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SHORT COMMUNICATION

Zygomaticofacial foramen location accuracy and reliability in cone-beam computed tomography

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Abstract

Objective. This study aimed to evaluate the possibility of detecting the zygomaticofacial foramen (ZFF) in cone-beam computed tomography (CBCT). ***Materials and methods.*** This study evaluated ZFFs in 151 macerated skulls (302 zygomatic bones, ZBs) by physical inspection, in which the presence and diameters of the ZFFs were determined. These data were compared with the CBCT images of the skulls to determine the accuracy of CBCT in detecting ZFFs. The diameters were measured by insertion of steel wires with known thicknesses into the ZFFs. The CBCT images were acquired by an i-CAT Classic® (International Imaging Sciences, Hatfield, PA) connected to a workstation (Model ITOX Midtower Workstation; Imaging Sciences International®) with a 20-inch Eizo monitor. The images were generated in coronal, sagittal and axial slices to evaluate the best tomographic plane for ZFF visualization. ***Results.*** The incidence of ZFF found by physical inspection was one foramen in 44% of ZBs ($n = 133$), two foramina in 28% ($n = 86$), three foramina in 8% ($n = 24$) and four foramina in 1% ($n = 2$). ZFF was absent in 19% ($n = 57$) of ZBs. The average diameter was 0.57 mm (± 0.27 mm). All foramina were observed in all tomography images. ***Conclusion.*** This preliminary study supports the conclusion that a CBCT scan has excellent accuracy in evaluating ZFFs.

Key Words: *Zygomatic bone, zygomaticofacial foramen, cone-beam computed tomography, radiology, anatomy*

Introduction

The increased demand for rehabilitation of edentulous ridges by reconstructive surgery and dental implants necessitates a more detailed anatomical study of the jaws [1–5]. The zygomatic bone (ZB) contains the zygomaticofacial foramen (ZFF), a structure where the zygomaticofacial nerve emerges on the face. In some cases, a tiny branch of the infraorbital artery emerges together with the zygomaticofacial nerve. The ZFF is located in the region where zygomatic implants are placed. The ZFF innervates the orbicularis oculi and supplies the sensory and some time the vascular features of the malar prominence. Consequently, if the ZFF is injured, numbness and/or bleeding may occur in the cheek region [6,7]. The location and number of ZFFs are not constant [7–11]. Sometimes, the zygomaticofacial nerve and the ZFF may be absent. The absence of the ZFF can explain the absence of the zygomaticofacial nerve or vice versa [11].

The variation in the anatomy of the ZB indicates the need for surgical planning by three-dimensional images. Conventional computed tomography (CT) and cone-beam computed tomography (CBCT) are imaging exams that allow the maxillary bones to be evaluated three-dimensionally [12]. However, a CBCT scan is considered better for a thorough examination of the maxillofacial structures due to such advantages as low cost and a reduced radiation dose compared to CT [12]. Moreover, imaging exams have an important role in implantology because, although the results of placement of dental implants are highly predictable, a pre-operative evaluation of volume and bone quality may allow for better prediction [13,14]. CBCT has been used to study regions

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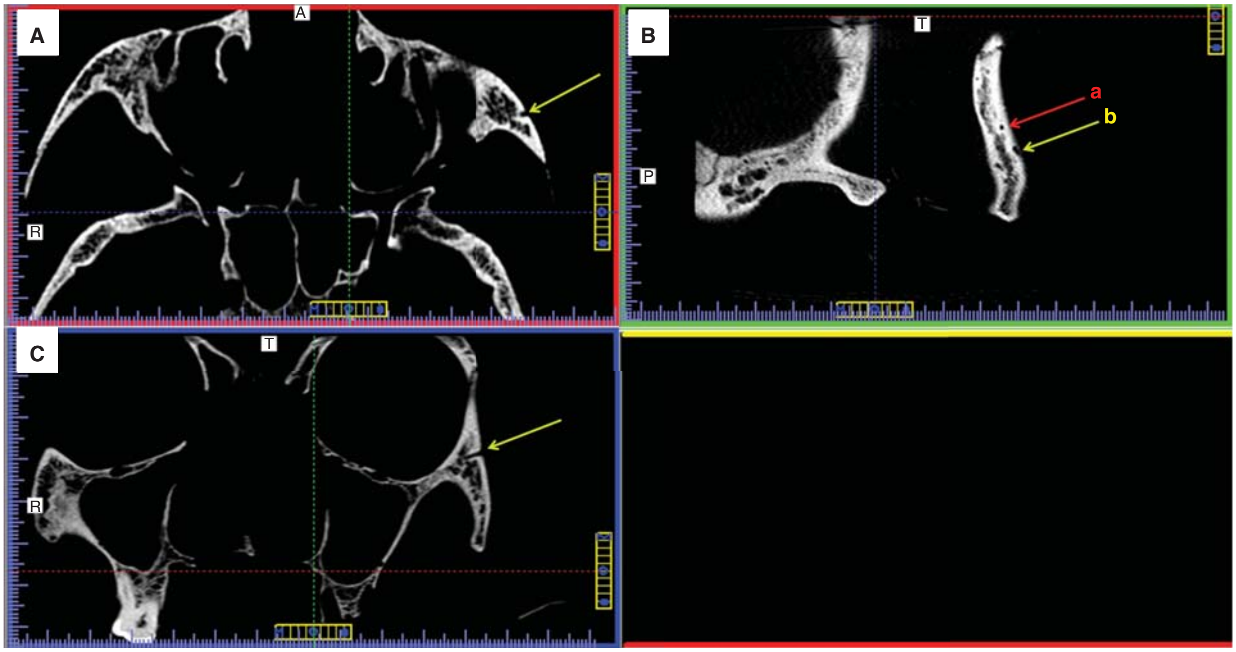

Figure 1. Representative CBCT images of reformatted axial (A), sagittal (B) and coronal (C) slices. The arrows indicate the ZFFs. In this example, two foramina are presented, with diameters of 0.16 mm (a) and 0.8 mm (b).

of interest in implantology, such as the region of the mandibular canal, the mandibular symphysis and the maxillary sinus [5,15,16]. However, there has been no anatomic study of the ZFF region using CBCT. Therefore, the aim of our study was to measure the accuracy of a CBCT scan to detect the ZFF.

Materials and methods

We selected macerated skulls of Brazilian adults, excluding those with spoiling or fracture of the ZBs. The final sample consisted of 151 skulls (302 ZBs).

Physical inspection

The 302 ZBs underwent physical inspection and then the ZFF incidence and number were tabulated.

Evaluating the ZFF diameter

Among of the 151 skulls, 20 were chosen randomly to assess the foramen diameter (FD). For the analysis of the FD, standardized orthodontic steel wire was used with the following thicknesses: 0.16 mm, 0.18 mm, 0.2 mm, 0.4 mm, 0.45 mm, 0.5 mm, 0.6 mm, 0.7 mm, 0.8 mm, 0.9 mm, 1.0 mm and 1.2 mm. An electronic digital caliper was used to check the diameter of each steel wire. The steel wires were placed into the foramen by trial and error, from the thick to the thin, until the penetration of the wire had been possible in all ZFF's extension.

Cone-beam CT evaluation of the ZFF

Afterward, CBCT images of those 20 skulls were acquired. Before the tomography exams, the macerated skulls were immersed in a water tank for 48 h so that the water would fill the marrow spaces and cavities to approximate the attenuation of X-ray beams provided by the soft tissue in patients. The CBCT images were acquired by an i-CAT Classic® (Imaging Sciences International, Hatfield, PA) connected to a workstation (Model ITOX Midtower Workstation, Imaging Sciences International®) with a 20-inch Eizo monitor. The imaging protocol was a 13 cm field of view (FOV), 0.3 mm voxel size and 20 s reconstruction time. The images were generated in coronal, sagittal and axial views (Figure 1). We analyzed the accuracy of CBCT in detecting the ZFF from the lowest to the largest diameter on the resulting images. In this preliminary study, one examiner evaluated all acquired tomographic images using the workstation

Results

When considering only the right side of the samples, the ZB most commonly had one isolated ZFF (41.72%, n = 63), followed by the presence of two ZFFs (29.14%, n = 44). The ZFF was absent in 19.87% (n = 30) of ZBs and three ZFFs were found in 9.27% (n = 14) of ZBs.

Similar to the right side, the left side showed a single ZFF in most of the samples (46.36%, n = 70), followed by two ZFFs (27.81%, n = 42). The ZFF was absent in 17.88% (n = 27) of ZBs and three ZFs were

Table I. Zygomaticofacial foramen incidence.

	0% (*n*)	1% (*n*)	2% (*n*)	3% (*n*)	4% (*n*)	5% (*n*
Martins et al. [7]	21.5 (22)	50.0 (51)	23.5 (24)	4.0 (4)	1.0 (1)	—
Mangal et al. [8]	24.7 (72)	50.6 (148)	21.6 (63)	3.1 (9)	—	—
Hwang et al. [9]	9.0 (10)	50.9 (56)	30.0 (33)	9.0 (10)	0.9 (1)	—
Loukas et al. [10]	39.0 (156)	40.0 (160)	15.0 (60)	5.0 (20)	1.0 (4)	—
Aksu et al. [11]	15.6 (25)	44.4 (71)	28.1 (45)	6.3 (10)	4.4 (7)	1.3 (2)
Our results	18.87 (57)	44.04 (133)	28.48 (86)	7.95 (24)	0.66 (2)	—

%, Percentage of foramens found; *n*, Number of foramens found.

found in 6.62% (n = 10) of ZBs. Finally, four ZFFs were found in only two cases (1.32%).

When both sides were considered together, in most cases there was a single ZFF (44%, n = 133) and in 19% (n = 57) of cases the ZFF was absent. Moreover, 28% (n = 86) of ZBs had two ZFFs and three ZFFs were found in 8% of cases (n = 24). Finally, four foramina were found in only 1% of the samples (n = 2) (Table I).

The mean FZF diameter was 0.57 mm (± 0.27 mm), ranging from 0.16–1.00 mm. Among the 72 FZFs assessed, 4.16% (n = 3) were not able to be penetrated by orthodontic wires because they had a diameter smaller than 0.16 mm.

CBCT was accurate to view all ZFFs in macerated skulls, even those with the smaller diameter. The best tomographic plane for visualization of the ZFF's trajectory was the coronal view, where the sequence of images was sharper than the other plans. On the other hand, in the axial plane, the generated images were less clear. However, it is important to note that all ZFFs, including the smaller ones, were observed in all CBCT images, whether they were in the coronal, sagittal or axial view (Figure 1).

Discussion

Few studies have described the features of the ZFF (Table I), but they agree that most ZBs have a single ZFF, with an incidence varying between 40–50% [7–11]. Our results concur, showing a prevalence of a single foramen of 44.04% (n = 133) (Table I). We found no studies on the diameter of ZFF to date. In our study, 72 foramina were measured with steel orthodontic wire and the diameters ranged from 0.16–1.00 mm, with an average of 0.57 mm (± 0.27 mm). The use of CBCT in the pre-operative planning of implants has become widely accepted due to the high-quality images that are produced, while, at the same time, the cost, radiation dose and time of CBCT scanning are substantially reduced compared to the conventional CT [12,17–25].

The ZFF is an important anatomical structure, which must be observed in surgery for the installation of zygomatic implants. This surgery is a well-known traumatic dental implant surgery. Concerning the complication with the zygomatic implant surgery, periorbital hematoma and temporary sensory nerve deficits on the zygomatic bone region are commonly reported [26]. Three-dimensional analysis is essential for assessment of craniofacial morphology. Valuable information can be obtained with a three-dimensional tomographic reconstruction [27]. When we evaluate the accuracy of CBCT to detect a small bone anatomic structure, this is also an evaluation of the accuracy of CBCT to diagnose bone defects.

This preliminary study supports the conclusion that a CBCT scan has excellent accuracy in evaluating ZFFs because it allows for the identification of even smaller foramina in macerated skulls. However, more studies with at least one more examiner, together with patient's image studies are necessary to confirm this excellent accuracy.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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