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CT interpretation of craniofacial anomalies: a comparative analysis by undergraduate dental students

Interpretação de anomalias craniofaciais em TC. Análise comparativa por alunos de graduação em Odontologia

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ABSTRACT: The aim of this study was to evaluate the accuracy and reproducibility of computed tomography (CT) image interpretation made in axial slices (2D-CT) and 3D reconstructed images (3D-CT) of patients with craniofacial anomalies. The analyses were made by undergraduate dental students, and compared with the diagnoses considered upon surgical intervention. Computed tomography of 43 patients were analyzed independently by three calibrated examiners (undergraduate students) with, respectively, one, two, and three semesters of experience in craniofacial CT training and interpretation. The analysis of 2D-CT and 3D-CT images were performed at distinct times using an independent workstation associated with a specific computer graphics software for volumetric images. The analysis of inter-examiner agreement and of the agreement between observers and the gold standard was performed using the Kappa test. The accuracy evaluation presented a progressively higher value for examiners with progressively broader experience in 2D-CT and 3D-CT image interpretation. 3D-CT analyses allowed a higher inter-examiner agreement (1 – 0.896) than 2D-CT analyses (1 – 0.614). 3D-CT was considered more precise and accurate than 2D-CT for all students' evaluations. The reproducibility and accuracy varied according to the experience in CT interpretation, and the most experienced student achieved results closer to the gold standard.

DESCRIPTORS: Tomography; Face; Craniosynostosis; Craniofacial abnormalities.

RESUMO: O propósito desta pesquisa foi avaliar a habilidade de alunos de graduação na análise de pacientes portadores de anomalias craniofaciais usando imagens de tomografia computadorizada (TC) em cortes axiais (2D-TC) e em terceira dimensão (3D-TC). A análise foi realizada por alunos de graduação em Odontologia, em comparação com o diagnóstico efetuado no ato operatório. Tomografias computadorizadas de 43 pacientes foram analisadas, independentemente, por três alunos de graduação previamente calibrados, com respectivamente um, dois e três semestres de tempo de experiência em interpretação de TC. As análises das imagens em 2D-TC e em 3D-TC foram obtidas em tempos e ocasiões distintos por meio de uma estação de trabalho independente utilizando-se um programa específico para imagens volumétricas. Para análise de concordância entre os observadores e destes com o diagnóstico definitivo foi utilizado o teste estatístico Kappa. Os valores de acurácia foram maiores quanto maior o tempo de experiência em interpretar imagens em 2D-TC e em 3D-TC. As análises em 3D-TC apresentaram indicadores mais elevados de concordância entre os examinadores (1 – 0,896) que as análises em 2D-TC (1 – 0,614). A 3D-TC foi considerada mais precisa e acurada em relação à 2D-TC na avaliação dos três alunos. A concordância entre os examinadores e entre estes e o diagnóstico variou de acordo com o tempo de treinamento em TC, sendo o aluno mais experiente aquele que obteve resultados mais próximos ao diagnóstico.

DESCRITORES: Tomografia; Face; Craniossinostose; Anormalidades craniofaciais.

INTRODUCTION

The normal development of the face depends on a perfect synchrony between the activity of the growth centers and associated structures. Any interference may change the correct order of progression and cause defects or deficiency on growth and development patterns[12]. Abnormal craniofacial morphology observed in patients with premature closure of the cranial suture has long been attributed to changes in growth patterns, which produce anomalies such as bossing, bulges and prominences[12,15]. During normal ontogeny, there is a chronologic progression until the cessation of

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growth at the various cranial syndesmoses and their transformation into synostoses[9]. Although there is a typical range of biological variations in the chronologic timing of suture closure, premature closure is termed craniosynostosis[9].

Craniosynostosis (the process) is a term currently used to describe the premature fusion of cranial sutures, although craniostenosis (the result) more accurately describes this pathological entity. When craniosynostosis occurs, growth is restricted at the affected suture, whereas compensatory growth occurs elsewhere[15]. Deformities vary according to type, intensity, extension, chronological time and etiological agent. Furthermore, deformities also depend on individual susceptibility, and the involvement of the growth center area may alter the abnormalities[12].

The recent advances in computer hardware and software of 3D imaging by computed tomography (CT) scans of craniofacial anomalies have been routinely used by most medical centers to define the individual aspects of complex anatomy, plan interventions and follow the results of such complex pathologies[2,5,8,11,13,16,17]. The defects can be exactly located by CT scans using three-dimensional reconstructed images[5,7,10,11,16,17].

The purpose of the present study was to compare levels of agreement between undergraduate dental students on image interpretation made in axial slices (2D-CT) and 3D-CT images for patients with craniofacial anomalies.

MATERIALS AND METHODS

The study population consisted of 43 patients, with craniofacial anomalies, with or without craniosynostosis, who were submitted to computed tomography (Toshiba X/Press, Toshiba Medical, Tustin, CA, USA) under the following protocol: 3 mm axial slices, 1.5 mm table feed and 1.5 mm reconstructed slice interval, in 1 second and 512 x 512 matrix.

The images were analyzed by three trained and calibrated examiners (undergraduate dental students), independently, with experience in CT interpretation of one (examiner 3), two (examiner 2) or three (examiner 1) semesters. The analyses of the 2D-CT and 3D-CT images were carried out at distinct times. Analyses consisted in identifying the presence or absence of premature closure of cranial sutures including: Metopic, Unicoronal, Bilateral coronal, Sagittal, and Unilateral lambdoid ones. Bilateral lambdoid sutures were not included in this study because we did not have cases of this abnormality. The examiners had no knowledge of the patient's clinical history, name, age or gender.

The original CT data was transferred to a Workstation (DELL hardware Precision 420 Windows NT 4.0, Austin, Texas, USA) with Vitrea® version 2.3 software (Vital Images Inc., Plymouth, MN, USA), for axial (2D-CT) and 3D volume rendering reconstructed image analyses. The 2D-CT images were analyzed only on axial slices. Software tools were used to allow the visualization and interpretation of tomographic slices from the orbital region until the vertex (Figures 1a and 2a). 3D reconstruction was analyzed and image manipulation was performed to allow improved visualization of the craniosynostosis. 3D volume rendering technique associated with a computer graphics system offers a wide choice of software tools, which also allows segmentation of the region of interest, "fly through" techniques, image rotation and translation, application of different color tables, contrast and transparency levels based on CT density. The gold standard for this study was considered the surgical intervention.

The 3D-CT images were analyzed according to the following protocol: craniofacial CT, 3D surface with color and window level – soft bone. The transparency level was in maximum degree to perform 2D analysis in order to avoid the 3D image visualization. Software tools were used to allow the rotation and translation of the images (Figures 1b, 1c, 1d, 2b, 2c and 2d).

The statistical analysis was carried out using the Kappa test[14].

RESULTS

Results in Table 1 show the sensitivity assessment (i.e., the Kappa statistics of diagnoses in agreement with the gold standard) in 3D-CT and 2D-CT. Values ranging from 0.8 to 1 mean a good agreement between each examiner and the gold standard. (Table 1)

The most experienced examiner (examiner 1) presented the best results on image interpretation for both 3D-CT and 2D-CT images, and 3D-CT was the most sensitive method for all examiners. Observation of the bilateral coronal sutures allowed higher agreement with the gold standard, followed by metopic sutures and unicoronal sutures.

Table 2 shows the reproducibility (i.e., the agreement of inter-examiner diagnoses) of 3D-CT and 2D-CT analysis.

Table 2 indicates that a higher agreement between examiners was found for 3D-CT analysis. It also shows that better results of agreement and

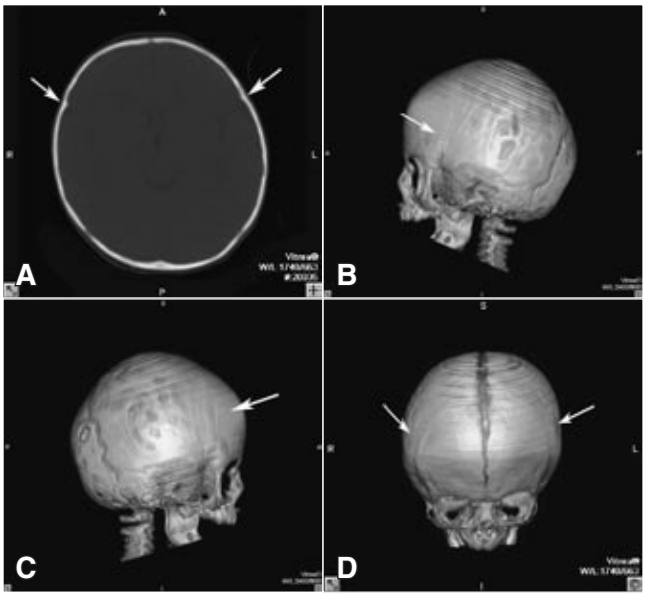

FIGURE 1 - Patient with bilateral coronal synostosis: 2D-CT axial slice shows a closed bilateral coronal suture (arrows) (**A**); 3D-CT: left lateral view (**B**), right lateral view (**C**) and frontal view (**D**) (arrows) demonstrate the premature closure of the bilateral coronal suture.

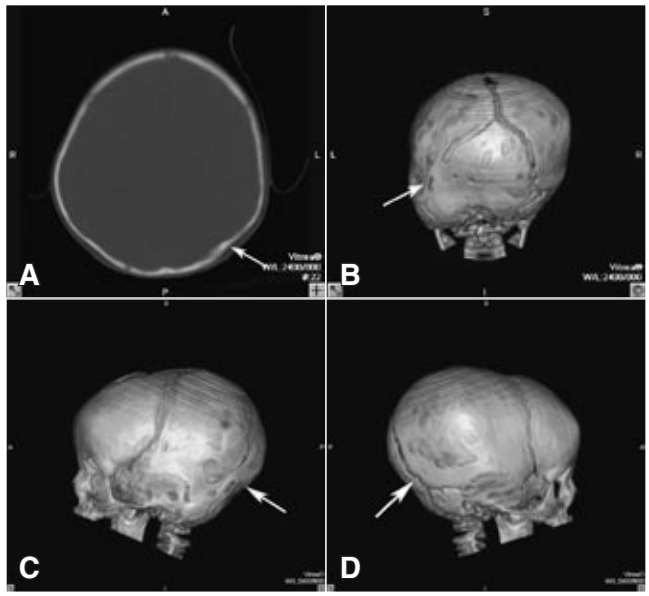

FIGURE 2 - Patient with left unilateral lambdoid synostosis: 2D-CT axial slice depicts a closure of the left lambdoid suture (arrow) (**A**); 3D-CT images show in rear (**B**) and left lateral (**C**) (arrows) views the left lambdoid suture premature closure. Right lateral (**D**) view shows the normal lambdoid suture (arrow).

TABLE 1 - Examiner sensitivity for all studied sutures in 3D-CT and 2D-CT. Fields with "–" denote that the examiner failed to identify positive cases.

Analytical method	Examiner 1	Examiner 2	Examiner 3
3D-CT			
Unicoronal	1.000	0.909	0.807
Bilateral coronal	1.000	1.000	1.000
Unilateral lambdoid	1.000	1.000	–
Sagittal	0.896	0.896	0.726
Metopic	1.000	1.000	0.870
2D-CT			
Unicoronal	0.909	0.728	0.691
Bilateral coronal	0.788	0.890	1.000
Unilateral lambdoid	0.656	0.656	–
Sagittal	0.614	0.688	0.541
Metopic	1.000	0.758	0.662

TABLE 2 - Statistical analysis for inter-examiner reproducibility for all sutures studied in 3D-CT and 2D-CT. Fields with "–" denote that the examiner failed to identify positive cases.

Analytical method	Examiner 1 *versus* Examiner 2	Examiner *1 versus* Examiner 3	Examiner 2 *versus* Examiner 3
3D-CT			
Unicoronal	0.909	0.807	0.896
Bilateral coronal	1.000	1.000	1.000
Unilateral lambdoid	1.000	–	–
Sagittal	1.000	0.632	0.632
Metopic	1.000	0.870	0.870
2D-CT			
Unicoronal	0.806	0.775	0.775
Bilateral coronal	1.000	0.788	0.788
Unilateral lambdoid	1.000	–	–
Sagittal	0.728	0.401	0.463
Metopic	0.758	0.662	0.469

higher agreement were achieved when a most experienced examiner (Examiner 1 *versus* Examiner 2) performed the analysis.

DISCUSSION

The diagnosis and treatment planning of abnormalities in the craniofacial complex are limited when only standard radiography is used, due to lack of dimensional accuracy, image distortion, and the presence of superimposed structures[1,11]. However, currently, three-dimensional computed tomography has improved diagnostic performance[5,6,16,17]. Comprehensive understanding of sutural anatomy is very important for the diagnosis and potential surgical correction of craniosynostosis[5,7,10,12,16,17].

The most recent approaches to the three-dimensional study of growth have come from the field of imaging. Levi *et al.*[6] (2002) used CT scans to reproduce the patient's malformed skull as a phantom to provide information about the clinical case, helping the treatment planning and also as an excellent teaching method for residents.

The results of our study are in agreement with those found in the related literature[1,2,7,8,11,16,17], showing that the gain in image quality with 3D-CT is higher than with 2D-CT images. The former images allow any examiner, experienced in CT image interpretation or not, to perform an easy and improved identification of abnormalities. The most experienced examiner showed values of agreement with the gold standard between 0.896 and 1 for 3D-CT and 0.614 and 1 for 2D-CT analysis, confirming the greater value of the volumetric images for that diagnostic task.

Professional experience is a fundamental requirement for a correct diagnosis. When the professional has had experience in image visualization, greater accuracy is observed for two-dimensional and three-dimensional computed tomography interpretation[1,11,16,17]. This was in agreement with our study, where examiner 1 (three semesters of experience in image interpretation) achieved the most accurate results, followed by examiner 2 (two semesters) and examiner 3, who had one semester of experience in computed tomography image interpretation. Similar results were found by Vannier *et al.*[16] (1989), when studying the value of 3D-CT in craniosynostosis diagnosis; Pilgram *et al.*[11] (1989), in their studies of image quality and correctness in diagnosis; and Vannier *et al.*[17] (1994), whose studies showed that experienced examiners can achieve nearly perfect diagnoses in all image modalities.

The influence of experience in the reproducibility of diagnoses was better demonstrated when we made a comparison between the examiners. Examiner one (three semesters of experience in image interpretation) *versus* examiner two (two semesters of experience) presented the highest values of agreement (0.909 – 1 (3D analysis) and 0.728 – 1 (2D analysis)).

Regarding the identification of affected sutures, for both 3D and 2D analyses, the identification of the Bilateral coronal suture had the best accuracy, followed by that of Metopic, Unicoronal, Sagittal and Unilateral lambdoid sutures. We believe that these results were found because the bilateral aspects cause higher alterations in the shape of the skull, which is responsible for marked asymmetry, although specific studies must be developed to test this hypothesis.

Cerovac *et al.*[4] (2002) stated that a correct diagnosis based on clinical findings was made in 100% of the cases analyzed by an experienced clinician, and that CT scans with 3D reconstructions provided diagnostic confirmation in 100% of the patients with complex craniosynostosis. Cavalcanti, Vannier[3] (1998) emphasized that 3D-CT imaging is a complementary modality to 2D-CT in maxillofacial diagnosis. Our experience shows that the first image interpretations have to be done on axial, coronal and sagittal slices (2D-CT), avoiding the negative influence that 3D reconstruction may exert. These methods enhance the accuracy of diagnostic decisions and instruct the selection of the most appropriate treatment plan.

CONCLUSIONS

3D-CT is a more accurate method than 2D-CT for image interpretation among undergraduate Dental students with experience or not. The time of experience in image interpretation is relevant for examiners to make a correct diagnosis when a volumetric imaging modality is used, especially the 3D volume rendering technique using an independent workstation.

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