A computed tomographic, mixed dentition, space analysis comparison

Luís Queijo,* Francisco do Vale,* Ana Corte-Real† and Sónia Alves*
Department of Orthodontics, Dentistry Area, Faculty of Medicine* and Forensic Sciences Area, Faculty of Medicine,† University of Coimbra, Coimbra, Portugal

Introduction: A considered space analysis aims to predict the combined mesiodistal widths of unerupted permanent canine and premolars. A miscalculation can lead to the application of inadequate and irreversible treatments.

Objective: To assess the level of agreement between predictions generated by three methods (Moyers’ predictive tables at the 50th and 75th percentiles and Tanaka-Johnston’s equations) on the sum of unerupted teeth compared with measurements derived from cone beam computed tomography, considered in the present study as a ‘gold standard’.

Materials and methods: The study sample was comprised of children (N = 26) aged 8–13 who visited the Department of Dentistry. Moyers’ predictive tables and the Tanaka-Johnston equation were applied to ascertain the space requirements. Cone beam computed tomography was performed on each patient and the volumetric data analysed. A concordance correlation coefficient between each method’s predictions was applied.

Results: The three methods tended to overestimate the cone beam computed tomography readings and were not able to entirely capture the variability of the sum of the unerupted teeth. Moyers’ 50th percentile estimate revealed a more balanced distribution between over- and underestimation.

Conclusion: The present study suggested that Moyers’ 50th percentile is the predictive method with the lowest absolute error and is preferred for clinical use.

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Luís Queijo: lcjqueijo@gmail.com; Francisco do Vale: franciscovale@gmail.com; Ana Corte-Real: a.corte.real4@gmail.com;
Sónia Alves: soalves@gmail.com

Introduction
The main therapeutic goal for all orthodontic patients is to achieve an ideal dental occlusion. Dentoalveolar malocclusions are the result of an imbalance between tooth and arch size and arise mostly during the mixed dentition period of development. If appropriately managed, space problems can be reduced in severity or even removed entirely.¹ Therefore, a correct diagnosis based on an adequate mixed dentition analysis (MDA) is the first step towards successful treatment.² An MDA aims to predict the combined mesiodistal widths of the unerupted permanent canine (C), first premolar (1PM) and second premolar (2PM) teeth.¹³ An accurate prediction method is required as errors may lead to the delivery of inadequate and irreversible treatment.

There are three main approaches that may be applied to space assessment: (1) Direct measurements of unerupted teeth on radiographs, which is an individualised method of MDA;³ (2) Using prediction equations and tables based on the measurements of erupted teeth. The most commonly used are Tanaka and Johnston’s regression equations⁵ and Moyers’ probability tables;⁶ (3) A combination of both methods.¹³⁷

Despite the diversity, no single method has been shown to deliver high accuracy and reliability, as all have limitations.
Cone beam computed tomography (CBCT) has many applications in orthodontic practice that justify its growing clinical use. The CBCT’s isotropic voxel allows greater accuracy in linear measurements, proven in many studies. Sakabe et al. and Nguyen et al. concluded that CBCT is a reliable and accurate method for MDA, overcoming the limitations of two-dimensional radiographs and allowing orthodontists to visualise and measure the tooth from many angles. CBCT allows direct measurement of mesiodistal tooth width rather than an estimation, which is a significant advantage over other predictive methods.

Moyers employed prediction tables and suggested the 75th percentile of probability be applied. The tables were based on a Northern European population and many subsequent studies indicated that the accuracy regarding the 75% probability level was poor when applied to a different population. Luís et al. tested Moyers’ tables and the Tanaka and Johnston predictive equation for applicability to the Portuguese population. The results showed that both methods had a tendency to over-predict the mesiodistal tooth widths. The 50th percentile presented values closer to the actual tooth dimensions, and identified a difference of less than 1 mm in 71% of cases.

The objectives of the present study were therefore to assess the level of agreement between predictions produced by three models (Moyers 75, Moyers 50 and Tanaka-Johnston) regarding the sum of the unerupted mesiodistal tooth widths of the permanent canine and premolars compared with a ‘gold standard’ generated by Cone Beam Computed Tomography.

Materials and methods

The study sample was comprised of children (N = 26) aged 8–13 who had paediatric/orthodontic appointments in the Department of Dentistry, University of Coimbra. The inclusion criteria stipulated: no previous orthodontic treatment; the presence and full eruption of the lower permanent incisors; the unerupted presence of the permanent canines; and that premolars and the teeth measured on dental casts had to be free of malformations, restorations, caries or fractures. It was mandatory that the dental impressions and study casts were of high quality and free of distortions and all subjects had a similar ethnic background (Portuguese ancestors). Further, a radiographic exam would be necessary for diagnosis and/or treatment planning of the patient for orthodontic treatment. The purpose of the study was explained to the parents/guardians and the children in accordance with the Helsinki Declaration. The children whose parents/guardians agreed in writing to participate in the study were recruited.

From the initial group of 130 patients, 26 were included, which represented a combined sample of 52 maxillary and mandibular arches.

Dental impressions of the selected children were taken with irreversible hydrocolloid alginate impression material (Orthoprint, Zhermack, Badia Polesine, Italy) and immediately poured with dental stone to limit time-related dimensional changes.

The mesiodistal tooth widths were measured as described by Jensen et al. A digital caliper using a vernier scale with an accuracy of 0.01 mm (0-150 mm, Talleres Mestraitua, S.L, Bilbao, Spain) was used for dental cast measurement. To determine measurement reliability, an intra-examiner calibration was performed by the primary investigator by randomly selecting and remeasuring five casts and five cone beam images. An inter-examiner calibration was also performed by a second operator, who also randomly selected and remeasured five dental casts and five cone beam images.

The CBCT images were obtained by an iCAT scanner (Imaging Sciences International, PA, USA), 120 kVp, 5.0 mA, 8.9 seconds per revolution, 8 × 16 cm field of view and a voxel size of 0.3 mm. The volumetric data were imported in DICOM format and analysed with In Vivo 5 (Anatomage Inc, CA, USA) software. The teeth were measured in the volumetric presentation. ‘Dental view’ was chosen, the contrast was boosted and the brightness reduced to isolate the teeth from the adjacent bone, which rendered the measurement of mesiodistal tooth widths easier. Using the software ‘cut’ tool, the three teeth of interest from each hemi-arch were isolated. The occlusal face of each tooth was aligned with the monitor and the mesiodistal width was measured with the ‘linear measurement’ tool. The measurements were then confirmed from a labial/palatal view in order to ensure that the correct mesiodistal width was being measured.

The sum of the mandibular incisors was calculated and applied to the Moyers’ tables. The predictive number was obtained from the 50th and 75th percentiles. Due to the 0.5 mm limitation of the Moyers’ tables, the
predictive values were determined by applying a linear interpolation between the closest values. The same value for the sum of the mandibular incisors was used in the Tanaka-Johnston equations when performing the space assessment.

The software environment R (version 3.1.0, R Foundation for Statistical Computing, Vienna, Austria) was used for statistical analysis. The differences (mm) between measurements on each method’s predictions and measurements by CBCT were determined and analysed. Descriptive statistics and paired t-tests for each pair method-CBCT were applied. Additionally, approximations for the density function for each method-CBCT difference and Lin’s concordance correlation coefficient (CCC) between each method’s predictions were verified.

An evaluation of the systematic error was assessed using the Student’s t-test for paired samples and the random error was governed by Dahlberg’s formula. The systematic error was negligible as there were no significant intra- or inter-examiner differences (p > 0.05). The random errors identified by Dahlberg’s formula varied between 0 and 0.51 mm.

**Results**

Table I shows the mean value, standard deviation, minimum and maximum values obtained for each method used. The model predictions were on average greater than the CBCT readings and unable to capture measurement variability as their standard deviation was approximately half that of the CBCT standard deviation.

Figure 4 shows that all three methods tended to overestimate the CBCT measurement. However, Figure 4 also shows that there were significant underestimates as well, particularly in the mandible, which measured almost 4 mm below the CBCT dimension.
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Lin’s concordance correlation coefficient (CCC) for agreement on a continuous measure obtained by two methods (Model-CBCT) is shown in Table II. The CCC combined measures of precision and accuracy to determine the deviation of the observed data from the line of perfect agreement. Like any correlation, CCC ranged from minus one to plus one, with perfect agreement at one. Table II shows that all methods agreed poorly with the CBCT measurement, as the highest CCC value was remote from one. The mean difference was statistically significantly different from zero for all methods except for the mandible when Moyers’ 50th percentile was used.

Tables III and IV show the frequency of the differences between the predictive values and the CBCT measurement. The tables indicate that the standard deviation of the CBCT measurement was very similar in the maxilla and mandible for each predictive model. Moyers’ 50th percentile reading showed a better distribution between over- and underestimation and, in six cases, only showed a deviation from the CBCT measurement above 1.5 mm.
Discussion

The correct estimation of tooth widths is desirable, as erroneous treatment planning may otherwise result. Nevertheless, it is important to correlate predictive values with their clinical significance. Lee-Chan et al.\textsuperscript{21} suggested that differences between actual and predicted measurements lower than 1.0 mm were clinically acceptable.

The results of the present study showed a greater standard deviation for CBCT measurements compared with the other three predictive methods. This may be interpreted as a limitation of the predictive methods in their ability to represent inter-individual variations. The statistics indicated that the model behind Moyers’ tables at the 50th percentile was the most accurate tooth size predictor, which generated the closest values to the CBCT dental measurements in the Portuguese population.

When the CCC was taken into consideration, all the methods had poor agreement with the CBCT measurement, as the highest CCC value was remote from one. Moyers’ 50th percentile reading showed the highest CCC values (0.26 mm maxilla, 0.33 mm mandible). The mean difference was statistically significantly different from zero for all models except the mandible using Moyers’ 50th percentile. According to Flores-Mir et al.\textsuperscript{22} and Lee-Chan et al.,\textsuperscript{21} the values must be interpreted with caution and according to their clinical significance. Moyers’ 50th percentile maxillary mean difference was statistically significantly different from zero but was less than 1.0 mm, which made it clinically acceptable. In addition, Moyers’ 50th percentile showed the greatest number of differences between 0 and 1.0 mm, with a slightly increased tendency to overestimate measurements in the maxilla and account for the lower CCC value. However, Tanaka-Johnston and Moyers’ 75th percentile showed greater overestimation, which represented a greater problem in treatment planning.

The results of the present study are in support of previous studies published for the Portuguese population.\textsuperscript{17} However, individual variation is an important factor to consider when planning orthodontic treatment. Using a CBCT image, the orthodontist can detect abnormalities in tooth shape.
including macro- or micro-dontia that would pass undetected using the predictive methods. There was a case of macrodontia in the present study, as a second mandibular premolar was over 11.0 mm wide which therefore explained a severe underestimation of almost 4.0 mm.

The isotropic voxel of CBCT (equal in the three dimensions) allows image reconstruction without magnification.\(^2\) The smaller the size, the better the resolution, but there is an inverse correlation with radiation dose.\(^3,4\) Mosfeghi et al.\(^12\) compared measurements obtained with a 0.15 mm voxel and 0.3 mm voxel size and concluded that there was no statistical difference between the two. There was also the possibility of error, which could range from 0 to the voxel size per measurement. In the present study, the sum of the measurement of the unerupted canine and premolars could lead to a maximum underestimation of 0.9 mm. As this value was always under 1.0 mm, the underestimation was statistically considered to be insignificant.\(^9,12\) Based on this conclusion, the voxel size used in this study was 0.3 mm, in order to keep the radiation dose to an acceptable level.

Although CBCT measurements provide accuracy and reliability, a faster and more inexpensive method is preferred by clinicians, which makes the Moyers’ predictive tables and Tanaka-Johnston equations the most commonly used tools in mixed dentition analyses.\(^1,3\) The CBCT method required higher radiation exposure, expensive software and additional time of 15–20 minutes per subject to measure the 12 unerupted teeth.

The present study provides a starting point for future investigations, which might assess the accuracy of CBCT in linear measurements. A review will be applied to the subjects of this study in which direct measurements of the fully erupted teeth will be undertaken for future comparison with the CBCT measurements.

**Conclusion**

Using CBCT measurements as the ‘gold standard’, the present study suggested that the use of Moyers’ 50th percentile was more balanced in over- and underestimating tooth size and was therefore the most acceptable predictive method when compared with Moyers’ 75th percentile and the Tanaka-Johnston equation.
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