Aims and Objective: The aim of the study was to evaluate the reliability of cone beam computed tomography (CBCT) obtained image over plaster model for the assessment of mixed dentition analysis.

Materials and Methods: Thirty CBCT-derived images and thirty plaster models were derived from the dental archives, and Moyer’s and Tanaka-Johnston analyses were performed. The data obtained were interpreted and analyzed statistically using SPSS 10.0/PC (SPSS Inc., Chicago, IL, USA). Descriptive and analytical analysis along with Student’s t-test was performed to qualitatively evaluate the data and $P < 0.05$ was considered statistically significant.

Results: Statistically, significant results were obtained on data comparison between CBCT-derived images and plaster model; the mean for Moyer’s analysis in the left and right lower arch for CBCT and plaster model was 21.2 mm, 21.1 mm and 22.5 mm, 22.5 mm, respectively.

Conclusion: CBCT-derived images were less reliable as compared to data obtained directly from plaster model for mixed dentition analysis.

Keywords: Digitalization, mixed dentition, model analysis, plaster models, reliability

Introduction

Comprehensive orthodontic diagnosis and treatment planning is the most pivotal component for the success of a treatment regime as it determines the course of action which is to be implemented. Key factors which assist in establishing a proper diagnosis are termed the diagnostic aids. Model analysis is an essential diagnostic record used to study occlusion and dentition from all the three-dimensional (3D) and analyze the degree and severity of malocclusion. Various methods have existed for decades for assessment of a case; however, with modernization and industrialization, the scope and clarity have increased multifold.

Introduction of radiographical imaging into orthodontics has eased the approach of treatment planning. Of particular interest are the validity, reliability, and accuracy of these latest technologies in relation to well-established methods, as like impressions and dental casts. Procuring the impressions and making the models followed by model analysis become really tedious and time-consuming and thus thrive us to search on modern techniques which would take care of the difficulty faced. On reviewing the literature, significant difference has been noted while comparing the different modern techniques with preexisted methods but still allows clinically acceptable measurements, such as the American Board of Orthodontics Objective Grading System, which has found digital scans to have insufficient accuracy for several individual measurements compared with plaster casts. Yet no matter how accurate the traditional techniques have been when dealing with pediatric cases the procedures becomes dilatory.
The latest technique in radioimaging used in orthodontics, i.e., cone beam computed tomography (CBCT), could potentially eliminate the trouble and complication of dealing with pediatric noncompliant patients. However, before implementing CBCT as diagnostic aid in pediatric cases, its accuracy, validity, and most importantly safety are to be assessed and assured. Various mixed dentition analysis are present in the literature, namely, Moyer’s analysis, Tanaka-Johnston analysis, Hixon-Oldfather analysis, Staley Kraber analysis, Huckaba’s analysis, and Ballard and Willie’s analysis. However, no previous study has compared the data obtained from plaster models directly to CBCT images during mixed dentition; therefore, the purpose of this study was to determine the reliability and reproducibility of mixed dentition analyses such as Moyer’s analysis with 75% and 95% error analysis and Tanaka-Johnston analysis obtained from CBCT images and comparing it with the conventional method of plaster study models by impressions.

**Materials and Methods**

A prospective hospital-based study was planned from November 1, 2015, to January 31, 2017. The study was directed in conformance with the Helsinki Declaration of 1975, as revised in 2000, and after Institutional Research and Ethical Committee clearance with letter number KIMS/KIIT/IEC/142/2015. The study was conducted after informed consent was received from all the patients’ guardians participating in the study. Thirty CBCT images of sample with mixed dentition along with sixty maxillary and mandibular impressions of the same fulfilling the inclusion criteria were obtained from Department of Pedodontics, Kalinga Institute of Dental Sciences, KIIT University, Bhubaneswar. The inclusion criteria for sample selection included patients in the age group of 8–14 years with well-aligned arch. Exclusion criteria of the study involved severe crowding, excessive spacing, congenitally missing teeth, and patients with any syndrome.

For clinical data collection, impressions of the maxillary and mandibular arch were taken using rubber base putty material on stock trays. Impressions were poured using ORTHOKAL (Kalabhai) and were assessed for voids and blebs. Study model preparation was carried out. The cast was polished and soaped. Moyer’s and Tanaka-Johnston analyses were then performed on the obtained cast using a 6-inch digital caliper with light-emitting diodes display (i.e., graduation: 0.01 mm, accuracy: 0.02 mm, repeatability: 0.01 mm) [Figure 1]. Calibration of the caliper was performed before each measurement. For data collection from the CBCT (My ray, Hyperion X9), Moyer’s and Tanaka-Johnston analyses were directly performed on the sagittal section at occlusal level [Figure 2].

Data were analyzed using Statistical Package for the Health Sciences SPSS 10.0/PC (SPSS Inc., Chicago, IL, USA). All results are expressed as mean-standard deviation; intermeasurement differences were analyzed with the paired $t$-test for continuous variables and the $\chi^2$ test for percentages. Moreover, $P < 0.05$ was considered statistically significant.

**Results**

Of the data collected, distribution of variation in CBCT-derived images and plaster models is depicted in Tables 1 and 2 for Moyer’s mixed dentition analysis. Highly statistically, significant difference was obtained for Moyer’s analysis. The mean for Moyer’s analysis in the left and right lower arch for CBCT and plaster model was 21.2 mm, 21.1 mm and 22.5 mm, 22.5 mm, respectively. The mean values for upper arch were 21.7


Table 1: Moyer’s analysis for plaster model and cone beam computed tomography image

|                  | Mean  | SD    | t     | P     |
|------------------|-------|-------|-------|-------|
| Actual CBCT (upper right) | 21.775 | 0.7111 | -6.686 | 0.001 |
| Actual model (upper right)  | 22.583 | 0.6337 |      |       |
| Actual CBCT (upper left)   | 21.642 | 0.6694 | -6.703 | 0.001 |
| Actual model (upper left)  | 22.658 | 0.6403 |      |       |
| Actual CBCT (lower left)   | 21.217 | 0.7614 | -5.543 | 0.001 |
| Actual model (lower left)  | 22.500 | 0.7977 |      |       |
| Actual CBCT (lower right)  | 21.133 | 0.7101 | -11.453 | 0.001 |
| Actual model (lower right) | 22.508 | 0.6612 |      |       |

P<0.05. CBCT=Cone beam computed tomography, SD=Standard deviation

Table 2: Prediction based on cone beam computed tomography and plaster cast model using Moyer’s analysis

|                  | Mean  | SD    | t     | P     |
|------------------|-------|-------|-------|-------|
| Predicted CBCT (maxillary arch) | 21.933 | 0.5630 | -3.443 | 0.005 |
| Predicted model (maxillary arch)  | 22.508 | 0.3088 |      |       |
| Predicted CBCT (mandibular arch) | 21.717 | 0.7056 | -6.751 | 0.001 |
| Predicted model (mandibular arch) | 22.742 | 0.5089 |      |       |

P<0.05. CBCT=Cone beam computed tomography, SD=Standard deviation

Table 3: Tanaka-Johnston analysis on plaster model and cast

|                  | Mean  | SD    | t     | P     |
|------------------|-------|-------|-------|-------|
| Tanaka-Johnston CBCT (upper) | 0.467 | 0.7901 | -0.470 | 0.648 |
| Tanaka-Johnston plaster model (upper) | 0.6133 | 1.30577 |      |       |
| Tanaka-Johnston CBCT (lower)   | 0.683 | 1.7092 | -1.344 | 0.206 |
| Tanaka-Johnston plaster model (lower) | 1.258 | 1.4774 |      |       |

P<0.05. CBCT=Cone beam computed tomography, SD=Standard deviation

mm and 21.6 mm for CBCT and 22.5 and 22.6 mm in plaster models. No significant results were obtained when comparing Tanaka-Johnston analysis on CBCT and plaster model [Table 3]. The mean values for upper arch were found 0.4 mm for CBCT and 0.6 for plaster model, and the mean value for lower arch was found 0.6 mm in CBCT and 1.2 mm in plaster model.

**DISCUSSION**

A variety of methods are available for model analysis of mixed dentition. Moyer’s and Tanaka-Johnston analysis are the most comprehensive nonradiographic method of evaluation of plaster models. In a study conducted by Kondapa et al.[7] found Moyer’s analysis to be the most reliable method for evaluation as compared to seven different mixed dentition analysis followed by Tanaka-Johnston. Therefore, in our study, we considered the two most established and reliable analysis to evaluate and collate the variation between data obtained from CBCT images and plaster models; we concluded that CBCT-derived images were less reliable as compared to data obtained directly from plaster model for mixed dentition analysis. In a study by Costalos et al.[4] comparison was conducted between plaster models and CBCT scanned digital models, they concluded as the merit of a digital model obtained from a CBCT scan of a plaster cast include good soft-tissue reproduction, no radiation exposure for the patient, no scatter on the image from metal dental restorations, no need to purchase another scanning method, and the ability to digitally archive any already existing plaster dental model. Clinical accuracy ensures that 3D digital models rendered from CBCT scans of plaster casts are an appropriate alternative to traditional plaster models. In our study, we focused to lessen the armamentarium used and focusing mainly on CBCT-derived images. As CBCT is routinely used for diagnosis in clinics, considering the distortion effect of metals on the scan we tried to evaluate the reliability of CBCT. All the parameters showed statistically significant results with clinically significant parameters for Moyer’s analysis with a standard deviation ranging from 0.6 to 0.7 on an average. Another source of the poor correlation is measurement error. Before concluding that sloppy measurement is to blame, some perspective in the measurement values is helpful. Our study was indeed an effort toward complete digitalization of orthodontic records by utilizing the cutting edge technology available in this modern era. Some authors compared the measurements made in plaster models in respect of the scanning models.[14-19] Others compared the measurements made in plaster models in respect to the digital CBCT image and scanned CBCT models of plaster cast.[20-22] and a few compared the three techniques.[22-25] CBCT is an important diagnostic tool in dentistry.[26,27] Nagarajamurthy et al. concluded multidetector computed tomography (MDCT) is a useful and reliable imaging tool to evaluate normal morphology and abnormalities of the dental arch. There were no significant differences in measurements obtained by MDCT and plaster cast, making MDCT a useful method for digital acquisition.[28]

The drawback of our study would be the radiation exposure as seen in CBCT is higher than conventional radiography. However, during conventional radiography, a patient is exposed multiple times to the radiographic procedure which when summoned might be equally or more deleterious than digital 3D CBCT. The values obtained in our study showed a basic difference of 1–1.5 mm in comparison to plaster cast and CBCT image. Therefore, CBCT can be used as a modality for mixed dentition analysis based on need and convenience of the
patient. In future, new studies should standardize the differences in value.

**CONCLUSION**

1. A significant difference was found between measurements obtained from CBCT and plaster models for mixed dentition analysis
2. Proper digitization and preserving data are more convenient by our dependency on CBCT.

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**CONFLICTS OF INTEREST**
There are no conflicts of interest.

**REFERENCES**

1. Berco M, Rigali PH Jr., Miner RM, DeLuca S, Anderson NK, Will LA. Accuracy and reliability of linear cephalometric measurements from cone-beam computed tomography scans of a dry human skull. Am J Orthod Dentofacial Orthop 2009;136:17.e1-9.
2. Leifert MF, Leifert MM, Efstratiadis SS, Cangialosi TJ. Comparison of space analysis evaluations with digital models and plaster dental casts. Am J Orthod Dentofacial Orthop 2009;136:16.e1-4.
3. Zilberman O, Huggare JA, Parikakis KA. Evaluation of the validity of tooth size and arch width measurements using conventional and three-dimensional virtual orthodontic models. Angle Orthod 2003;73:301-6.
4. Costalos PA, Sarraf K, Cangialosi TJ, Efstratiadis S. Evaluation of the accuracy of digital model analysis for the American Board of Orthodontics objective grading system for dental casts. Am J Orthod Dentofacial Orthop 2005;128:624-9.
5. Hildebrand JC, Palomo JM, Palomo L, Sivik M, Hans M. Evaluation of a software program for applying the American Board of Orthodontics objective grading system to digital casts. Am J Orthod Dentofacial Orthop 2008;133:283-9.
6. Okunami TR, Kusnoto B, BeGole E, Evans CA, Sadowsky C, Fadavi S. Assessing the American Board of Orthodontics objective grading system: Digital vs. plaster dental casts. Am J Orthod Dentofacial Orthop 2007;131:51-6.
7. Kondapaka V, Sesham VM, Neela PK, Mamillapalli PK. A comparison of seven mixed dentition analysis methods and to evaluate the most reliable one in Nalgonda population. J Indian Orthod Soc 2015;49:3-9.
8. Stevens DR, Flores-Mir C, Nebbe B, Raboud DW, Heo G, Major PW. Validity, reliability, and reproducibility of plaster vs. digital study models: Comparison of peer assessment rating and Bolton analysis and their constituent measurements. Am J Orthod Dentofacial Orthop 2006;129:794-803.
9. Quimby ML, Vig KW, Rashid RG, Firestone AR. The accuracy and reliability of measurements made on computer-based digital models. Angle Orthod 2004;74:298-303.
10. Nouri M, Abdi AH, Farzan A, Mokhtarpour F, Baghban AA. Measurement of the buccolingual inclination of teeth: Manual technique vs. 3-dimensional software. Am J Orthod Dentofacial Orthop 2014;146:522-9.
11. Mullen SR, Martin CA, Ngan P, Gladwin M. Accuracy of space analysis with models and plaster models. Am J Orthod Dentofacial Orthop 2007;132:346-52.
12. Favero L, Terrazzani C, Favero V, Stellini E, Cocilovo F. Virtual study models: A comparison of modular application systems. Prog Orthod 2009;10:16-25.
13. Sjögren AP, Lindgren JE, Huggare JA. Orthodontic study cast analysis – Reproducibility of recordings and agreement between conventional and 3D virtual measurements. J Digit Imaging 2010;23:482-92.
14. Reuschl RP, Heuer W, Stiesch M, Wenzel D, Dittmer MP. Reliability and validity of measurements on digital study models and plaster models. Eur J Orthod 2016;38:22-6.
15. Tomasetti JJ, Taloumis LJ, Denny JM, Fischer JR Jr. A comparison of 3 computerized Bolton tooth-size analyses with a commonly used method. Angle Orthod 2001;71:351-7.
16. Santoro M, Galinkin S, Teredesai M, Nicolay OF, Cangialosi TJ. Comparison of measurements made on digital and plaster models. Am J Orthod Dentofacial Orthop 2003;124:101-5.
17. Luu NS, Mandich MA, Flores-Mir C, El-Bialy T, Heo G, Carey JP, et al. The validity, reliability, and time requirement of study model analysis using cone-beam computed tomography-generated virtual study models. Orthod Craniofac Res 2014;17:14-26.
18. Akylcin S, Dyer DJ, English JD, Sar C. Comparison of 3-dimensional dental models from different sources: Diagnostic accuracy and surface registration analysis. Am J Orthod Dentofacial Orthop 2013;144:831-7.
19. Fleming PS, Marinho V, Johal A. Orthodontic measurements on digital study models compared with plaster models: A systematic review. Orthod Craniofac Res 2011;14:1-16.
20. Gamba TO, Oliveira ML, Flores IL, Cruz AD, Almeida SM, Haiter-Neto F, et al. Influence of cone-beam computed tomography image artifacts on the determination of dental arch measurements. Angle Orthod 2014;84:274-8.
21. Periago DR, Scarfe WC, Mosbahi M, Scheetz JP, Silveira AM, Farman AG. Linear accuracy and reliability of cone beam CT derived 3-dimensional images constructed using an orthodontic volumetric rendering program. Angle Orthod 2008;78:387-95.
22. Tarazona B, Llamas JM, Cibrian R, Gandia JL, Paredes V. A comparison between dental measurements taken from CBCT models and those taken from a digital method. Eur J Orthod 2013;35:1-6.
23. Lagravère MO, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. Am J Orthod Dentofacial Orthop 2008;134:112-6.
24. Ganguly R, Ruprecht A, Vincent S, Hellstein J, Timmons S, Qian F. Accuracy of linear measurement in the Galileos cone beam computed tomography under simulated clinical conditions. Dentomaxillofac Radiol 2011;40:299-305.
25. Kau CH, Littlefield J, Rainy N, Nguyen JT, Creed B. Evaluation of CBCT digital models and traditional models using the Little's Index. Angle Orthod 2010;80:435-9.
26. Okano T, Sur J. Radiation dose and protection in dentistry. Jpn Dent Sci Rev 2010;46:112-21.
27. Silva MA, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: A radiation dose evaluation. Am J Orthod Dentofacial Orthop 2008;133:640.e1-5.
28. Nagamurthy, Vishwanath TT. Comparative Study of MDCT with Plaster Cast Model of Dentalveolar Arch Morphology. Int J Anat Radiol Surg 2017;6:17-20.