ONLINE ONLY

Accuracy and reliability of linear cephalometric measurements from cone-beam computed tomography scans of a dry human skull

Mauricio Berco, Paul H. Rigali, Jr, R. Matthew Miner, Stephelynn DeLuca, Nina K. Anderson, and Leslie A. Will
Boston, Mass

Introduction: The purpose of this study was to determine the accuracy and reliability of 3-dimensional craniofacial measurements obtained from cone-beam computed tomography (CBCT) scans of a dry human skull.

Methods: Seventeen landmarks were identified on the skull. CBCT scans were then obtained, with 2 skull orientations during scanning. Twenty-nine interlandmark linear measurements were made directly on the skull and compared with the same measurements made on the CBCT scans. All measurements were made by 2 operators on 4 separate occasions.

Results: The method errors were 0.19, 0.21, and 0.19 mm in the x-, y- and z-axes, respectively. Repeated measures analysis of variance (ANOVA) showed no significant intraoperator or interoperator differences. The mean measurement error was –0.01 mm (SD, 0.129 mm). Five measurement errors were found to be statistically significantly different; however, all measurement errors were below the known voxel size and clinically insignificant. No differences were found in the measurements from the 2 CBCT scan orientations of the skull.

Conclusions: CBCT allows for clinically accurate and reliable 3-dimensional linear measurements of the craniofacial complex. Moreover, skull orientation during CBCT scanning does not affect the accuracy or the reliability of these measurements.

Read the full text online at: www.ajodo.org

EDITOR'S SUMMARY

Although radiographic cephalometry is arguably one of the most significant diagnostic advancements in the history of the orthodontic specialty, combining 2-dimensional records with clinical qualitative interpretations invites discrepancies in diagnostic assessment that can lead to suboptimal treatment outcomes. Mah and Hatcher emphasized repeatedly that, if the aim is to improve the "quality, efficiency and accessibility of craniofacial care," then there is great need for "accurate and effective imaging modalities." CBCT is not used routinely in orthodontics, and only a few investigations have assessed the accuracy of 3-dimensional (3D) linear measurements over the entire craniofacial complex. With that in mind, the purpose of this study was to test the accuracy and reliability of linear measurements obtained from a CBCT scan (iCAT) of a dry human skull by using 3D imaging software (Dolphin Imaging).

Sequential slices from a CBCT image were scanned with 3D imaging software until the previously placed radiopaque markers for each landmark of interest were localized. Linear measurements were then computed by selecting the appropriate landmarks from the 3D reconstruction. Accuracy of the measurements was limited to the known voxel size of 0.4 mm.

Overall, the results of this study suggest that the accuracy of CBCT linear measurements is within 0.3 mm, which is below the resolution of the scan and approximates the method error. It was also comforting to learn that skull orientation during scanning did not influence the accuracy of the measurements.

Am J Orthod Dentofacial Orthop 2009;136:17-8
0889-5406/$36.00

doi:10.1016/j.ajodo.2009.03.027

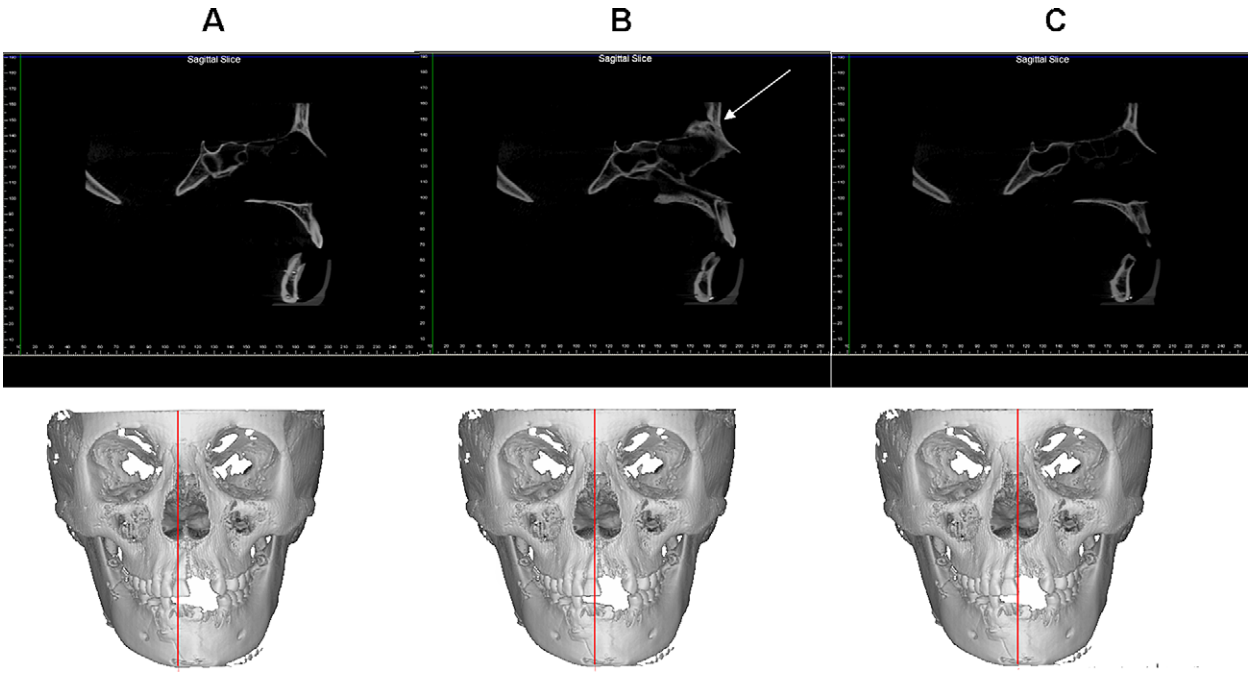

Fig 4. Sample of 3 sequential sagittal slices used to identify radiopaque N marker, surrounding the midline anatomic point N: **A-C,** the sagittal slices are sequential cuts from the right side of the skull to the left. Each slice is delineated by a *red line* on the frontal view below the respective sectional slice. The *white arrow* shows the radiopaque N marker, which is most prominent in slice *B*.

Q & A

Editor: Has anyone developed an appropriate set of 3D craniofacial landmarks for analyzing growth or treatment changes?

Will: I understand that at least 2 analyses are being developed, but, to my knowledge, they have not been distributed or used widely. As with 2-dimensional analyses, I believe that ultimately various analyses will be developed, each with its own focus and area of strength. At Tufts University, we are developing a 3D analysis using a sample from a private office.

Editor: Do you plan to use more 3D radiography at Tufts because of its advantages for research to study many unanswered questions?

Will: At Tufts, we routinely obtain CBCT scans of several types of patients, including those who need multidisciplinary care or have dentoskeletal deformities, congenital anomalies, impacted teeth, or temporomandibular joint dysfunction. We have several ongoing research projects in these areas of orthodontic care but to date have not begun research that would require the exposure of a CBCT scan purely for research.

Editor: Do you think this type of information should be available for all prospective orthodontic patients?

Will: Not now. Although 3D imaging is exciting and informative, it is not necessary for treatment of many straightforward problems, especially since no analyses for the 3D image are in common use. In addition, it is not feasible to obtain scans of all patients because machines are not widely available. There are also concerns regarding radiation exposure and the orthodontist's legal liability about the content of the scans. Once some of these issues are addressed and valid, reliable analyses are available, CBCT might well become the standard of care, and their use will greatly change clinical orthodontics.