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Reliability evaluation of 3-D models when compared with plaster models for mixed dentition analysis

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Abstract---AIM: Inclination towards digital models in orthodontics is increasing and several software programs are available to perform virtual model analyses for diagnosis & treatment planning. The aim of this study was to compare as well assess the accuracy and validity of 3D models over plaster casts for mixed dentition analysis. MATERIALS AND METHODS: This prospective cross-sectional study was conducted on 16 children from the age group of 8-13 years with mixed dentition. Intraoral scanning using a 3D scanner (MEDIT) to generate digital models of the upper and lower arches, then alginate impressions were taken and models poured. Mixed dentition model analysis, specifically Moyers and Tanaka Johnston analysis, were performed with measurements made on both plaster models using digital vernier calipers and digital models. Obtained data was statistically analyzed using SPSS software (IBM corp, version 13). RESULTS: Statistical analysis of the data comparison between digital and plaster models of both Moyers and Tanaka Johnston mixed dentition analysis gave us a ‘p’ value greater than 0.05 hence proving the null hypothesis. CONCLUSION: When analysing mixed dentition,

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virtual models are 95% as accurate as plaster models. Digital models might be considered as a substitute to plaster models for doing mixed dentition space analysis with appropriate clinical accuracy and predictability.

***Keywords*---**mixed dentition analysis, plaster models, digital models, reliability.

Introduction

Malocclusions are 3rd most common oral health problem followed by dental caries & periodontal diseases as estimated by the World Health Organization (WHO)(1). Crowding or spacing between teeth in the dental arch is one of the key concerns for patients seeking orthodontic treatment(2). Dentition development can only be monitored if mesiodistal tooth dimension can be accurately predicted for the unerupted permanent canines and premolars(3,4). Mixed dentition space analysis (MDSA) assists in identifying space discrepancies and evaluating the width of unerupted premolars and canines. Several prediction methods are available based on regression equations from study models(5–7), radiographs (8,9) and a combination of both(10–12). Among these, radiographic methods have magnification error, combination of both prediction equation and table overestimates or underestimates the size of unerupted teeth. However, the regression equation is relatively reliable and has systematic error at a lower level than the other methods. Hence, in this study we have taken regression equation methods for mixed dentition analysis.

Both Moyers and Tanaka-Johnston methods use linear correlations existing between the sum of mesiodistal tooth widths of lower permanent incisors & unerupted lower or upper permanent canines and premolars. With Moyers' prediction tables, it was possible to calculate the mesiodistal width of premolars and permanent canines based on the sum of mandibular incisor widths(13). Tanaka and Johnston developed an equation in an attempt to elucidate the mixed dentition space analysis (7). Traditionally model analyses were conducted on plaster casts by using vernier calipers which were recognized as the clinical standard for linear measurements. However, some impediments exist with the use of plaster casts. Time for fabrication, weight and volume, storage space, possibility of breakage and degradation, deterioration, and difficulty in communicating information with other professionals are some of its drawbacks(14).

Digital models such as OrthoCad and Emodels (laser-based scanners) were introduced commercially in 1999 and 2001 respectively and direct scanning of impressions by Digimodel (CBCT based scanners) and several other laser scanners such as VIVID8, 3Shape etc., are available. Digital models have positive impact over plaster dental casts as it can be viewed in all planes of space, visualized with respect to either arch, quick accessibility from storage area. It can be transferred and assigned anywhere for referral and confabulation with colleagues and patients. Performing appropriate diagnostic set-ups of various extraction patterns also improves clinical acumen and judgement. In this study we used digital 3D software MEDIT for direct intraoral scan of patients. The aim of this study was to compare as well asassess the accuracy and validity of 3D models over plaster casts for performing mixed dentition analysis.

Materials and Methods

This prospective cross-sectional study was carried out in the Department of Orthodontics at Private dental college under the supervision of two blinded observers. The sample size calculation was done and 16 children were randomly selected for the study(15). Approval was granted from the Institutional Review Board. Gender differentiation was not considered. Children of age 8-13 years with fully erupted permanent mandibular incisors & permanent molars in both arches as well as at least one deciduous tooth in each quadrant were included. Loss of tooth structure as a result of proximal caries, restoration or fractures as well as subjects with severe crowding, abnormal inclination, severe rotation, congenitally missing teeth, supernumerary teeth, and any other congenital craniofacial anomalies were excluded.

Impression and scanning

All children were scanned intraorally using 3D intraoral scanner(MEDIT) followed by alginate impressions of both arches in the same appointment. The scanned data was processed and viewed with 3Shape Ortho Analyzer (Copenhagen, Denmark) for making base and also for recording measurements. The pouring was done immediately the alginate impressions were poured immediately with dental plaster (ORTHOKAL) on a model vibrator to avoid formation of voids and blebs.

Measurements and data recording

The mesiodistal width of the teeth on plaster models were obtained by measuring the greatest distance between contact points on proximal surfaces using a digital Vernier caliper providing measurements to 0.01 mm accuracy. The measurements were recorded by placing the digital vernier caliper perpendicular to the long axis of the teeth and parallel to the occlusal surface if they appeared to be aligned normally (Figure 1) (16). Otherwise, the mesiodistal crown width was measured between the points where normal contact with the next tooth occurs(17). Transverse lines drawn across the greatest mesiodistal width of posterior teeth from occlusal view and anterior teeth from labial view on digital casts served as a guide for measuring measurements (Figure 2) (18–20). The same investigator performed all measurements again on 5 randomly selected models and then kappa statistics was done to check intra rater reliability.

Moyers method

In order to estimate canine and premolar width, a 75th percentile probability chart was utilized to calculate the sum of mandibular permanent incisors(13).

Tanaka and Johnston method

In order to determine the mesiodistal dimensions of the permanent canine and premolars, a regression equation for both sides of the upper [Y = 11 + 0.5 (X)] and lower [Y = 10.5 + 0.5 (X)] dental arches was utilised, where X is total of four erupted permanent incisors and Y is total width of unerupted canines and premolars (7). Using SPSS software, the data was imported into an Excel spreadsheet and analysed (IBM Corp, Version 23). All four quadrants were evaluated in a paired t-test, which found a significant difference between the actual and predicted measurements using Moyers and Tanaka Johnston mixed dentition analysis. A p-value of less than 0.05 was considered significant.

Results

The data obtained for Moyer's mixed dentition analysis was tabulated, Table 1 shows Mean and SD for actual values. The actual values in Moyers mixed dentition analysis between plaster and digital models were 23.81±1.10 and 23.89±0.89 in first quadrant, 23.63± 1.85and 23.69±1.72 in second quadrant, 23.00±1.75 and 23.23±1.44 in third quadrant, 23.3±1.74 and 23.43±1.41 in fourth quadrant respectively. There was no statistically significant difference in the actual values of the Moyers mixed dentition analysis between plaster and digital models (Table 1). Table 2 shows Mean and SD for predicted values. The predicted values in Moyers mixed dentition analysis between plaster and digital models weres 21.69±0.43 and 21.67±0.41 in first quadrant, 21.65±0.45 and 21.68±0.42 in second quadrant, 21.70±0.50 and 21.65±0.45 in third quadrant, 21.71±0.48 and 21.67±0.44 in fourth quadrant respectively. There was no statistically significant difference in the predicted values of the Moyers mixed dentition analysis between plaster and digital models (Table 2). Table 3 shows Mean and SD values for Tanaka Johnston analysis between plaster and digital models, it was 22.71±0.40 and 22.63±0.44 in maxilla and 22.21±0.40 and 22.07±0.50 in mandible respectively. There was no statistically significant difference for Tanaka Johnston analysis between plaster and digital models (Table 3).

Discussion

Previous researches has confirmed that with the help of digital software, dental anatomical features can be reproduced to a high degree of accuracy(21)(22).Orthodontic diagnostic and treatment planning using digital models is becoming more widely accepted than using traditional plaster models(23). Using digital model in orthodontics is on the horizon, with a plethora of software tools available for virtual model analysis and orthodontic appliance fabrication (24). Hence there is a need to evaluate the reliability and validity of 3D digital models with respect to the conventional standards. Analyzing the mesiodistal width of teeth in the mixed dentition stage utilising mixed dentition space analysis is used to diagnose developing malocclusion. Inappropriate space analysis may have a negative impact on extraction decision , which may alter the patient's facial profile and thus precision in treatment planning is essential in the management of malocclusion throughout the mixed dentition phase(25). Tanaka-Johnston(7) and Moyers techniques(13) are the two most often utilized methods of mixed dentition analysis in children. Among the seven different mixed dentition analyses, Moyer's mixed dentition analysis was shown to be the most reliable and valuable method of evaluation(26). The sum of the mesiodistal dimensions of the erupted lower permanent incisors in the 75th percentile of Moyer's mixed dentition prediction table is used to estimate the width of unerupted permanent teeth. In mixed dentition, the mandibular permanent incisor may be preferable since it emerges early, allows for a quick measurement, and has only minor size variations(25). Therefore, in our study, we considered the two most established valuable and reliable analyses to compare and assess the precision and reliability of 3D models over plaster casts in mixed dentition analysis and concluded that accuracy and reliability of data obtained from 3 D model is as comparable as data collected from plaster model for mixed dentition analysis. To our knowledge, this is the first study that compares the reliability and precision of measurements in mixed dentition analysis on digital models produced from intraoral compared to manual analyses on plaster casts using a digital calliper.

Plaster conventional models were chosen as a standard reference to investigate the precision and reliability of digital models in mixed dentition analysis since direct measurement can be carried out on plaster models with digital callipers regularly used in orthodontic diagnosis and treatment planning. Regardless of the fact that plaster conventional models have been considered as gold standard in diagnosis and treatment planning for, it has some impediments such as cost, time , weight and volume, need space for storage, potential for breakage & difficulty of exchanging information with other professionals. In order to avoid inaccuracy in linear measurements of teeth, selection bias and examiner bias should be considered because it is important to consider several factors that might persuade the accuracy of digital measurements. Hence, the factors that include selection bias are the degree of crowding(27), excessive spacing, abnormal inclination and rotated teeth. Therefore, in this study subjects with severe crowding and malformation of teeth were precluded to avoid alterations in accuracy of tooth measurements(28).

The examiner's digital measuring training, expertise, and experience are all susceptible to examiner bias since inexperience leads to fatigue and laboriousness, which may contribute to measurement inaccuracy(29) and also determination and identification of landmarks may be difficult on 3D images because image can be viewed only in 2 dimensional (27,30). Hence, the examiner in this current investigation had previously been well-versed in model analysis and had used this software on a regular basis in clinical practise to avoid measurement inaccuracy. Another element that impacts measuring accuracy is the production of plaster models (31). It is possible to see substantial dimensions changes in dental models poured within an hour of the impression being taken, as opposed to those poured 24 hours later (32). Hence in this study to eliminate measurement distortion or fluctuation due to alginate impressions, plaster models made from impressions were poured immediately and digital models created by intraoral scanning showed no statistically significant difference in linear measurements. In this study, measurements showed almost perfect agreement of kappa statistics of 0.95-0.99 for digital models and 0.93-0.96 for plaster models.

Nowadays, different softwares and methods of scanning are available for measuring dimensions of teeth. Both intraoral and cone-beam computed tomography scanning of alginate impressions are reliable methods for tooth width measurements as well as Bolton analysis for diagnosis and treatment planning(33). ITero's extraoral model scanning is more precise than intraoral scanning(34). CBCT-derived images in mixed dentition analysis were considered as unreliable as compared to data obtained directly from the plaster model for mixed dentition analysis(15). Some literature opposes that measurements from plaster models with digital calipers were considered as more meticulous and predictable than those obtained with digital models(27).More accurate measurements were noticed, especially in height and width, but less accurate in depth in digital models obtained with a surface laser scanner compared with conventional plaster dental casts(22,35). Digital models with scanned casts showed superior measurements compared with plaster models in evaluating the mixed dentition space analysis by Tanaka and Johnston's equation(20).

Some related literature supports the results of the present study such as measurements from digital models from impressions that semmed to be as valid, accurate and predictable as measurements made from plaster models(36,37). One systematic review showed that orthodontic measurements with digital models were comparable and consistent to those derived from plaster dental models(23). Digital dental models have been shown to be as accurate, trustworthy, and reproducible as conventional plaster dental models(38). The present study also showed that accuracy and reliability of 3 D models is comparable with plaster casts in mixed dentition analysis.

Conclusion

Digital models were found to be 95 % as reliability of the plaster models in mixed dentition analysis. Models made from plaster had no statistically significant differences between the digital vernier calliper measurements and the 3D models obtained using intraoral scanning. Digital models might be considered an alternative to plaster models in mixed dentition space analysis because of their clinically acceptable accuracy and repeatability in tooth measurements.

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All three authors have equal contributions in bringing out this research.

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Figures

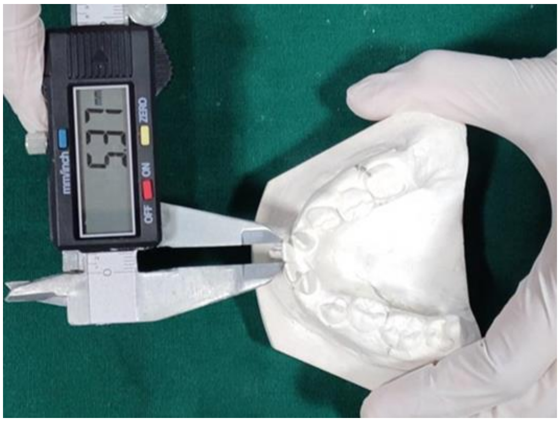

Figure 1. Digital vernier caliper used for mesiodistal width measurements in plaster casts

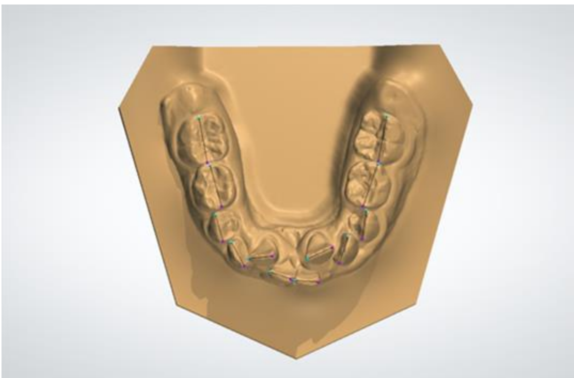

Figure 2. Measurements of mesiodistal width in digital casts by using measurement tool in 3Shape Ortho Analyzer

Tables

Table 1
Actual values based on plaster and digital models using Moyers mixed dentition analysis

		N	Mean	Standard Deviation	P value
FIRST QUADRANT	PLASTER	16	23.81	1.10	0.452
	DIGITAL	16	23.89	.89	
SECOND QUADRANT	PLASTER	16	23.63	1.85	0.558
	DIGITAL	16	23.69	1.72	
THIRD QUADRANT	PLASTER	16	23.00	1.75	0.409
	DIGITAL	16	23.23	1.44	
FOURTH QUADRANT	PLASTER	16	23.31	1.74	0.621
	DIGITAL	16	23.43	1.41	

Table 2
Predicted values based on plaster and digital models using Moyers mixed dentition analysis

		N	Mean	Standard Deviation	p value
FIRST QUADRANT	PLASTER	16	21.69	0.43	0.333
	DIGITAL	16	21.67	0.41	
SECOND QUADRANT	PLASTER	16	21.65	0.45	0.585
	DIGITAL	16	21.68	0.42	
THIRD QUADRANT	PLASTER	16	21.70	0.50	0.539
	DIGITAL	16	21.65	0.45	
FOURTH QUADRANT	PLASTER	16	21.71	0.48	0.252
	DIGITAL	16	21.67	0.44	

Table 3
Tanaka Johnston analysis between plaster and digital models in both maxilla and mandible

		N	Mean	Standard Deviation	P value
MAXILLA	PLASTER	16	22.71	0.40	0.0670
	DIGITAL	16	22.63	0.44	
MANDIBLE	PLASTER	16	22.21	0.40	0.0730
	DIGITAL	16	22.07	0.50	