

Gross Anatomical Visualization of Waters' View Radiography Using Digital Dissection System

Visualización Anatómica Macroscópica de la Radiografía en Proyección de Waters Mediante un Sistema de Disección Digital

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SUMMARY: Despite the clinical importance of the Waters' radiographic view in skull imaging, there has been limited study on its gross anatomical visualization. This study aims to enhance the visualization and understanding of gross anatomical structures of the head, as seen in Waters' view radiography, by utilizing a digital dissection system. Visual representations of head anatomical structures were constructed using the Anatomage Table, a virtual and digital dissection system. This approach enabled detailed observation and documentation of anatomical structures commonly identified in radiographic imaging. Twelve gross anatomical structures were effectively visualized using the digital dissection system in the Waters' view. Key structures typically highlighted in Waters' view radiography—such as the maxilla, zygomatic bone, frontal bone, and nasal septum—were distinctly identified, along with additional features including the parietal bone, sphenoid bone, temporomandibular capsule, mandible, ethmoid bone, external acoustic meatus, nasal bone, and temporal bone. The results show that digital dissection systems like the Anatomage Table effectively support the visualization and study of gross anatomy in radiographic views, enhancing anatomical education and aiding interpretation of images such as the Waters' view.

KEY WORDS: Waters' view radiography; Virtual dissection system; Gross anatomical visualization; Radiographic anatomy education.

INTRODUCTION

Radiography is a medical imaging method that uses radiation to reveal the internal structures of an object, particularly the human body. It is used for multiple clinical applications, such as diagnosis, treatment planning, and assessing outcomes. Conventional radiography, a prevalent form of medical imaging, utilizes X-rays to create images of the body's internal structures (Parks & Williamson, 2005; Korner *et al.*, 2007). Also, conventional radiography includes various standard X-ray views, mainly comprising anteroposterior (AP), posteroanterior (PA), lateral, oblique, and specific angles designed for particular anatomical areas (Sapkaroski *et al.*, 2019; Tafti & Byerly, 2020; Sujar *et al.*, 2022). These views are commonly utilized for assessing the chest, skull, spine, limbs, and paranasal sinuses, among other regions. Each view provides unique diagnostic benefits based on the orientation and the structure being examined (Penenberg *et al.*, 2018).

The occipitomeatal or Waters' view is a radiographic projection commonly used to evaluate the paranasal sinuses and midfacial bones (Williams Jr. *et al.*, 1992; Saiki & Yumoto, 1997; Young *et al.*, 2004). By positioning the patient with a 37° tilt of the orbitomeatal line relative to the image receptor, this view optimizes the visualization of the maxillary sinuses, orbital floors, zygoma, and nasal septum. This projection is especially useful for diagnosing conditions like sinusitis, facial trauma, and orbital blowout fractures (Konen *et al.*, 2000; Goh & Low, 2002). Waters' view has long been employed for the evaluation of the paranasal sinuses and midfacial structures, with its diagnostic value demonstrated in comparative studies with computed tomography (Aaekken *et al.*, 2003). More recently, it has been applied in emerging imaging modalities, including digital image processing and AI-based analysis, underscoring its continued relevance across diverse platforms (Chondro *et al.*, 2020).

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In contrast to standard anatomical images that display separate skeletal structures using orthogonal planes, the Waters' view offers an angled occipitomeatal projection that results in a complex overlap of midfacial bones, such as the maxillary sinuses, orbital floors, zygomatic arches, and nasal cavity. This two-dimensional representation compresses anatomical landmarks, which diminishes the spatial clarity found in traditional illustrations. Consequently, interpreting the Waters' view can be challenging for students, as many anatomical atlases lack visual references for this particular projection.

To overcome these interpretive difficulties, a virtual dissection system incorporating high-resolution, digitized human anatomical datasets can be utilized (Lukic' *et al.*, 2003; Erolin, 2019; Boscolo Berto *et al.*, 2021; Chytas *et al.*, 2023). This platform permits interactive segmentation and three-dimensional exploration of the human body from any desired orientation, thereby surpassing the constraints imposed by the fixed orthogonal planes of conventional anatomical atlases (Wainman *et al.*, 2021; Raja *et al.*, 2022; Wickramasinghe *et al.*, 2022). Through precise manipulation of the cutting plane, specific radiographic projections—such as the angled occipitomeatal view of the Waters' technique—can be accurately reproduced. The system further enables the selective isolation or removal of overlapping structures, including the maxillary sinuses, orbital floors, zygomatic arches, and nasal cavity. Its organ-system-based categorization supports focused visualization of skeletal, muscular, vascular, or nervous elements, either individually or in integrated form. Such capabilities enhance the delineation of spatial relationships that are frequently obscured in two-dimensional radiographic images, thereby providing an anatomical reference that facilitates the correlation between complex radiographic appearances and the underlying structural anatomy (Cho *et al.*, 2021).

The objective of this study is to mitigate the difficulties inherent in interpreting complex radiographic projections through the application of a high-resolution

virtual anatomical platform. This methodology is designed to enhance the instructional value of specific imaging views, exemplified by the Waters' projection, by enabling the visualization of three-dimensional anatomical configurations and their spatial interrelationships—features that are often challenging to appreciate in conventional two-dimensional images.

MATERIAL AND METHOD

Phantom Position and X-ray Image

In this experiment, X-ray radiographs were obtained using a cranial phantom to replicate the Waters' projection. Initially, the phantom was positioned in the standard AP orientation to acquire a baseline skull image (Fig. 1a). The phantom was then repositioned for the Waters' technique, in which the orbitomeatal line (OML) was inclined 37° relative to the image receptor's imaging plane. During image acquisition, the central X-ray beam was directed perpendicular to the imaging plane, as indicated by the black arrow in Figure 1b. The yellow arrow denotes the inclination of the phantom's cranial axis corresponding to the 37° OML tilt. The resulting radiograph (Fig. 1b) presents the image obtained in the Waters' position alongside the phantom reference image, demonstrating the spatial orientation and beam incidence used for this projection.

Anatmage Table and Waters' View

A digital dissection table (Anatmage, San Jose, CA, USA) was employed to prepare the anatomical imaging planes. This system incorporates a segmented three-dimensional whole-body anatomical dataset, enabling the generation of arbitrary sectional planes in addition to the conventional orthogonal views. The platform presents life-sized, interactive digital representations of human anatomy on a touchscreen interface (Baratz *et al.*, 2019; Kavvadia *et al.*, 2023).

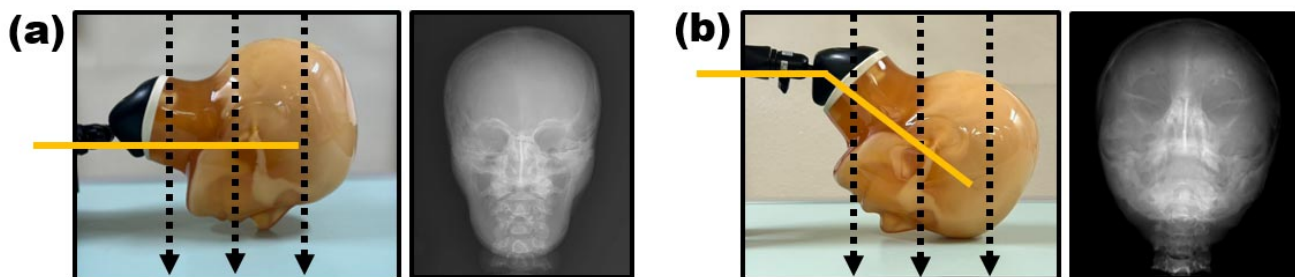


Fig. 1. X-ray images captured with a phantom in AP and Waters' positions. (a) Baseline skull image in standard AP orientation. (b) Waters' projection with orbitomeatal line (OML) inclined 37° relative to the image receptor. Black arrow indicates the central X-ray beam direction; yellow arrow denotes the phantom's cranial axis inclination corresponding to the 37° OML tilt.

Specialized and oblique gross anatomical planes were generated through meticulous segmentation procedures. To ensure precise anatomical sectioning, the visibility of selected organ systems was adjusted, with primary emphasis placed on the skeletal system's categories and structural components. The vascular and digestive systems were concurrently referenced to verify anatomical accuracy in plane positioning.

For the reproduction of the Waters' view, the cranial dataset was manipulated to align the OML at a 37° inclination relative to the image plane, matching the geometric configuration used in the radiographic technique. This oblique anatomical plane was defined by sequentially isolating the relevant craniofacial skeletal structures and removing overlying soft tissue components to replicate the projection pathway of the X-ray beam. The resulting digital section provided a direct anatomical correlation to the radiographic image, facilitating a side-by-side comparison between the gross anatomy representation and the phantom-based Waters' radiograph.

RESULTS

Using the digital dissection system, twelve distinct gross anatomical structures were successfully visualized in

the reconstructed Waters' view. Structures typically emphasized in conventional Waters' radiography—such as the maxilla, zygomatic bones, frontal bone, and nasal septum—were clearly identifiable with sharply defined anatomical margins.

Additional cranial elements were distinctly observed in specific orientations as depicted in Figures 2 to 4. In Figure 2, the right and left parietal bones (Fig. 2a, b), sphenoid bone (Fig. 2c), right and left temporomandibular capsules (Fig. 2d, e), and mandible (Fig. 2f) were clearly delineated. Figure 3 shows the frontal bone (Fig. 3a), ethmoid bone (Fig. 3b), maxilla (Fig. 3c), and the right and left external acoustic meatuses (Fig. 3d, e). Figure 4 presents the right and left nasal bones (Fig. 4a, b), nasal septum (Fig. 4c), right and left zygomatic bones (Fig. 4d, e), and the right and left temporal bones (Fig. 4f, g).

The visualization allowed precise discrimination of skeletal contours and spatial relationships between adjacent structures, even in regions prone to superimposition in conventional radiography. The segmentation-based rendering ensured consistent identification of both midline and lateral cranial elements, enabling direct correspondence between the digitally reconstructed gross anatomy planes and the phantom-based Waters' radiographs.

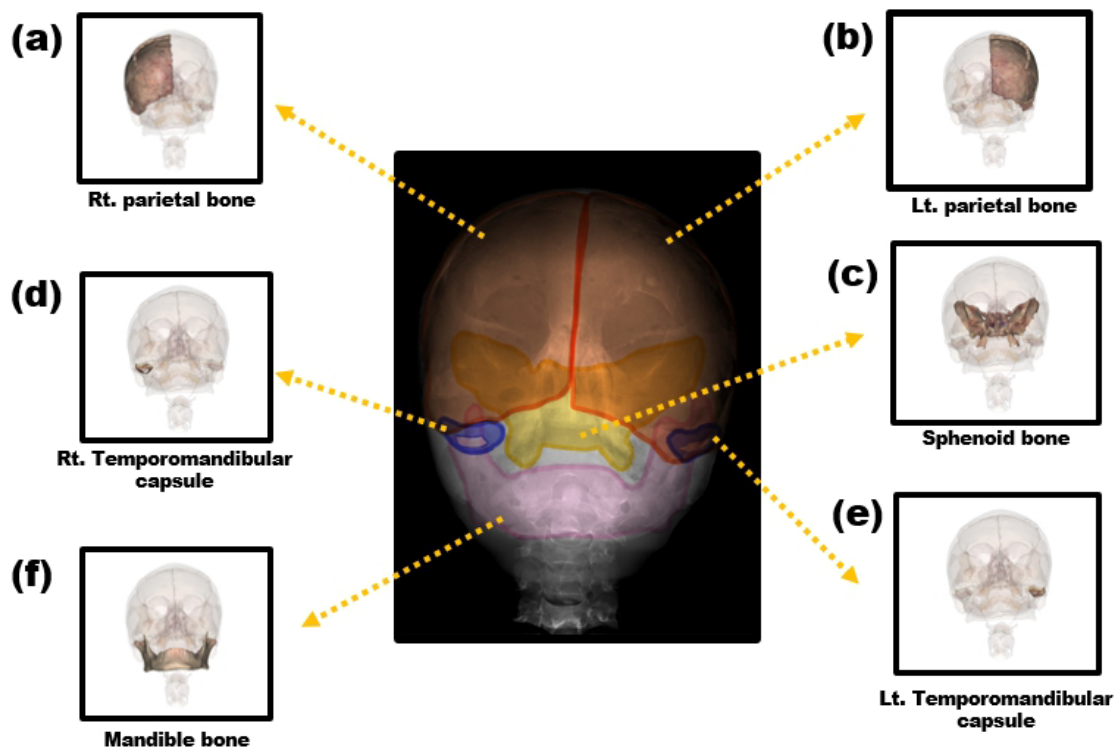


Fig. 2. Gross anatomical structures visualized in Waters' view using the digital dissection system. (a) Right parietal bone. (b) Left parietal bone. (c) Sphenoid bone. (d) Right temporomandibular capsule. (e) Left temporomandibular capsule. (f) Mandible.

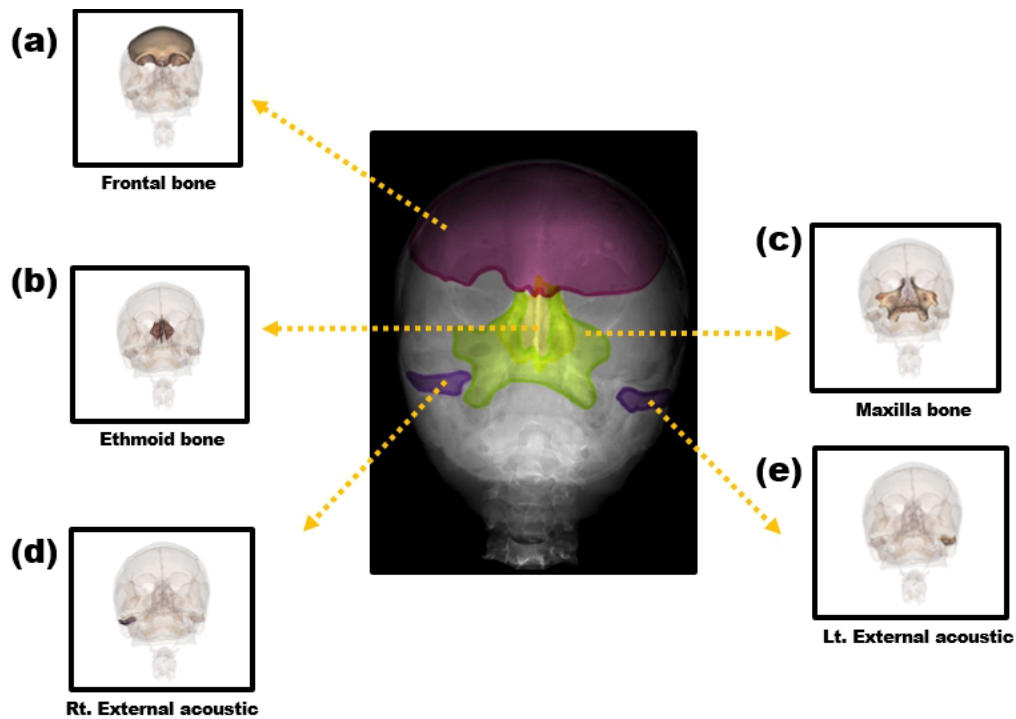


Fig. 3. Additional anatomical structures in Waters' view. (a) Frontal bone. (b) Ethmoid bone. (c) Maxilla. (d) Right external acoustic meatus. (e) Left external acoustic meatus.

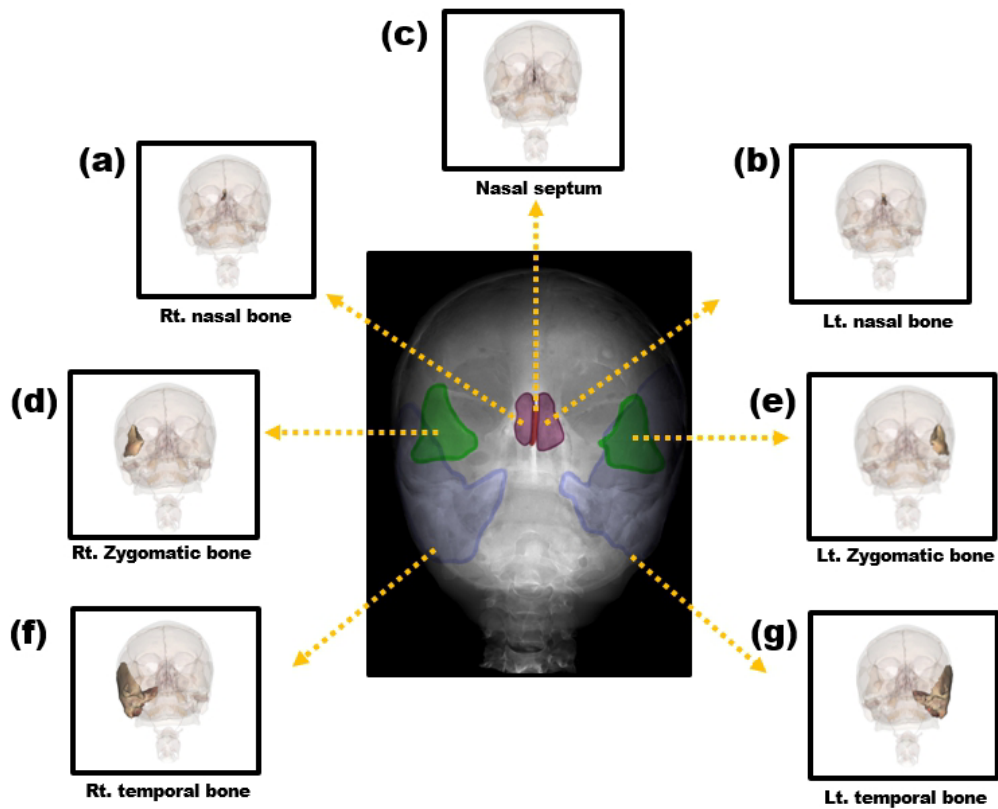


Fig. 4. Lateral and midline cranial structures in Waters' view. (a) Right nasal bone. (b) Left nasal bone. (c) Nasal septum. (d) Right zygomatic bone. (e) Left zygomatic bone. (f) Right temporal bone. (g) Left temporal bone.

DISCUSSION

The reconstructed Waters' view, generated via the digital dissection table, revealed distinct visual features for each cranial structure that align with the geometric principles of an occipitomeatal projection. Key midfacial structures like the maxilla and zygomatic bones were prominent, with clearly defined lateral margins and minimal overlap from adjacent elements. The frontal bone was seen as a superior contour, while the nasal septum provided a distinct midline reference. Symmetrically positioned in the upper midface were the nasal bones, and the ethmoid bone was a compact outline located centrally behind the nasal cavity.

The parietal bones appeared in the upper lateral cranial field, partially overlapping toward the sagittal plane due to the projection's oblique angle. The sphenoid bone was identifiable by its lateral wing contours, situated deeper within the cranial base. The temporomandibular capsules were bilaterally evident, articulating clearly with the mandibular condyles. While the mandible was largely visible, its inferior margin was partially obscured by projection geometry. The external acoustic meatuses were discernible as distinct openings lateral to the mandibular rami, and the temporal bones were clearly outlined in the lateral cranial region with a symmetrical relationship to the zygomatic arches.

A key benefit of the digital dissection table is its ability to create life-sized, interactive three-dimensional anatomical models that can be freely manipulated to match the specific angulation of the Waters' projection. Unlike fixed, two-dimensional illustrations, this system offers direct visualization of gross anatomical structures in oblique planes tailored for specific radiographic techniques. By isolating skeletal elements and adjusting the visibility of soft tissues, the system accurately replicates the spatial relationships found in Waters' radiography. This capability not only improves the interpretation of complex craniofacial anatomy but also bridges the gap between radiographic imaging and gross anatomical knowledge, helping users visualize the exact correspondence between anatomical landmarks and their radiographic appearance.

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RESUMEN: A pesar de la importancia clínica de la radiografía en proyección de Waters para la obtención de imágenes del cráneo, existen pocos estudios sobre su visualización anatómica macroscópica. Este estudio tiene como objetivo mejorar la visualización y la comprensión de las estructuras anatómicas macroscópicas de la cabeza, tal como se observan en la radiografía

en proyección de Waters, mediante el uso de un sistema de disección digital. Se construyeron representaciones visuales de las estructuras anatómicas de la cabeza utilizando Anatomage Table, un sistema de disección virtual y digital. Este enfoque permitió la observación y documentación detalladas de las estructuras anatómicas comúnmente identificadas en las imágenes radiográficas. Se visualizaron eficazmente doce estructuras anatómicas macroscópicas utilizando el sistema de disección digital en la proyección de Waters. Las estructuras clave que suelen destacarse en la radiografía de Waters —como el maxilar, el hueso cigomático, el hueso frontal y el tabique nasal— se identificaron claramente, junto con otras características como el hueso parietal, el hueso esfenoides, la cápsula temporomandibular, la mandíbula, el hueso etmoides, el meato auditivo externo, el hueso nasal y el hueso temporal. Los resultados demuestran que los sistemas de disección digital, como la mesa Anatomage, facilitan la visualización y el estudio de la anatomía macroscópica en las radiografías, mejorando la enseñanza de la anatomía y facilitando la interpretación de imágenes como la de Waters.

PALABRAS CLAVE: Radiografía de Waters; Sistema de disección virtual; Visualización anatómica macroscópica; Enseñanza de la anatomía radiográfica.

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