การหาความเท่ากันของกระดูกโหนกแก้มในผู้ป่วยในโรงพยาบาลราชวิถี

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Symmetry Measurement of Zygomaticomaxillary Complex of the Patients in Rajavithi Hospital

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Abstract

Background: The zygomaticomaxillary complex is the main component of the mid-facial skeleton involving functional support of the peri-orbital area and aesthetics of the cheek. Current developments in computer-aid design, computer-assisted surgery, and intraoperative navigation system require knowledge of the three-dimensional landmark to assist preoperative planning and intra-operative performance. **Objective:** The aim of this study was to assess the symmetry of the cheek bone and study the zygomaticomaxillary complex anatomy in Rajavithi Hospital. **Methods:** Facial computed tomography data of sixty patients (thirty males and thirty females) were obtained and aligned in iPlan software. Five reference points (i.e., obitale, maxillozygoin, suprajugal curvature, jugale, and zygoin) were marked on the three-dimensional reconstruction. Distances between the nasion and the reference points were measured in the three planes. Differences in the distance between the landmarks and the asymmetrical index were calculated. Two plastic surgeons performed this process to assess interrator reliability. **Results:** The three-dimensional distance between nasion and four zygomaticomaxillary complex landmarks were not statistically different bilaterally except for the distance at obitale which was only 3.11±3.32 mm different. The asymmetrical index of the five landmarks ranged between 4.89±3.38 mm and 6.31±4.71 mm. **Conclusions:** The study showed the anatomical location of five landmarks in three dimensions. The anatomical landmarks of the zygomaticomaxillary complex were symmetrical. Thus, knowledge of the three-dimensional locations could aid in computer-aid design, computer-assisted surgery, and navigation-assisted surgery for both restorative, reconstructive, and aesthetic aims.

Keyword: Symmetry, Zygomatic fracture, Zygomaticomaxillary complex, 3D-CT scan, Asymmetry index

บทคัดย่อ

ภูมิหลัง: กระดูกโหนกแก้ม (zygomaticomaxillary complex) เป็นส่วนของกระดูกใบหน้าหลายชิ้นที่ประกอบขึ้นเป็นโครงสร้างของกระดูกโหนกแก้มทั้งสองข้าง และเป็นองค์ประกอบหลักของกระดูกส่วนกลางของใบหน้า ทำหน้าที่เป็นฐานของกระดูกบริเวณเบ้าตาและให้สัดส่วนความงามของโหนกแก้ม การแก้ไขความผิดรูปของกระดูกโหนกแก้มให้มีความเท่ากันเป็นเรื่องสำคัญ ในปัจจุบันได้มีการนำเอาคอมพิวเตอร์มาช่วยสร้างภาพสามมิติเพื่อใช้ในการวางแผนก่อนการผ่าตัดรักษาและช่วยนำร่องในการผ่าตัด (navigation-assisted surgery) **วัตถุประสงค์:** จุดมุ่งหมายของการศึกษานี้ เพื่อประเมินความสมมาตรของโหนกแก้มและศึกษากายวิภาคของกระดูกโหนกแก้มของผู้ป่วยโรงพยาบาลราชวิถี **วิธีการ:** ได้ทำการศึกษาโดยนำข้อมูลเอกซเรย์คอมพิวเตอร์ของกระดูกใบหน้าของผู้ป่วย 60 ราย (ชาย 30 คน และหญิง 30 คน) มากำหนดจุดอ้างอิงมาตรฐาน 5 จุด โดยใช้ซอฟต์แวร์ iPlan ซึ่งจุดอ้างอิง 5 จุดนี้จะถูกทำเครื่องหมาย ในการสร้างภาพสามมิติและสร้างเป็น 3 ระนาบ โดยมีการคำนวณความแตกต่างของระยะห่างระหว่างจุดอ้างอิงและดัชนีสมมาตร โดยมีศัลยแพทย์ตกแต่งสองคนเป็นผู้ดำเนินการเพื่อประเมินความน่าเชื่อถือ **ผล:** ระยะห่างสามมิติระหว่าง nasion และจุดสังเกตที่ zygomaticomaxillary complex ทั้งสี่ไม่แตกต่างกันทางสถิติทั้งสองข้าง ยกเว้นระยะทางที่ obitale ซึ่งแตกต่างกันเพียง 3.11±3.32 มม. ดัชนีอสมมาตรของจุดสังเกตทั้งห้าอยู่ระหว่าง 4.89±3.38 มม. และ 6.31±4.71 มม. **สรุป:** จากการศึกษาพบว่าระยะห่างระหว่างจุดตรงดั้งจมูกและจุดอ้างอิงทั้ง 4 ไม่มีความแตกต่างกันทางสถิติทั้งสองด้าน จึงทำให้เชื่อถือได้ว่า จุดอ้างอิงทางกายวิภาคของกระดูกโหนกแก้มมีความสมมาตร สามารถนำไปใช้อ้างอิงในการสร้างภาพสามมิติโดยใช้คอมพิวเตอร์ออกแบบช่วยการผ่าตัดและใช้คอมพิวเตอร์ช่วยกำหนดเป้าหมายในการผ่าตัดแก้ไขเสริมสร้างและศัลยกรรมความงาม

คำสำคัญ: สมมาตร, กระดูกหักของไซโกมาติก, กระดูกโหนกแก้ม ไซโกมาติโกแมคซิลาลี่, การสแกนซีทีสามมิติ, ดัชนีสมมาตร

Introduction

The zygomaticomaxillary complex (ZMC) is one of the main components of the mid-facial skeleton involving functional support of the periorbital area, maxilla, and aesthetics of the cheek.[1] Restoration of the zygomaticomaxillary complex from facial trauma is a common procedure. Other ZMC defects may be caused by congenital anomaly or tumor resection. In the severe case of any etiology, ZMC reconstruction would be difficult because of its 3D structure.

In dealing with these complex cases, well planned, accurate, and safe surgery through computer-assisted design, computer-assisted surgery, and navigation-assisted surgery have developed and proved to be effective in both preoperative and intraoperative phases.

The computer-aid design needs referent points, values, or structures to recreate what is absent or destroyed.[2-3] The mirroring strategy is a popular technique used for restoration of facial bone trauma based on the normal contralateral side such as in orbital reconstruction. The navigator-assisted surgery has proven to aid ZMC fracture fixation.[4-5] However, there is no evidence supporting their symmetry. Thus, the purpose of this study was to verify the reliability of the premise of the mirroring technology in zygomaticomaxillary complex reconstruction surgery by assessing the level of asymmetry.[6-7] Moreover, the three-dimensional location of their surface landmarks would be the referent points which aid complex bilateral reconstruction planning.

Material and Methods

Patients Selection

Computed tomography (CT) scans of 60 patients were randomly enrolled at the Plastic Surgery Unit, Rajavithi Hospital from July of 2020 to February 2022. The inclusion criteria were ages between 18 and 60 years. The exclusion criteria were patients who have any pathological findings related to the zygomaticomaxillary complex, and history of congenital facial anomaly. The Institutional Review Ethic Committee of Rajavithi Hospital approved the study protocol.

Data Collection

The patients undertaken the non-contrast facial computed tomography for diagnostic purposes using the standardized trauma protocol. The CT data were exported in Digital Imaging and Communication in Medicine Images (DICOM) with 1.25 slice thickness and imports into iPlan Cranial software platform version 3.0 (Brainlab AG, Feldkirchen, Germany).

Setting Up the Plane

The three standard planes were used to realign computed tomographic images. Each plane is systematically referent in the three dimensions. 1) the Frankfort horizontal plane is defined by plane with horizontal alignment plane of the orbitale (Table 1) and tragion (an anthropometric point situated in the notch just above the tragus of the ear), 2) the coronal plane is set by the plane perpendicular to the Frankfort horizontal plane through the sella point (the midpoint of the pituitary fossa (sella turcica)) divides between dorsal and ventral sections, and 3) the midsagittal plane (the vertical plane pass through nasion, anterior nasal spine, and posterior nasal spine) divides between right and left side of the facial skeleton. (FIGURE 1)

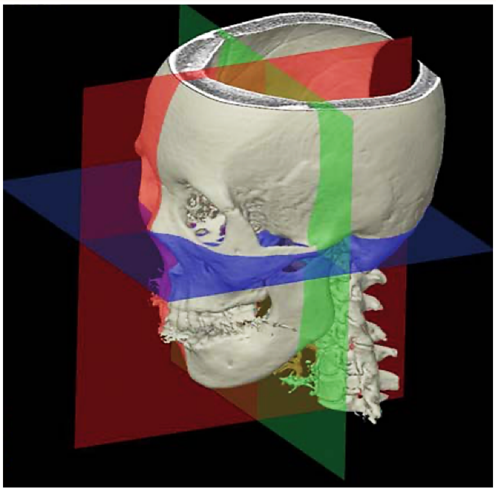

FIGURE 1. The three standard planes were used to realign the computed tomographic images: the Frankfort horizontal, the coronal plane, and the midsagittal plane.

Three-Dimensional Analysis of Zygomaticomaxillary Complex Asymmetry

Nasion was chosen to be the midline referent point of the face. Five points on the surface of ZMC were marked. These points represent the prominence of each part of ZMC (Table1).[8] The locations of each pair of surface landmarks (FIGURE 2) were calculated in 3 dimensions using custom script run in iPlan Cranial software platform version 3.0 (Brainlab AG, Feldkirchen, Germany) generated the plane of transformation and then computed the values using the X, Y, and Z coordinates for each landmark as input values, respectively (Table 3).

Table 1. Landmark selected for ZMC symmetry analysis.

Landmark	Abbreviation	Description
Orbitale	O	Most inferior point of the infraorbital rim[8]
Maxillozygion	MZ	Most anterior point on the maxillozygion suture line below the lateral third of the orbit[8]
Suprajugal curvature	SJC	Most convex point of posterior edge of frontal process of zygomatic bone superior to jugale[8]

Landmark	Abbreviation	Description
Jugale	J	Most concave point between lateral margin of frontal process and upper margin of the temporal process of zygomatic bone[8]
Zygion	Z	Most lateral point on zygomatic arch[8]

Interrater Reliability

Two plastic surgeons independently performed each measurement for assessment of interrater reliability.

Statistical Analysis

The statistical method to compare the length form nasion to each pair of the surface landmarks is the paired t-test. The absolute values of the differences and 95 percent confidence intervals were calculated. Statistical analyses were performed using IBM SPSS Version 26.0 (IBM Corp., Armonk, N.Y.). The value of $p < .05$ was considered significant. Asymmetry index (AI) was measured using formula: $AI = \sqrt{(Ldx\ Rdx)^2 + (Ldy\ Rdy)^2 + (Ldz\ Rdz)^2}$, was calculated from 3 dimensions values of each point where X, Y, and Z are the coordinates of a landmark (Table 3); L stands for left and R stands for right. A perfectly symmetrical landmark has an AI of 0. Interrater reliability of the methods was assessed by using interclass correlation coefficients, which were calculated using a two-way random-effects model for absolute agreement. A high degree of correlation was suggested by an interclass correlation coefficient greater than 0.75.

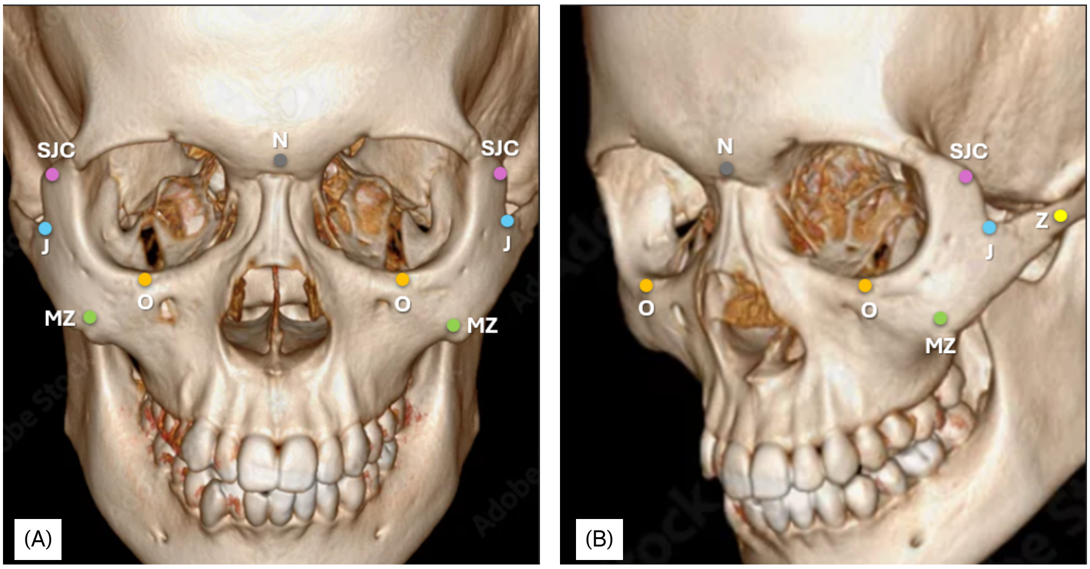

FIGURE 2. Selected zygomatic landmarks on a three-dimensional model of the craniofacial skeleton. The craniofacial model is shown from both (A) anterior and (B) oblique view. Landmark abbreviations shown above are N (Nasion), o (Orbitale), MZ (Maxillozygion), SJC (Suprajugal curvature), J (Jugale), and Z (Zygion) as listed in Table 1 along with landmark descriptions.8

Table 2. Results of three-dimensional analysis of zygomaticomaxillary complex.

Measurement	Mean±SD	Difference	p-value	Asymmetrical index
Nasion to O, mm				
Right	47.28±4.36	3.11±3.32	.030	5.44±5.52
Left	48.48±3.81			
Nasion to MZ, mm				
Right	59.45±7.94	2.29±1.77	.278	5.13±2.45
Left	59.84±7.47			
Nasion to SJC, mm				
Right	59.13±6.00	2.82±4.55	.498	5.57±5.75
Left	59.57±4.57			
Nasion to J, mm				
Right	69.75±3.54	2.12±1.81	.554	4.89±3.38
Left	69.54±3.52			
Nasion to Z, mm				
Right	89.43±5.57	2.89±4.40	.602	6.31±4.71
Left	89.69±5.66			

Results

The study sample consisted of thirty men and thirty women with a mean age of 33 years (range, 18 to 60). The mean location in three dimensions from the nasion of each pair of surface landmarks was calculated for asymmetrical index (Table 2). The mean three-dimensional distance from the nasion to point O was 47.28±4.36 mm on the right side and 48.48±3.81 mm on the left side, with significant difference between the left and the right sides (p = .030). The mean absolute difference in distance between both sides was 3.11±3.32 mm (Table 2). The asymmetrical index of the pair of O landmarks was 5.44±5.52.

The mean three-dimensional distance from the nasion to point MZ was 59.45±7.94 mm on the right side and 59.84±7.47 mm on the left side, with no significant difference between the left and the right sides (p = .278). The mean absolute difference in distance between both sides was 2.29±1.77 mm (Table 2). The asymmetrical index of the pair of MZ landmarks was 5.13±2.45.

The mean three-dimensional distance from the nasion to point SJC was 59.13±6.00 mm on the right side and 59.57±4.57 mm on the left side, with no significant difference between the left and the right sides (p = .498). The mean absolute difference in distance between both sides was 2.82±4.55 mm (Table 2). The asymmetrical index of the pair of SJC landmarks was 5.57±5.57.

The mean three-dimensional distance from the nasion to point J was 69.75±3.54 mm on the right side and 69.54±3.52 mm on the left side, with no significant difference between the left and the right sides (p = .554). The mean absolute difference in distance between both sides was 2.12±1.81 mm (Table 2). The asymmetrical index of the pair of J landmarks was 4.89±3.38.

The mean three-dimensional distance from the nasion to point Z was 89.43±5.57 mm on the right side and 89.69±5.66 mm on the left side, with no significant difference between the left and the right sides (p = .602). The mean absolute difference in distance between both sides was 2.89±4.40 mm (Table 2). The asymmetrical index of the pair of Z landmarks was 6.31±4.71.

The absolute difference in bilateral measurement in three-dimensional location; distance from the nasion to the maxillozygion (MZ), the nasion to the suprajugal curvature (SJC), the nasion to the juggler (J), the nasion to the zygion (Z) were not significant **except** for the distance from the nasion to the orbitale (O).

Interrater reliability testing demonstrated strong agreement between the two raters for all measurement categories. All interclass correlation coefficients ranged from approximately 0.94 to 0.99.

Table 3. Input values of three-dimensional locations of zygomaticomaxillary complex landmarks.

Measurement	Total	Male	Female
Nasion to O, mm			
Right			
X	38.21±2.91	39.14±2.77	37.16±2.75
Y	24.65±4.05	24.97±3.46	24.28±4.65
Z	11.19±6.11	12.48±7.62	9.73±3.28
Left			
X	39.07±2.91	39.11±3.21	39.03±2.59
Y	26.09±4.61	26.47±4.11	25.66±5.14
Z	10.58±4.01	10.77±4.53	10.36±3.38
Nasion to MZ, mm			
Right			
X	45.59±10.81	49.54±9.68	41.14±10.41
Y	33.63±6.22	34.06±5.60	33.15±6.91
Z	13.59±7.04	14.96±7.12	12.03±6.71
Left			
X	45.48±9.60	48.55±9.09	42±9.08
Y	34.60±5.90	35.39±4.84	33.71±6.88
Z	13.75±7.57	15.17±7.87	12.15±7.01
Nasion to SJC, mm			
Right			
X	54.01±4.03	55.4±2.80	54.01±4.03
Y	4.43±3.60	5.29±4.12	4.43±3.60
Z	22.92±6.45	24.31±7.98	22.92±6.45
Left			
X	54.4±2.12	55.20±1.93	53.49±1.99
Y	3.73±3.32	4.41±3.89	2.96±2.36
Z	23.13±6.87	24.96±8.10	21.05±4.40

Measurement	Total	Male	Female
Nasion to J, mm			
Right			
X	57.59±2.86	59±2.72	55.99±2.10
Y	21.19±6.82	22.96±6.68	19.18±6.51
Z	32.22±4.51	32.31±5.04	32.13±3.91
Left			
X	57.48±2.43	58.59±2.20	56.23±2.06
Y	21.9±6.01	23.41±5.86	20.20±5.82
Z	31.78±3.72	32.07±4.11	31.45±3.25
Nasion to Z, mm			
Right			
X	65.3±3.04	66.51±2.74	65.3±3.04
Y	26.74±8.43	28.61±8.74	26.74±8.43
Z	54.12±6.50	54.69±6.19	54.12±6.50
Left			
X	65.28±3.01	66.51±3.02	63.90±2.37
Y	27.94±7.98	30.04±7.62	25.56±7.82
Z	54.08±6.19	54.76±6.59	53.32±5.73

The locations of each 5 pairs of surface landmarks were calculated in 3 dimensions using custom script run in iPlan Cranial software platform version 3.0 (Brainlab AG, Feldkirchen, Germany) generated the plane of transformation and then computed the values using the X, Y, and Z coordinates for each landmark as input values, respectively (O, orbitale; MZ, maxillozygion; SJC; suprajugal curvature, J; jugale; Z; zygion).

Discussion

To achieve excellent aesthetic outcomes is always a challenge in all maxillofacial procedures. This came from its complex three-dimensional structure, which composes facial appearance. Traditionally, variable surgical outcomes come from subjective experience of surgeons in preoperative assessment, intraoperative decision making, adjustment of bone and soft tissue, and estimation of the endpoint of the surgery. Zygomaticomaxillary complex is one of the most encountered structures in which complex cases such as severe trauma cases or congenital anomaly require precise planning and accurate intraoperative assessment.

Recently, computer-aid design, computer-assisted surgery, and real-time intraoperative navigation play an extensive role in maxillofacial surgery. By obtaining three-dimensional reconstruction of computed tomography of a patient, surgeons can accommodate preoperative planning, perform virtual surgery, fabricate a cutting guide, and invent a prototyping model. The real-time intraoperative navigation system facilitates assessment in limited surgical fields and determines the endpoint of the procedure. Surgical tasks which prolonged operative time and cause variable results such as tissue repositioning, osteotomy cuts, and prosthesis placement can be accomplished via combination of these innovations.

Symmetry is the main goal in every facial reconstruction. Computer-aid design using mirroring technique by segmentation of the unaffected contralateral side and mirroring it over the affected side is gaining popularity and widely validated in literature. The patient-specific planning provides surgeons and patients with the expected result of the surgery. This requires measurement of asymmetry of the facial structure to validate the technique. Zygomaticomaxillary complex defines appearance of the cheek and composes the orbital wall integrity via its quadripod shape. These are considered essential in restoration and reconstruction when there is a lack of objective endpoints in surgery.

Previously, Y. R. Chen et al. identified facial soft tissue asymmetry by evaluating asymmetrical indexes of the landmarks which appear larger in lower face than upper face.[9] The range of the indexes varied from 0.76 to 2.82. Otherwise, most of these landmarks are on the midline of the face and rely on soft tissues. Jean Pierre T. F. Ho. et al. measured zygomaticomaxillary complex symmetry with the use of mirroring and surface based matching techniques.[10] This study reports accuracy of the mirroring technique in discriminating between regular variation of symmetry and a displaced ZMC fracture. The average absolute distance was 0.84±0.29 mm. This value relies on surface-based matching which is software specific, and all surfaces may not be essential for the symmetrical appearance of the cheek. Thus, this study evaluates three-dimensional symmetry of the zygomaticomaxillary complex based on its surface landmarks and relies on protuberant parts of ZMC. Moreover, the three-dimensional location of each point would be a reference for a complex or bilateral reconstruction case.

The absolute difference in bilateral measurement in three-dimensional location distance from the nasion to all landmarks except orbitale were not significant. Aside, the mean absolute difference in distance between both sides of orbitales was 3.11±3.32 mm. This means most of the prominent points of ZMC were symmetrical on both sides with differences around 2 mm. For orbitale points, the difference may reach 3 mm. In general, skeletal deviation must be equal to or greater than 4 mm. to render the asymmetry visible in an individual's face. If the difference is lower, the condition tends to be considered mild and unperceivable.

The asymmetrical indexes of all points which range from 4 to 6 state that there is no absolute symmetry in the pair of ZMC. Tingwei Bao et al. assesses the symmetry recovery in navigation-assisted surgical reduction of zygomaticomaxillary complex fractures. By using the navigation system, the AI of five landmarks in ZMC fracture were corrected from 4 to 12 preoperatively to 3 to 6 postoperatively.[11]

Our study demonstrates the symmetry of the zygomaticomaxillary complex in the population. There was truly a slight difference in orbitale landmarks, which is unapparent. This result verifies mirroring technology in computer-assisted planning. Whenever discrepancy in the three-dimensional location is significant there will be an error when using mirroring technique. The calculated distances from nasion can define the surface landmarks of reconstructed ZMC and their symmetry can be verified using an acceptable index of each point. Rapid prototype models created from the reference value will simulate a surgical outcome. A real-time intraoperative navigation system should be used to confirm the final result. By applying this method in computer-assisted design, computer-assisted surgery, and intraoperative navigation system, not only unilateral ZMC defect can be restored but asymmetrical congenital disease or bilateral disease of ZMC can also be reconstructed. The limitation of this study is the variety of facial skeletal shapes among races and ages.

Conclusions

The three-dimensional location of the zygomaticomaxillary complex appears to be almost symmetrical. The asymmetry at orbitale points is unperceivable. Computer-assisted design using mirroring technology can be used for unilateral defects. In asymmetrical congenital or bilateral diseases, the reference values of distance from nasion and asymmetrical index can be used as guide for reconstruction. In these complex cases, rapid prototype models using three-dimensional printing technology and real-time intraoperative navigation system should be used to confirm the result.

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