expanders are well adapted by orthodontic patients

Treating sagittal maxillary fractures by maxillary expanders

and so did in this study. Unlike other reported closed reduction techniques, which have disadvantages including irritation of or new injury to oral soft tissues, inconvenience for oral hygiene, and disturbances of speech and food ingestion [1, 2, 4, 10, 14], maxillary expanders were proved more tolerable and comfortable when treating sagittal maxillary fractures. Since transversal maxillae stability could be achieved by this technique, intermaxillary fixation was avoided, which made early mandibular mobilization, better oral function and cosmetic appearance possible. Though open surgery is preferred by many surgeons to achieve anatomical reduction, disadvantages as risk, cost and iatrogenic injury associated with surgery and anesthesia were unavoidable [2, 4, 8, 15]. However, this method is a non-surgical procedure and those disadvantages were definitely overcome. By this method, not only were fractured fragments reduced, but palatal soft tissue lacerations and oronasal fistulae were also found spontaneously healed without additional sutures or palatal flaps. It means that no palatal surgery for internal fixation was needed, which would simplify the treatment and avoid rigid fixation devices removal caused by discomfort, exposure of hardware and other associated complications [2, 5]. It may be of great help for those victims with isolated sagittal maxillary fracture (or combined with hemi-Le fort maxillary fractures) and those who would not accept surgical procedure or could not bear the surgical procedure because of poor system conditions.

According to this preliminary study, this technique could produce enough transversal force and achieve rigid stability for reduction of sagittal maxillary fractures with minimal invasion, less risks and cost but better oral hygiene and function. It may prevail over other existed techniques in some way, especially for delayed treatment and those who could not bear surgical operation. However, this technique needs orthodontic skills and laboratory work. Despite that, it proved to be an innovative, efficient and safe treatment alternative for reduction of sagittal maxillary fractures. Although the result of this preliminary study is promising, there are some limitations of this study. This was a non-randomized study with a small sample size which was just conducted in our department and no control groups were designed. Further prospective case-control study is needed to

testify the conclusions of this study and more work should be done to fully assess this technique and its indications. We would like to share our experience and expect similar study conducted by different institutions in the future.

Acknowledgements

This work was supported by the China Postdoctoral Science Foundation (No. 2014M55-2697).

Disclosure of conflict of interest

None.

Address correspondence to: Drs. Guoxiong Zhu and Zhaoling Wang, Department of Stomatology, General Hospital of Jinan Military Command, Jinan 250031, Shandong, China. Tel: +86 531 51665976; E-mail: jzkqk@sina.com (GXZ); zhaolingw@163.com (ZLW)

References

- [1] Manson PN, Shack RB, Leonard LG, Su CT, Hoopes JE. Sagittal fractures of the maxilla and palate. *Plast Reconstr Surg* 1983; 72: 484-489.
- [2] Chen CH, Wang TY, Tsay PK, Lai JB, Chen CT, Liao HT, Lin CH, Chen YR. A 162-case review of palatal fracture: management strategy from a 10-year experience. *Plast Reconstr Surg* 2008; 121: 2065-2073.
- [3] Park S, Ock JJ. A new classification of palatal fracture and an algorithm to establish a treatment plan. *Plast Reconstr Surg* 2001; 107: 1669-1676.
- [4] Kumaravelu C, Thirukonda GJ, Kannabiran P. A novel adjuvant to treat palatal fractures. *J Oral Maxillofac Surg* 2011; 69: e152-154.
- [5] Hendrickson M, Clark N, Manson PN, Yaremchuk M, Robertson B, Slezak S, Crawley W, Vander Kolk C. Palatal fractures: classification, patterns, and treatment with rigid internal fixation. *Plast Reconstr Surg* 1998; 101: 319-332.
- [6] Denny AD, Celik N. A management strategy for palatal fractures: a 12-year review. *J Craniofac Surg* 1999; 10: 49-57.
- [7] Sabherwal R, Irvine G, Sandy J. Orthodontic management of a Le Fort II and midline palatal fracture. *Br Dent J* 2007; 202: 739-740.
- [8] Cienfuegos R, Sierra E, Ortiz B, Fernández G. Treatment of palatal fractures by osteosynthesis with 2.0-mm locking plates as external fixator. *Craniomaxillofac Trauma Reconstr* 2010; 3: 223-230.
- [9] Pollock RA. The search for the ideal fixation of palatal fractures: innovative experience with a mini-locking plate. *Craniomaxillofac Trauma Reconstr* 2008; 1: 15-24.

Treating sagittal maxillary fractures by maxillary expanders

- [10] Davis DG, Constant E. Transverse palatal wire for the treatment of vertical maxillary fractures. *Plast Reconstr Surg* 1971; 48: 191-193.
- [11] Manson PN, Glassman D, Vanderkolk C, Petty P, Crawley WA. Rigid stabilization of sagittal fractures of the maxilla and palate. *Plast Reconstr Surg* 1990; 85: 711-717.
- [12] Waldrop J, Dale EL, Halsey J, Sargent LA. Palate fracture repair with light-cured resin splint: technical note. *J Oral Maxillofac Surg* 2015; 73: 1977-80.
- [13] Agarwal A, Mathur R. Maxillary expansion. *Int J Clin Pediatr Dent* 2010; 3: 139-146.
- [14] Contar CM, Muller PR, Brunetto AR, Machado MA, Rappoport A. Surgical treatment of maxillary transverse deficiency: retrospective study of 14 patients. *J Maxillofac Oral Surg* 2009; 8: 249-253.
- [15] Stephenson E Jr. A new classification of palatal fracture and an algorithm to establish a treatment plan. *Plast Reconstr Surg* 2002; 109: 2610.