Original Article

Opening of Circumaxillary Sutures by Alternate Rapid Maxillary Expansions and Constrictions

Yu-Chi Wang[a]; Peter M.S. Chang[b]; Eric Jein-Wein Liou[c]

ABSTRACT

Objective: To analyze quantitatively the circumaxillary suture opening after alternate rapid maxillary expansions and constrictions (Alt-RAMEC).

Materials and Methods: Twelve inbred cats were randomly grouped into two equal groups for 1 week of rapid maxillary expansion (RME) (1 mm/day) or 5 weeks of Alt-RAMEC (1 mm/day). At the end of the experiment, the craniofacial skeleton of each cat was harvested. Each circumaxillary suture was then probed at three sites with a 0.5-mm pointed periodontal probe. A smooth probing without penetration was an ineffective suture opening ($<$0.5 mm), while a probing with penetration was an effective suture opening ($>$0.5 mm). For each suture, the quantity of suture opening (%) was the effective suture opening/(effective + ineffective suture opening). The intergroup differences were analyzed by chi-square test ($P < .05$).

Results: Five weeks of Alt-RAMEC opened the circumaxillary sutures significantly more than 1 week of RME. This affected the circumaxillary sutures running coronally and articulating directly to the maxilla (56.9% vs 36.1%, $P < .001$), the sutures running sagittally, but articulating indirectly to the maxilla (94.4% vs 64.8%, $P < .001$), and the sutures running coronally, but articulating indirectly to the maxilla (58.3% vs 33.3%, $P < .01$). The sutures running sagittally were opened significantly more (94.4%–100.0%) than those running coronally (56.9%–58.3%), no matter if they articulated directly or indirectly with the maxilla.

Conclusions: Alt-RAMEC opens both the sagittally and coronally running circumaxillary sutures quantitatively more than conventional RME. However, more than 5 weeks of Alt-RAMEC would be needed to increase the opening of the coronally running circumaxillary sutures. (*Angle Orthod.* 2009:79;)

KEY WORDS: Rapid maxillary expansion; Sutures

INTRODUCTION

The combined use of rapid maxillary expansion and facemask has been a contemporary technique for the maxillary protraction in growing patients with Class III or cleft under the assumption that the rapid maxillary expansion opens the circumaxillary sutures and facilitates the maxillary protraction.[1–6] The average protraction amount by using rapid maxillary expansion and facemask protraction is 1.5–3 mm in 10 to 12 months.[7–9] However, the protraction should be more than this amount when the circumaxillary sutures are well opened. This could be because the devices are tooth-borne so that the results are mostly dental effects,[10] or the circumaxillary sutures are not opened enough.

It has been reported that the amount of maxillary protraction was 5–6 mm in 5 months under the protocol of alternate rapid maxillary expansions and constrictions (Alt-RAMEC) and was significantly more than rapid maxillary expansion.[11–14] The explanation of this result was the Alt-RAMEC opened the circumaxillary sutures more extensively than rapid maxillary expansion.[12,13] However, this assumption has not been tested. The purposes of this study were to test this hypothesis and to study quantitatively the extent of circumaxillary suture opening through an experimental model on cats.

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Accepted: April 2008. Submitted: March 2008.

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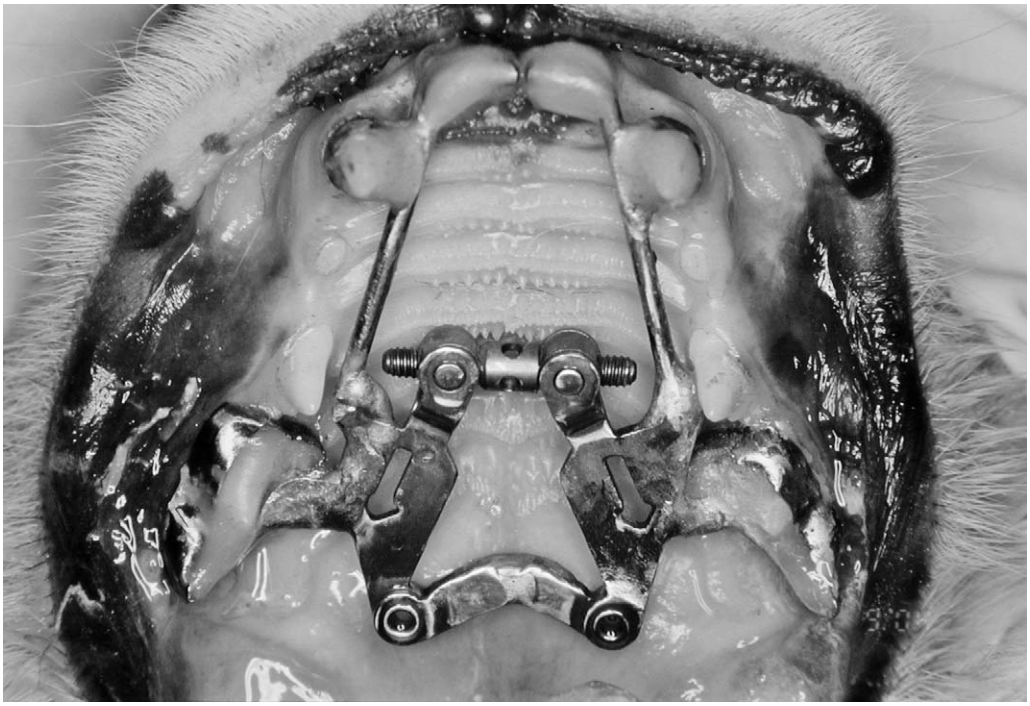

Figure 1. The double-hinged expander.

MATERIALS AND METHODS

This experimental project (NSC93-2314-B-182A-001) was reviewed and approved by the National Science Council of Taiwan and the animal welfare committee of Chang Gung Memorial Hospital, Taipei, Taiwan. The experimental animals were twelve 10- to 12-month-old inbred cats, randomly divided into two equal groups for two different protocols of rapid maxillary expansion. The rapid maxillary expanders were the double-hinged expanders[8–11] (Bestdent, Kaoshiung, Taiwan) (Figure 1). Before each operation, the cats were weighed and anesthetized with intramuscular ketamine hydrochloride (30 mg/kg) and xylazine (3 mg/kg).

The maxillary third premolars and canines of each cat were banded and alginate impression of the maxilla was taken for fabricating the double-hinged expanders. The expansion screw was oriented perpendicularly to the intermaxillary suture. Two extension bars (0.051-inch stainless steel wires) were extended anteriorly and bilaterally from the canine bands toward the central incisors. After the fabrication, the inner surface of each band and the extension bars were sandblasted before cementation. The expander was bonded to the maxillary third premolars and canines, and the extension bars were bonded to the maxillary incisors with light-cured composite resin (Enlight, Ormco, Glendora, Calif) under etching and bonding (Figure 1).

One day after the cementation, the double-hinged expanders were activated. The activation protocol for the first group was 1 mm/day for 1 week of rapid maxillary expansion (1wk-RME). In the second group, the activations were 5 weeks of Alt-RAMEC (5wk-Alt-RAMEC), commencing with expansion in the first week, alternating to constriction in the second week, and ending with expansion in the fifth week (Table 1). The daily expansion or constriction of the Alt-RAMEC was 1 mm.

Table 1. Experiment Protocol of the 5 Weeks of Alternate Rapid Maxillary Expansions and Constrictions (5wk-Alt-RAMEC)

Alternate Weekly Sequence	Weekly Amount of Expansion/Constriction	Daily Amount of Activation
Expansion	7 mm	1 mm
Constriction	7 mm	1 mm
Expansion	7 mm	1 mm
Constriction	7 mm	1 mm
Expansion	7 mm	1 mm

All animals were sacrificed with an overdose of intracardiac injection of ketamine (5 mL/kg) at the end of the experiment. After sacrificing, the skeleton of the nasomaxillary complex of each cat was preserved in 10% formalin for the examination of the circumaxillary suture opening. The suture opening was examined by one of the investigators without knowing the grouping of the specimen. A 0.5-mm pointed periodontal probe (Williams periodontal probe, Hu-Friedy, Chicago, IL) was used for grossly detecting any suture that was wider than 0.5 mm. The circumaxillary sutures were classified into four groups (Figure 2).

—Sutures running sagittally and articulating directly to

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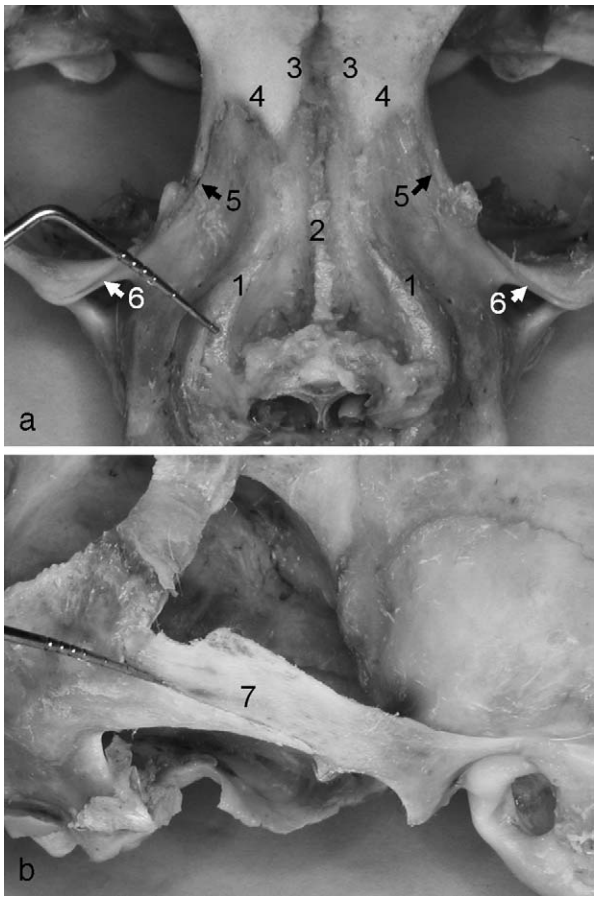

Figure 2. The examined circumaxillary sutures in this study (a and b). 1: nasomaxillary suture; 2: internasal suture; 3: nasofrontal suture; 4: frontomaxillary suture at frontal process of maxilla; 5: frontomaxillary suture at body of maxilla; 6: zygomaticomaxillary suture; 7: zygomaticotemporal suture.

maxilla (Sutures-1): the intermaxillary and nasomaxillary sutures.

—Sutures running coronally and articulating directly to maxilla (Sutures-2): the frontomaxillary suture at the frontonasal process of maxilla, at the body of maxilla, and inside the orbit, and the zygomaticomaxillary suture.

—Sutures running sagittally but articulating indirectly to the maxilla (Sutures-3): the internasal and zygomaticotemporal sutures.

—Sutures running coronally but articulating indirectly to the maxilla (Sutures-4): the nasofrontal suture.

Both the right and left sutures were examined, and each suture was examined at the distal/upper, middle, and medial/lower sites of the suture. The periodontal probe was moved back and forth across each site of each suture. At each probing site, a smooth probing without penetration was an ineffective suture opening ($<$0.5 mm), while a penetration was an effective suture opening ($>$0.5 mm) (Figure 2). For each suture, the quantity of suture opening (%) was the effective suture opening/(effective + ineffective suture opening). The right and left sides, and the intergroup differences were analyzed by chi-square test ($P < .05$).

RESULTS

The quantity of suture opening of each right and left suture was not significantly different ($P > .05$); therefore, right and left sutures were combined for analyzing the intergroup differences. For the sutures running sagittally and articulating directly to the maxilla (Sutures-1), the quantity of suture opening was 100.0%. They were all opened by the 1wk-RME and the 5wk-Alt-RAMEC (Table 2).

For the sutures running coronally and articulating directly to the maxilla (Sutures-2), the sutures running sagittally and articulating indirectly to the maxilla (Sutures-3), and the sutures running coronally and articulating indirectly to the maxilla (Sutures-4), their quantity of suture opening by the 5wk-Alt-RAMEC was significantly higher than that by the 1wk-RME. In each circumaxillary suture of them, the quantity of suture opening by the 5wk-Alt-RAMEC was also significantly

Table 2. Intergroup Comparison of the Quantity of Suture Opening Between 1 Week of Rapid Maxillary Expansion (1wk-RME) and 5 Weeks of Alternate Rapid Maxillary Expansions and Constrictions (5wk-Alt-RAMEC)

Sutures[a]		1wk-RME		5wk-Alt-RAMEC		Chi-Square	
Sutures-1	Intermaxillary suture	100.0% (18/18)	100.0% (54/54)	100.0% (18/18)	100.0% (54/54)	NS	NS
	Nasomaxillary suture	100.0% (36/36)		100.0% (36/36)		NS	
Sutures-2	Frontomaxillary suture a	69.4% (25/36)	36.1% (52/144)	66.7% (24/36)	56.9% (82/144)	NS	***
	Frontomaxillary suture b	13.9% (5/36)		30.6% (11/36)		NS	
	Frontomaxillary suture c	22.2% (8/36)		52.8% (19/36)		**	
	Zygomaticomaxillary suture	38.9% (14/36)		77.8% (28/36)		***	
Sutures-3	Internasal suture	66.7% (12/18)	64.8% (35/54)	100.0% (18/18)	94.4% (51/54)	*	***
	Zygomaticotemporal suture	63.9% (23/36)		91.7% (33/36)		**	
Sutures-4	Nasofrontal suture	33.3% (12/36)		58.3% (21/36)		*	

[a] Sutures-1: sutures running sagittally and articulating directly to the maxilla. Sutures-2: sutures running coronally and articulating directly to the maxilla. (Frontomaxillary suture a: at the frontonasal process of the maxilla. Frontomaxillary suture b: at the body of the maxilla. Frontomaxillary suture c: inside the orbit.) Sutures-3: sutures running sagittally but articulating indirectly to the maxilla. Sutures-4: sutures running coronally but articulating indirectly to the maxilla. * $P < .05$; ** $P < .01$; *** $P < .001$. NS indicates not significant.

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Table 3. Cross Comparisons of the Quantity of Suture Opening Among the Sutures Running Sagittally vs Coronally, and Among the Sutures Articulating Directly vs Indirectly to the Maxilla[a]

	Chi-Square			
	Sagittally Running vs Coronally Running Sutures		Sutures Articulating Directly vs Indirectly to the Maxilla	
Protocol	Sutures-1/Sutures-2	Sutures-3/Sutures-4	Sutures-1/Sutures-3	Sutures-2/Sutures-4
1wk-RME	100%/36.1%***	64.8%/33.3%**	100%/64.8% ***	36.1%/33.3% NS
5wk-Alt-RAMEC	100%/56.9%***	94.4%/58.3%***	100%/94.4% NS	56.9%/58.3% NS

[a] 1wk-RME indicates 1 week of rapid maxillary expansion; 5wk-Alt-RAMEC, 5 weeks of alternate rapid maxillary expansions and constrictions; NS, not significant. ** $P < .01$; *** $P < .001$.

higher than that by the 1wk-RME, except the frontomaxillary suture at the nasofrontal process of maxilla and at the body of the maxilla (Table 2). These results supported the assumption that the Alt-RAMEC opens the circumaxillary sutures more extensively than the rapid maxillary expansion.

The circumaxillary sutures running sagittally were significantly opened more quantitatively than those running coronally, no matter they articulated directly or indirectly to the maxilla. On the other hand, there was no significant difference of the quantity of suture opening between the sutures articulating directly (Sutures-1 and Sutures-2) and indirectly (Sutures-3 and Sutures-4) to the maxilla, except the Sutures-1 vs Sutures-3 under 1wk-RME (Table 3). These results indicated that, for the quantity of suture opening, a circumaxillary suture running sagittally was more crucial than its direct articulation to the maxilla.

DISCUSSION

The expansion force of rapid maxillary expansion has been found to be more than twice as large as its original force.[15,16] It also has been revealed that, in photoelastic studies[17,18] and in animal studies,[19,20] the expansion force reached to and opened the circumaxillary sutures. The histologic pictures of the circumaxillary sutures showed stretched collagen fibers running across the sutures and immature bony tissue depositing along the borders of the sutures. In dry skull studies[21,22] and clinical studies,[23] it was found that the expansion force displaced not only the maxilla but also the circumaxillary bones, as far as the nasal bones and pterygoid process of the sphenoid bone. However, the extent of circumaxillary suture opening by the expansion force, either by rapid maxillary expansion or Alt-RAMEC, has not been well explored quantitatively. In this experimental study, we quantitatively studied the extent of circumaxillary suture opening after 1 week of rapid maxillary expansion or 5 weeks of Alt-RAMEC, and the results supported the assumption that Alt-RAMEC opens the circumaxillary sutures more extensively than rapid maxillary expansion.

The factors that might affect the quantity of circumaxillary suture opening in this study include the expansion width and frequency of rapid maxillary expansion, direct/indirect articulation of the circumaxillary suture to the maxilla, or orientation of circumaxillary sutures (sagittal vs coronal).

It is reasonable to assume that the wider the rapid maxillary expansion, the more the suture opening of the circumaxillary sutures. However, the question is what width is wide. In clinical studies, some reported 5 mm, while the others reported at least 12 to 15 mm of rapid maxillary expansion.[9,24,25] In this experimental study on cats, 7 mm of rapid maxillary expansion was not adequate to open all of the circumaxillary sutures enough quantitatively. The quantity of suture opening in some of the circumaxillary sutures after 1 week (7 mm) of rapid maxillary expansion was only 13.9% to 33.3%.

To expand the maxilla wider than 7 mm might open the circumaxillary sutures more extensively, but it is not practical clinically. The coordination of the maxillary and mandibular dental arches could be a problem after such an expansion. The purpose of rapid maxillary expansion in maxillary protraction is to open the circumaxillary sutures rather than to expand the maxilla widely.

The Alt-RAMEC was developed to open the circumaxillary sutures without the disadvantages of overexpansion of the maxilla.[11–14] Its strategy is to amplify the effects of rapid expansion by increasing the frequency of rapid maxillary expansion through alternating rapid expansion and constriction for several times. In this study, 5 weeks of Alt-RAMEC, significantly increased the quantity of suture opening 1.5–1.8 times than 1 week of rapid maxillary expansion in the frontomaxillary, zygomaticomaxillary, internasal, zygomaticotemporal sutures, and nasofrontal sutures.

Theoretically, the circumaxillary sutures that articulate directly to the maxilla are subjected more directly to the rapid expansions and constrictions of maxilla than the indirect-articulated circumaxillary sutures, and therefore could be opened more extensively. However, the results of this study do not support this assumption.

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The circumaxillary sutures running sagittally (Sutures-1, Sutures-3) were opened significantly more extensively than the circumaxillary sutures running coronally (Sutures-2, Sutures-4), no matter they articulated directly or indirectly to the maxilla. They also ran perpendicularly to the expansion screw of the expander, and they were directly impacted by the line of action of the expander. The quantity of suture opening of Suture-1 and Sutures-3 was 94.4% and 100%, while that of Sutures-2 and Sutures-4 was 56.9% and 58.3% after 5 weeks of Alt-RAMEC. This meant that the orientation of the circumaxillary sutures (sagittal vs coronal) is more crucial to the quantity of circumaxillary suture opening than the suture articulation to the maxilla (direct vs indirect).

It is the sutures running coronally rather than the sutures running sagittally that needed to be well opened quantitatively for maxillary protraction. The results of this study revealed that 5 weeks of Alt-RAMEC significantly opened the sutures running coronally more extensively than 1 week of RME. However, these sutures were not opened quantitatively enough (56.9% to 58.3%) after 5 weeks of Alt-RAMEC. To open the coronal running sutures quantitatively enough for maxillary protraction, we infer that 7 to 9 weeks of Alt-RAMEC (4 to 5 times of expansion) would be necessary.

CONCLUSIONS

- By increasing the frequency of expansion, the Alt-RAMEC opens both the sagittal and coronal running circumaxillary sutures quantitatively more than the rapid maxillary expansion.
- More than 5 weeks of Alt-RAMEC would be needed to increase the opening of the coronally running circumaxillary sutures.

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