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AAO Foundation Final Report Form
(a/o 5/30/2021)

In an attempt to make things a little easier for the reviewer who will read this report, please consider these two questions before this is sent for review:

- *Is this an example of your very best work, in that it provides sufficient explanation and justification, and is something otherwise worthy of publication? (We do publish the Final Report on our website, so this does need to be complete and polished.)*
- *Does this Final Report provide the level of detail, etc. that you would expect, if you were the reviewer?*

Please prepare a report that addresses the following:

Type of Award: Orthodontic Faculty Development Fellowship Award

Name(s) of Principal Investigator(s): Bingshuang Zou

Institution: The University of British Columbia

Title of Project: Comparison of transverse and circummaxillary suture changes in different maxillary expansion protocols

Period of AAOF Support: 07-01-2020 to 06-30-2021

Amount of Funding: $20,000

Summary/Abstract:

Introduction: Maxillary expansion is common in orthodontic clinical practice and there are many different expansion protocols including Alternating Rapid Maxillary Expansion and Constriction (Alt-RMEC) which was introduced in 2005 in a population of cleft lip and palate patients.

Objectives: To analyze three-dimensional (3D) cone beam computed tomography (CBCT) records to compare the transverse dentoalveolar and skeletal changes due to 2 different maxillary expansion protocols: conventional rapid maxillary expansion (RME) and Alt-RMEC.

Additionally, to assess the amount of circummaxillary suture opening due to the aforementioned maxillary expansion protocols (RME vs. Alt-RMEC).

Methods: Thirty-four growing Class III (maxillary deficient) patients, aged between 7.2 – 12.5 years old, were included in this retrospective study. Patients were randomly 1:1 allocated to either RME or Alt-RMEC treatment groups. Pre-treatment (T0) and post-treatment (T1) CBCT records were used to measure the angulation of posterior teeth, basal and alveolar widths from both buccal and lingual aspects on posterior, middle and anterior coronal sections. In addition, mid-palatal, internasal, nasomaxillary, frontonasal and zygomaticofrontal sutures were measured either directly or indirectly to account for treatment changes in circummaxillary sutures. Cervical vertebral maturation stage (CVMS) and mid-palatal suture density (MPSD) ratio were measured using T0 CBCTs. Differences between the two protocols with respect to linear and angular transverse dentoalveolar and skeletal changes and circummaxillary sutural changes were compared using t-test. Multiple linear regression models were used to explore the influence of age, CVMS, sex, MPSD ratio and treatment protocol on the degree of palatal basal width expansion and circummaxillary sutural opening.

Results: Both expansion protocols produced a pyramidal expansion pattern anterior-posteriorly. Alt-RMEC produced statistically and clinically significantly less amount of maxillary 1st molar tipping ($P < 0.05$) and resulted in increased nasal aperture widening ($P < 0.05$) as a result of distraction of multiple midline craniofacial sutures. Males had larger amounts of posterior and middle palatal basal width expansion than females, with sex accounting for 20.0% and 20.5% of treatment change variation. Increasing CVMS and females produced larger amounts of right nasomaxillary suture opening, with both explanatory variables accounting for 34.0% of the variation in treatment change. Age and MPSD ratio were not correlated with any dentoalveolar, skeletal or sutural treatment change.

Conclusions: RME and Alt-RMEC resulted in similar transverse dentoalveolar and skeletal measurements in addition to circummaxillary sutural changes. Aside from Alt-RMEC causing less maxillary 1st molar tipping and increased widening of the nasal aperture, the complexities of the protocol may not justify its use over conventional maxillary expansion in terms of maxillary expansion only. One should continue to consider factors such as age and skeletal maturity, as assessed by CVMS, when considering maxillary expansion in an orthodontic patient.

Detailed results and inferences:

1. If the work has been published please attach a pdf of manuscript OR
2. Describe in detail the results of your study. The intent is to share the knowledge you have generated with the AAOF and orthodontic community specifically and other who may benefit from your study. Table, Figures, Statistical Analysis, and interpretation of results should be included.

Results:

The general demographic data of the overall study population is outlined in Table 1. Of the 34 subjects, 24 (70.6%) were female and 10 (29.4%) were male. The majority of the subjects had potential for significant skeletal growth as assessed by T0 CVMS: with 14 (41.2%) in CVM1, 8 (23.5%) in CVM2 and 7 (20.6%) in CVM3.

Table 1. Demographic data of general study population.

Sex	Number of subjects (n =34)	% of n
Female	24	70.6%
Male	10	29.4%
CVMS	**Number of subjects (n=34)**	**% of n**
1	14	41.2%
2	8	23.5%
3	7	20.6%
4	3	8.8%
5	2	5.9%
6	0	0.0%
Expansion Protocol	**Number of subjects (n =34)**	**% of n**
RME	17	50.0%
Alt-RMEC	17	50.0%
Age Descriptor	**Age (years)**	
Mean	10.1	
Median	9.8	
Range	7.2-12.5	

Demographic information stratified by treatment protocol is described by Table 2. The mean age of the RME group was 9.8 years old whereas 10.3 years old was the mean age of the Alt-RMEC group. For both treatment groups, the majority of the subjects were female and had significant skeletal growth potential as assessed by CVMS (CVM1-3).

Table 2. Demographic data stratified by treatment group.

Sex	RME (n=17)	% of n	Alt-RMEC (n=17)	% of n
Female	11	64.7	13	76.5
Male	6	35.3	4	23.5
Age Descriptor	**RME**		**Alt-RMEC**	
Mean	9.8		10.3	
Median	9.2		10.5	
Range	8.3 - 12.5		7.2 – 12.4	
CVMS	**RME (n=17)**	**% of n**	**Alt-RMEC (n=17)**	**% of n**
1	8	47.1	6	35.3
2	5	29.4	3	17.6
3	2	11.8	5	29.4
4	1	5.9	2	11.7
5	1	5.9	1	5.9
6	0	0	0	0

1. Dentoalveolar and Skeletal Linear and Angular Measurements

1.1 Intra-Class Correlation/Error Analysis

As per Koo et al's explanation of ICC values: values >0.9 indicate excellent reliability, values between 0.75 and 0.9 represent good reliability, values between 0.5 and 0.75 moderate reliability and any values less than 0.5 are of poor reliability. An arbitrary ICC threshold of 0.60 was used – any measurements where the ICC was <0.6 was interpreted as being very challenging to measure and thus no further statistical investigation would be warranted for that given measurement /variable. All measurements were repeated by a single investigator at least 2 weeks apart to allow for an adequate washout period. All linear and angular measurements showed satisfactory agreement, with no ICC value below 0.6.

1.2 Student's *t*-test analysis

Subjects were randomly allocated to either treatment group (RME or Alt-RMEC), and adequate randomization was evidenced by there being no statistically significant differences (p<0.05) between each treatment group's baseline measurements at T0. There were also no statistically significant differences (p<0.05) between the two treatment groups after maxillary expansion (T1). Table 3 highlights that there were statistically significant treatment changes (p<0.05) in the angulation of the maxillary left first molar, and in the overall angulation of the maxillary 1st molars.

Table Error! No text of specified style in document.**. Student's *t*-test comparing the two treatment groups with regard to treatment changes (T1-T0) in dentoalveolar and skeletal linear and angular measurements.**

Treatment Changes (T1-T0)	**RME** mean (sd)	**Alt-RMEC** mean (sd)	**95CI% of the difference**	**Significance**
Maxillary inter-molar width (mm)	6.0 (1.3)	5.5 (1.7)	-0.5; 1.6	0.317
Angulation of UR6 (°)	3.6 (3.2)	2.3 (3.4)	-1.0; 3.6	0.266
Angulation of UL6 (°)	3.6 (3.1)	0.3 (3.7)	0.9; 5.7	**0.008**
Angulation of U6 (°)	3.6 (3.1)	1.3 (3.7)	0.7;3.9	**0.007**
Posterior maxillary basal width (mm)	2.5 (1.6)	2.9 (1.7)	-1.5; 0.8	0.518
Posterior maxillary alveolar width (mm)	3.2 (1.3)	4.1 (1.7)	-2.0; 0.2	0.108
Posterior palatal base width (mm)	2.4 (1.0)	3.0 (1.4)	-1.5; 0.2	0.136
Posterior palatal alveolar width (mm)	3.1 (2.7)	3.8 (1.6)	-2.2; 0.9	0.408
Posterior right alveolar angulation (°)	3.0 (7.3)	0.5 (5.7)	-2.1; 7.0	0.279
Posterior left alveolar angulation (°)	3.3 (3.8)	1.5 (5.5)	-1.5; 5.0	0.285
Middle maxillary basal width (mm)	2.7 (1.5)	2.9 (2.5)	-1.6; 1.2	0.777
Middle maxillary alveolar width (mm)	4.4 (1.3)	4.7 (1.5)	-1.3; 0.7	0.532
Middle palatal base width (mm)	3.0 (1.5)	3.2 (1.1)	-1.1; 0.7	0.660
Middle palatal alveolar width (mm)	3.4 (1.1)	3.5 (1.7)	-1.1; 0.8	0.773
Middle right alveolar angulation (°)	2.6 (5.0)	1.8 (5.2)	-2.7; 4.4	0.638
Middle left alveolar angulation (°)	0.4 (3.4)	1.2 (4.7)	-3.6; 2.1	0.594
Anterior maxillary basal width (mm)	2.9 (1.5)	2.2 (1.6)	-0.4; 1.8	0.217
Anterior maxillary alveolar width (mm)	4.4 (1.5)	4.7 (1.4)	-1.3; 0.7	0.550
Anterior palatal base width (mm)	2.7 (1.9)	2.7 (1.6)	-1.2; 1.3	0.915
Anterior palatal alveolar width (mm)	4.0 (1.5)	3.6 (1.8)	-0.7; 1.6	0.461
Anterior right alveolar angulation (°)	-0.5 (10.4)	1.7 (5.3)	-7.9; 3.7	0.462
Anterior left alveolar angulation (°)	-0.9 (9.4)	0.4 (6.1)	-6.1; 5.0	0.854

1.3 Univariate analysis and Multiple Linear Regression Model

Univariate analyses for the treatment change (T1-T0) of posterior, middle and anterior palatal basal widths were done to identify statistically significant explanatory variables to include in a subsequent linear regression model (Table 4). The variables which were included in the univariate analysis were age, regional MPSD ratio (i.e. the MPSD ratio for that respective section: anterior, middle or posterior), CVMS, sex and treatment group. The univariate analysis shown in Table 3-8 revealed that sex was a statistically significant explanatory variable for treatment change in posterior and middle palatal basal widths ($p<0.05$), and thus was included in their respective linear regression model. The model, outlined in Table 5, revealed that sex explains 20.0% and 20.5% of the treatment change variation in posterior and middle palatal basal widths respectively. In other words, males had larger treatment changes in posterior and middle palatal basal widths than females.

Table 4. Univariate analysis for change in posterior, middle and anterior palatal basal width.

	Change in Posterior Palatal Basal Width (mm)		**Change in Middle Palatal Basal Width (mm)**		**Change in Anterior Palatal Basal Width (mm)**	
Pearson's Correlation	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
Age	-0.071	0.690	-0.092	0.605	0.240	0.171
Regional MPSD Ratio	0.036	0.842	-0.003	0.989	-0.286	0.101
CVMS	-0.215	0.222	-0.182	0.303	0.223	0.204
Student's *t*-test	*t*-value	*p*-value	*t*-value	*p*-value	*t*-value	*p*-value
Sex (Males vs. Females)	-3.040	**0.005**	-3.082	**0.004**	0.174	0.086
Treatment (Alt-RMEC vs. RME)	-1.530	0.136	-0.444	0.660	0.107	0.915

Table 5. Simple linear regression models for changes in posterior, middle and anterior palatal basal widths.

	Change in Posterior Palatal Basal Width (mm)			**Change in Middle Palatal Basal Width (mm)**			**Change in Anterior Palatal Basal Width (mm)**		
	Estimate	*t*-value	*p*-value	Estimate	*t*-value	*p*-value	Estimate	*t*-value	*p*-value
Sex (Males vs. Females)	0.473	3.040	**0.005**	0.478	3.082	**0.004**	-	-	-
	Adjusted R-squared = 0.200			Adjusted R-squared = 0.205			Adjusted R-squared = N/A		

2. Circummaxillary Sutures

2.1 ICC/Error Analysis

Measurements were performed by a single investigator on two separate occasions, at least 2 weeks apart, to allow for adequate washout. All measurements had good reliability with ICC >0.6, except that the right zygomaticofrontal suture and posterior nasal spine measurements were not included in further investigations or statistical analyses due to their poor ICC (<0.6).

2.2 Student's *t*-test analysis

Satisfactory randomization of patients to either treatment group was supported by there being no statistically significant differences (p<0.05) between each treatment group's baseline circummaxillary suture measurements at T0. There were also no statistically significant differences (p<0.05) between the two treatment groups after maxillary expansion (T1). The *t*-test analysis of the treatment changes (T1-T0), shown in Table 6, comparing the two treatment groups revealed that Alt-RMEC results in a statistically significantly larger amount of nasal aperture widening (2.541mm ±0.892mm) compared to RME (1.824mm ±0.814mm) (p<0.05).

Table 6. Comparison of treatment changes (T1-T0) in circummaxillary sutures based on treatment group.

Treatment differences	**RME**	**Alt-RMEC**	**95CI% of the difference**	**Significance**
	mean (sd)	mean (sd)		
Frontonasal Suture (mm)	0.255 (0.151)	0.308(0.194)	-0.174;0.692	0.387
Internasal Suture (mm)	0.226 (0.301)	0.289 (0.178)	-0.236;0.110	0.464
Right Nasomaxillary Suture (mm)	0.293(0.136)	0.274(0.099)	-0.064;0.102	0.637
Left Nasomaxillary Suture (mm)	0.288 (0.148)	0.250 (0.100)	-0.050;0.125	0.388
Right and Left Nasomaxillary Suture (mm)	0.290 (0.140)	0.262(0.097)	-0.030;0.087	0.333
Left Zygomaticofrontal Suture (mm)	0.195 (0.147)	0.221 (0.104)	-0.115;0.063	0.557
Mid-Palatal Suture (ANS) (mm)	3.335 (0.901)	2.624 (1.132)	-0.003;1.427	0.051
Mid-Palatal Suture (MP) (mm)	0.712 (0.536)	1.076 (0.730)	-0.812;0.083	0.107
Mid-Palatal Suture (LT) (mm)	0.818 (0.813)	1.334 (0.996)	-1.153;0.118	0.107
Nasomaxillary (indirect, medial orbits) (mm)	0.600 (0.439)	0.612 (0.444)	-0.320;0.297	0.939
Nasomaxillary (indirect, lateral orbits) (mm)	0.912 (0.894)	-4.176 (21.353)	-5.470;15.646	0.334
Nasomaxillary, frontonasal, zygomaticomaxillary (indirect, nasal aperture) (mm)	1.824 (0.814)	2.541 (0.892)	-1.314;-0.121	**0.020**

2.3 Univariate Analysis and Multiple Linear Regression Model

Univariate analyses for the treatment change (T1-T0) of mid-palatal suture proxy measurements was performed and summarized in Table 7. None of the variables which were included in the univariate analysis (age, averaged MPSD ratio, CVMS, sex and treatment group) were statistically significant for any mid-palatal suture proxy measurement, so a subsequent linear regression was not necessary.

Table 7. Univariate analysis for treatment changes in mid-palatal suture proxy measurements.

	Change between right and left Anterior Nasal Spine (mm)		**Change between right and left Posterior Nasal Spine (mm)**		**Change between right and left Medial Pterygoid Plates (mm)**		**Change between right and left Lateral Pterygoid Plates (mm)**	
Pearson's Correlation	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
Age	-0.245	0.162	-0.114	0.521	-0.199	0.260	-0.152	0.390
Averaged MPSD Ratio	-0.198	0.262	-0.135	0.447	-0.082	0.643	-0.024	0.891
CVMS	0.069	0.699	-0.108	0.542	0.024	0.895	0.174	0.325
Student's *t*-test	*t*-value	*p*-value	*t*-value	*p*-value	*t*-value	*p*-value	*t*-value	*p*-value
Sex (Males vs. Females)	-0.071	0.944	-1.039	0.307	-1.067	0.294	-0.332	0.742
Treatment (Alt-RMEC vs. RME)	2.028	0.051	1.005	0.323	-1.660	0.107	-1.660	0.107

Table 8 shows the univariate analysis for the treatment changes in the following direct circummaxillary suture measurements: frontonasal, internasal, right and left nasomaxillary and left zygomaticofrontal sutures. Note that the right zygomaticofrontal suture was not analyzed due to poor ICC. CVMS was a statistically significant explanatory variable for treatment change in the right nasomaxillary suture ($p<0.05$). Table 9 summarizes the linear regression model for treatment changes in the right nasomaxillary suture, where CVMS and sex account for 34.0% of variation in the treatment change of the right nasomaxillary suture.

Table 8. Univariate analysis for the treatment change in direct circummaxillary suture measurements.

	Δ Frontonasal		**Δ Internasal**		**Δ R Nasomaxillary**		**Δ L Nasomaxillary**		**Δ L Zygomaticofrontal**	
Pearson's Correlation	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value	*r*	*p*-value
Age	-0.001	0.995	-0.254	0.147	0.194	0.271	-0.041	0.818	-0.193	0.274
Averaged MPSD Ratio	0.154	0.386	-0.222	0.207	0.043	0.811	0.095	0.592	0.154	0.386
CVMS	-0.075	0.675	-0.129	0.469	0.553	**0.001**	0.074	0.678	-0.102	0.567
Student's *t*-test	*t*-value	*p*-value	*t*-value	*p*-value	*t*-value	*p*-value	*t*-value	*p*-value	*t*-value	*p*-value
Sex (Males vs. Females)	-1.540	0.133	0.292	0.772	2.251	**0.031**	1.303	0.202	-0.406	0.687
Treatment (Alt-RMEC vs. RME)	-0.877	0.387	-0.741	0.464	0.477	0.637	0.875	0.388	-0.594	0.557

Table 9. Multiple linear regression model of the treatment changes (T1-T0) in the right nasomaxillary suture.

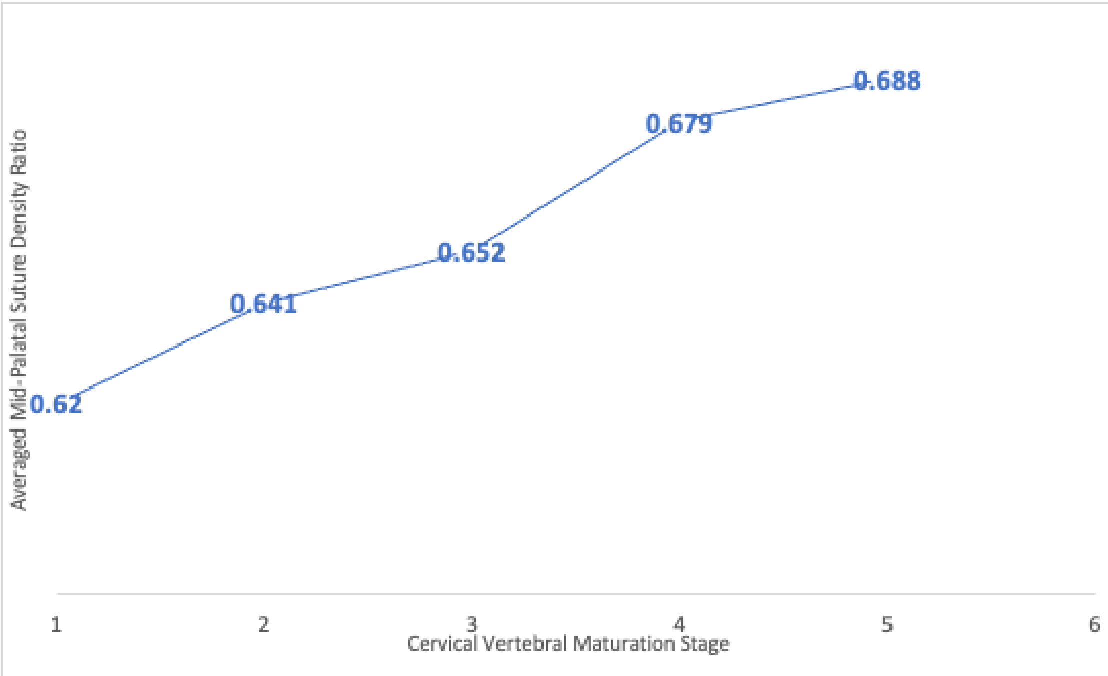
	Δ R Nasomaxillary		
	Estimate	*t*-value	*p*-value
CVMS	0.553	3.756	**0.001**
Sex (Males vs. Females)	-0.277	-1.927	0.063
	Adjusted R-squared = 0.340		

3. Mid-Palatal Suture Density (MPSD) Ratio

3.1 ICC/Error Analysis

Repeated measurements of T0 MPSD ratio were performed with a minimum of a 2-week washout period. Excellent intra-rater reliability was evidenced by ICC values >0.8. Figure 1 helps to visualize the relationship between MPSD ratio and CVMS.

Figure 1. Averaged pre-treatment (T0) MPSD ratio plotted against CVMS.



Conclusions:

1. Both maxillary expansion protocols, RME and Alt-RMEC, result in similar transverse dentoalveolar and skeletal treatment changes and circummaxillary sutural disarticulation.
2. Alt-RMEC produces statistically and clinically significantly lesser degrees of maxillary first molar tipping than RME.
3. Alt-RMEC results in a statistically larger degree of nasal aperture widening than RME as a result of disarticulation of a combination of circummaxillary sutures.
4. Both protocols produce pyramidal expansion patterns except with Alt-RMEC producing a significant parallel expansion pattern at the anterior nasal level.
4. Sex has a correlation with posterior and middle palatal width expansion; males tend to have more expansion than females.
6. MPSD ratio and treatment type do not have a correlation with any transverse dentoalveolar, skeletal or circummaxillary sutural treatment changes included in this study.

<u>Respond to the following questions</u>:

1. Were the original, specific aims of the proposal realized?
   Yes, the original, specific aim of the proposal was realized.
2. Were the results published?
   a. If so, cite reference/s for publication/s including titles, dates, author or co-authors, journal, issue and page numbers
   b. Was AAOF support acknowledged?
   c. If not, are there plans to publish? If not, why not?

Yes, we are writing up the manuscript now and will submit it once it's done.

3. Have the results of this proposal been presented?
    a. If so, list titles, author or co-authors of these presentation/s, year and locations
    Yes, the results of this proposal has been presented on 2021 UBC Dentistry Research Day by Dr. Emily Thong, a orthodontic resident.
    b. Was AAOF support acknowledged?
    Not yet.
    c. If not, are there plans to do so? If not, why not?
4. To what extent have you used, or how do you intend to use, AAOF funding to further your career?

The funding will be used to its full extent as illustrated in the grant proposal, including but not limited to publications, presentations, research materials, and research staff support.

Conclusions: