Accuracy of Model Estimation versus Tanaka and Johnston Arch Length Analysis

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Objectives: *This study examines how accurate pediatric dentists are at estimating dental arch lengths by comparing their model estimations (guesstimating the arch length without measuring) to the Tanaka and Johnston mixed dentition arch length analysis.* ***Study Design:*** *This study consisted of two parts, a survey of practitioners and a model estimating and measuring component. The survey was designed and given to 44 pediatric dentists to determine how many were practicing orthodontics and using arch length analyses routinely. Then 18 pediatric dentists and 13 pediatric dental residents examined 20 sets of mixed dentition models and estimated how much space was available. These estimations were compared to the calculated gold standard, the Tanaka and Johnston arch length analysis of the same models.* ***Results and Conclusions:*** *More than half of the dentists surveyed that practice comprehensive orthodontics use arch length estimates. Pediatric dentists and pediatric dental residents are just as good as each other at estimating arch length. Pediatric dentists and pediatric dental residents underestimated arch length by –3.6 and –3.1 mm, respectively. More research needs to be done to determine if model estimation is a clinically acceptable way to judge arch length.*

Keywords*: arch length analysis, orthodontics, mixed dentition, pediatrics, Tanaka-Johnston, space maintenance*

INTRODUCTION

Many practitioners are practicing orthodontic treatment in the mixed dentition phase.[1] There are several advantages of early orthodontic treatment such as a decrease in overall cost and prevention of further orthodontic treatment.[2] However, with early orthodontic interception comes the importance of mixed dentition arch analysis. While somewhat time consuming, a mixed dentition arch analysis can help predict the mesial-distal width of the permanent canine and premolars which can reveal tooth-size arch length discrepancies.[3] Overprediction of the permanent dentition arch length may result in undesirable extraction therapy, which can significantly compromise the final orthodontic treatment and facial esthetics.

Many different mixed dentition analyses have been discussed in the literature. These analyses usually fall into one of three categories: measurements from radiographs, measurements from study models, or a combination of both.[3] While not as accurate for more diverse populations, some of the most popular methods are the Moyers and the Tanaka and Johnston which both use study models.[3,4] Studies have suggested that the various mixed dentition analyses have high validity and reliability.[5] The Tanaka and Johnston method is one of the most commonly used in the literature for comparison of new methods as it is universally accepted and relatively simple.[3,5,6] The Tanaka and Johnston method uses the mesio-distal widths of the mandibular permanent incisors from study models to predict the mesio-distal width of permanent canine and premolars accurate at the 75th percentile.[7]

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While there is an abundance of literature on the validity of various mixed dentition analyses, little research has been conducted on the number of practitioners that routinely utilize them. Furthermore, little has been published comparing the different accepted mixed dentition analyses versus model estimation via guesstimating without measurement. The aims of this paper are as follows:

- to determine the number of practitioners actively utilizing mixed dentition analyses
- to compare practitioner model estimations to the results from the Tanaka and Johnston mixed dentition analyses for accuracy.
- to determine if model estimations by more experienced pediatric dentists were more accurate than that of pediatric dental residents to evaluate the implications that this may have on treatment planning

MATERIALS AND METHOD

A survey was given to forty-four pediatric dentists associated with the University of Tennessee Pediatric Alumni and the Indiana University Dental School Faculty to determine the percentage of pediatric dentists who perform arch length analysis and what method of analysis they use. The survey was given after an orthodontic seminar for pediatric dentists. The results of the survey were compiled and analyzed.

To compare the difference between practitioner model estimations and the Tanaka and Johnston method, twenty mixed dentition study models from the orthodontic dental clinic at the Indiana University Dental School were used for the analysis. Eighteen pediatric dentists and thirteen pediatric dental residents evaluated the same twenty study models. Each participant evaluated all twenty study models using a best guesstimate, or estimation method, without knowing the results of the Tanaka and Johnston analysis. Examiner A measured the mesial-distal width of the maxillary and mandibular incisors using a digital Boley gauge and performed the calculations described by Tanaka and Johnston[7]. Examiner A was blinded from the results of the participants. Examiner B performed the same measurements to show repeatability and accuracy. The Tanaka and Johnston analysis calculated by Examiner A were used as the control analysis.

Statistical analysis

All analyses were conducted for the whole mouth, i.e., data for maxillary and mandible jaws combined, and for each jaw separately.

The repeatability of each examiners measurements was verified by having Examiner A repeat measurements for all 20 models and then Examiner B repeat calculations for 10 randomly selected models. The measurements were analyzed statistically via mean differences and paired t-tests to test the hypotheses of zero mean difference in measurements. The differences between the dentists' and residents' measurements and the gold standard (Examiner A's measurements) were then calculated for each model and categorized as being a clinically acceptable difference, absolute value of the difference was less than two mm. Differences were categorized as clinically acceptable if they were less than two mm as space excess or deficiencies above two mm typically require more extensive treatment planning and early intervention. [8] The frequency of a clinically acceptable arch length was tabulated, and the mean difference was tested for statistical significance using a paired t-test.

The intra class correlation coefficient (icc) was also estimated using a mixed model with random terms for model and examiner. The icc is the amount of between model variability relative to the total variability. An icc value close to one shows that variability coming from repeated measurements on a model (within model variability) is small relative to the total variability. Total variability is comprised of variability from measurements of different models, from different examiners, and from repeated measurements on the same model.

The differences between the dentists' and residents' measurements versus the gold standard (Tanaka and Johnston measurements) were calculated for each model and categorized as being a clinically acceptable difference, absolute value of the difference was less than two mm. Using this dichotomized response, frequencies were tabulated for each professional type (dentist and resident) for each model. A Cochran Mantel Haenszel statistic (stratified by model) tested the hypothesis of no association between the clinically acceptable difference category and professional type (dentist versus resident).

RESULTS

Profile of pediatric dentists practicing orthodontics

Forty-four dentists were surveyed for the type of orthodontia they practice. Mean number of years practicing pediatric dentistry was 24 with a minimum of 5 years and maximum of 38 years. Of the 44 surveyed, 33 (75%) responded that they practice comprehensive orthodontics. The mean number of years of practicing pediatric dentistry for this subgroup was 24.3. Of these 33 pediatric dentists, 91% responded that they take study models during the mixed dentition and permanent dentition stages. Twenty-six of these 33 (78.79%) responded that they perform arch length analysis. Of these 26, the two most used methods of arch length analysis were model estimation and the Moyers method, used by 50% and 38.5% respectively. Many pediatric dentists indicated the use of more than one type of analysis (Table 1).

Repeatability of each examiner's measurements:

The difference between measurements repeated by each examiner was analyzed for the whole mouth and by jaw. All mean differences by both examiner A and B were less than two mm. Paired t-tests were not significant indicating that repeated measurements by each individual examiner were on average not different from the original measurements thus verifying repeatability of individual measurements (Table 2).

The intra class correlation coefficients of just under one showed that the variability coming from within each model was negligible when compared with the total variability (Table 3).

Because the measurements taken by Examiner A and B were determined to be repeatable across examiners with low variability, measurements from one examiner, Examiner A, were used in the Tanaka and Johnston formula to calculate the predicted arch-length discrepancy. These calculations created the gold-standard for comparison with the estimations by pediatric dentist and residents. The differences in measurements from the gold standard were classified as being a clinically acceptable distance of less than or equal to two mm from the gold standard. For both pediatric dentists and residents, the majority of the estimations were over the clinically

acceptable distance, 78.19% and 73.85% respectively (Table 4). Additionally, the Cochran Mantel Haenszel test showed no association between professional type (dentist or resident) and the category of clinically acceptable difference (Table 5).

Table 1: Profile of Pediatric Dentist that practice orthodontics

mean years practicing pediatric dentistry	24.3 years
Timing of study models	
mixed dentition	9%
mixed dentition and permanent dentition	91%
Type of Orthodontics practiced	
comprehensive orthodontics	9.09%
early and comprehensive orthodontics	2.27%
space maintenance	6.82%
space maintenance and early orthodontics	2.27%
space maintenance, early orthodontics, comprehensive orthodontics	2.27%
space maintenance, space regaining	2.27%
space maintenance, space regaining, early orthodontics	13.64%
space maintenance, space regaining, early orthodontics, comprehensive orthodontics	61.36%
Arch length analysis	
use of arch length analysis	78.79%
no arch length analysis	21.21%
Types of Arch Length analysis used	
Model estimation	50.00%
Moyers	38.40%
Tanaka-Johnston	23.00%
Hixon-Oldfather	15.30%
Other	26.90%

DISCUSSION

The study revealed many of the pediatric dentists surveyed are practicing some sort of orthodontics. Of those that practice orthodontics, most use an arch length analysis with the most popular method being model estimation. Due to the wide use of estimation, it is important to see how reliable this method is because it can greatly influence how these dentists are planning orthodontic treatment.

The statistical analysis of the data shows that the gold standard calculation, Tanaka and Johnston, is repeatable, reliable, and can be used to examine the clinical acceptability of the model estimations made by practitioners. The results indicated that model estimations by both pediatric dentists and pediatric dental residents were often outside the clinically acceptable range. When looking at the whole mouth (maxillary and mandibular) analysis for overall percent of clinically acceptable distance, dentists were within the clinically acceptable range 26.81 percent of the time and residents were in the clinically acceptable range 26.15 percent of the time. In the by jaw analysis, the maxillary arch percentage of clinically acceptable distance was 16.94 % for dentists and 18.46% for residents, which is much worse than the whole mouth percentages. On the other hand, the mandibular arch measurements were much better, with 63% of the pediatric dentists and 61% of the pediatric dental residents estimating the arch length within the clinically acceptable standard that was set at + or – two mm. That is to say, the dentists were much better at estimating the arch lengths in the mandibular arch than the maxillary arch.

Additionally, the Cochran-Mantel-Haenszel test stratified by model showed there was no association between professional type (dentist or resident) and the category of clinically acceptable difference. Pediatric dentists were no better than pediatric dental residents at predicting arch length which could mean that they do not improve upon their arch-length analysis skills past residency.

Because the present study indicates that most pediatric dentists are using model estimations that are often outside the clinically acceptable range to analyze space in the mixed dentition, it is imperative to determine what implications this has on treatment planning. The space requirements and conditions determined in the mixed dentition phase will often translate to the permanent dentition

Table 2: Mean Difference for examiners A and B

	N	Mean difference	Std dev	Std error	Min	Max	Difference	tValue	DF	pvalue
Examiner A whole mouth	40	-0.15	0.62	0.1	-1.52	1.52	y_A–y_A2	-1.58	39	0.12213
Examiner B whole mouth	20	-0.19	0.92	0.21	-1.87	1.65	y_b–y_b2	-0.93	19	0.36167
Examiner A maxillary	20	-0.18	0.67	0.15	-1.52	1.52	Mx_A–Mx_A2	-1.2	19	0.24669
Examiner B maxillary	10	-0.05	1.04	0.33	-1.87	1.65	Mx_B–Mx_B2	-0.16	9	0.87802
Examiner A mandibular	20	-0.13	0.57	0.13	-1.17	0.89	Md_A–Md_A2	-1	19	0.3278
Examiner B mandibular	10	-0.33	0.82	0.26	-1.54	0.88	Md_B–Md_B2	-1.29	9	0.22957

Table 3: Mean difference between measurements of Examiner A and B

	N	|d|<=2	Mean	Std dev	Std error	Min	Max	Difference	tValue	DF	pvalue	Between model var	Between examiner var	Within model var	icc
whole mouth	40	1	-0.04	0.75	0.12	-1.38	1.43	y_A-y_b	-0.3	39	0.7668	17.98	0	0.27	0.99
maxillary	20	1	0.03	0.73	0.16	-1.28	1.43	Mx_A-Mx_B	0.18	19	0.86076	14.68	0	0.25	0.98
mandibular	20	1	-0.1	0.78	0.17	-1.38	1.27	Md_A-Md_B	-0.57	19	0.57341	16.42	0	0.29	0.98

Table 4: Mean difference and clinically acceptable distance in mm between Participant estimations and gold-standard calculations

	N	Mean difference	Std dev	Std error	Min	Max	CAD |d|<=2	|d|>2
Dentist whole mouth	720	-3.6	4.1	0.2	-20.3	7.8	26.81%	73.19%
Resident whole mouth	520	-3.1	3.5	0.2	-12.7	8.9	26.15%	73.85%
Dentist maxillary	360	-4.7	3.7	0.2	-17.4	7.8	16.94%	83.06%
Resident maxillary	260	-4.2	3	0.2	-12.7	7.1	18.46%	81.54%
Dentist mandibular	360	-2.6	4.3	0.2	-20.3	7	36.67%	63.33%
Resident mandibular	260	-1.9	3.6	0.2	-11.3	8.9	33.85%	66.15%

Table 5: Cochran-Mantel-Haenszel test to show association between profession

	cmh	df	pvalue
WHOLE MOUTH	0.075	1	0.78388
MAXILLARY	0.314	1	0.57522
MANDIBULAR	0.632	1	0.42672

which can allow nonideal arch lengths to be detected early. Dental arch space excess of one-two mm is usually ideal which will often allow the permanent teeth to erupt with little crowding and without intervention. However, if there is too much space available (>3 mm), decisions have to be made regarding potential space closure, and more long-term planning. Space deficiencies, on the other hand, often require more immediate intervention. A space deficiency of less than -3 mm might necessitates a lower lingual holding arch, while a space deficiency of greater than -3 mm may require a space regaining, arch expansion or extraction treatment.[8] The present study indicates that pediatric dentists are often underestimating the space available by an average of -3.6 mm, which is roughly half the size of an average premolar.[9] Following the traditional space deficiency measurements, they may be inclined to undesirably create space with an appliance or extractions, when the dentition may have been acceptable for early observation with no intervention.

There are several theoretical advantages to early treatment such as improved control of growth, improved self-esteem of the patient, and decreased cost and extent of treatment in the permanent dentition.[10] Some studies suggest that early intervention may have two improved treatment outcomes of less relapse and treatment times.[11] However, overall there seems to be insufficient evidence to support the additional benefits of early treatment over traditional treatment options.[12,13] Early treatment may add additional cost as permanent teeth may erupt into undesirable locations even after intervention, which would require correction with stage II treatment.[14]The lack of evidence supporting early mixed dentition therapy combined with the results of the present study suggests that early treatment should be restricted to conservative treatment options especially if practitioners are not using accurate measurements of arch space.[12] More irreversible methods like extraction therapy should perhaps be reserved until the occlusion has further developed. Early intervention should only be done if it will be truly efficient and effective as suggested by Proffit.[14] If pediatric dentists are to begin treatment in the mixed dentition, the results of this study indicate that they should use an established mixed dentition analysis to aid in more accurate treatment planning.

A limitation to this study was that we were not able to determine how accurate the measurements and estimations were to the actual permanent dentition arch length. Future studies could follow that arch length development into the full permanent dentition to allow this consideration.

CONCLUSIONS

1. More than half of the dentists surveyed that practice comprehensive orthodontics do model estimation arch length analysis.
2. Pediatric dentists and pediatric dental residents are just as good as each other at estimating arch length.
3. Pediatric dentists and pediatric dental residents underestimated whole mouth arch lengths by –3.6 and –3.1 mm, respectively.
4. Both pediatric dentists and pediatric dental residents are better at estimating mandibular arch lengths than maxillary arch lengths.

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