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Original Article

Evaluation of cortical bone thickness at the nasomaxillary and zygomaticomaxillary buttresses using cone-beam computed tomography imaging for Le Fort I osteotomy

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Zygomaticomaxillary buttress

Abstract *Background/Purpose:* Studies have indicated that 50%—55% of the population have malocclusion, and approximately 5%—10% require orthognathic surgery to correct this condition. Optimal placement of plates and screws significantly affects the success rate of the surgery and postoperative stability. This study evaluates the cortical thickness of the maxillary bone in the nasomaxillary and zygomaticomaxillary buttress regions in Taiwanese patients based on cone-beam computed tomography (CBCT) images.
Materials and methods: 128 Patients undergoing Le Fort I osteotomy were selected for this study. Their CBCT images were input into medical imaging software to simulate the placement of titanium screws and plates. The cortical bone thickness at these positions was measured to assess the thickness in the nasomaxillary buttress (surrounding the nasal opening) and the zygomaticomaxillary buttress (surrounding the maxillary zygomatic process). Associations of these thicknesses with gender, age, and screw position were analyzed.
Results: In the nasomaxillary region, cortical bone was thicker on the upper and lower vertical regions, with men generally having thicker bone. The zygomaticomaxillary region had increased thickness near the zygomatic end and distal region. Younger adults had significantly greater bone thickness in certain areas than those over 30 years.
Conclusion: The nasomaxillary region's upper and lower vertical regions and the zygomatic end in the zygomaticomaxillary region provide optimal screw placement sites. Bone thickness

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differences by gender and age suggest occlusal force and age-related bone resorption as influencing factors.

Introduction

Abnormalities in the jawbone can not only affect the normal development of the cranial bones but also lead to problems such as temporomandibular joint dysfunction, obstructive sleep apnea, chewing difficulties, and speech disorders.[1—3] Studies have indicated that approximately 5%—10% of patients with jawbone abnormalities require orthognathic surgery to correct malocclusion.[4,5] Orthognathic surgery is used for correcting jawbone anomalies that cannot be corrected using orthodontic appliances. The surgery involves cutting and repositioning of the maxilla and mandible, followed by fixation with screws and plates to achieve facial symmetry, improved occlusion, and enhanced overall aesthetics. Le Fort osteotomy is a surgical technique used for separating the midfacial skeleton from the cranial base, enabling the repositioning of the maxilla. Le Fort osteotomies are classified into three types depending on the level of the osteotomy cut.[6—8] Le Fort I osteotomy is a standard procedure used for correcting midface deformities and vertical maxillary excess. Although it is less common, Le Fort II osteotomy can be used to adjust the positions of the nose and maxilla. Le Fort III osteotomy is used for severe craniofacial deformities and involves adjusting nearly the entire midfacial skeleton.[7]

The craniofacial skeleton is supported by a system of vertical and horizontal buttresses, which constitute the more rigid areas of the facial skeleton. These structures protect vital components such as the teeth, nasal cavities, sinuses, and eyeballs[9] and help transmit or absorb external forces and masticatory pressure to the cranial base.[10] Vertical buttresses determine the vertical height of the face and offer bony support to the masticatory muscles. Vertical buttresses encompass the nasomaxillary, zygomaticomaxillary, pterygomaxillary, and vertical mandibular regions of the facial skeleton. Horizontal buttresses determine the facial width and anteroposterior dimensions, maintaining transverse skeletal stability. They encompass the frontal bar, infraorbital rim, hard palate, and horizontal mandibular regions of the facial skeleton.[11] Owing to their relative thickness and rigidity, the buttress systems are often used for the placement of screws and plates in craniofacial surgeries. The nasomaxillary and zygomaticomaxillary buttresses, with their thicker cortical bone, are commonly recommended for skeletal anchorage in orthodontics.[12,13]

The maxilla is a critical bony structure that significantly influences facial contouring.[14] Clinically, the maxilla is commonly fixated using bone screws and plates after osteotomy or is subjected to mechanical forces through the use of anchorage mini-screws and elastics to correct malocclusion. Numerous studies have discussed the bone quality of the maxilla.[14—18] Patients may have bone screws or plates implanted for various clinical reasons, and the insertion sites are typically within the relatively hard nasomaxillary buttress and zygomaticomaxillary buttress regions or their surrounding bones. Studies have indicated that the nasomaxillary region tends to have thicker bone at the superior and inferior aspects, with thinner bone in the middle; similarly, bone thickness increases superiorly and laterally in the zygomaticomaxillary region. Clinically, internal fixation is one of the most crucial factors influencing postoperative stability in orthognathic surgery[19] because it physically reconnects the bones, directly placing screws and plates inside the body to secure the bones in the correct position and preventing abnormal healing during the recovery process. Traditionally, the use of four bone plates in Le Fort I osteotomy has been considered the gold standard in orthognathic surgery; however, studies have reported successful fixation using only two bone plates in the piriform aperture region.[20,21] Reducing the number of screws and plates, when clinically appropriate and acceptable, can decrease surgical time, treatment cost, and the risks of intraoperative anesthesia, postoperative infection, and potential complications.[22]

The quality of the maxillary bone is a critical determinant of the success rate of orthognathic surgery and postoperative stability. Literature is limited on the influence of maxillary bone thickness on the success of Le Fort I osteotomy. Therefore, this study investigated cortical bone thickness at screw implantation sites in the nasomaxillary and zygomaticomaxillary buttress regions by using cone-beam computed tomography (CBCT) images. This research presents clinically useful findings on the most suitable and safe locations for screw placement and the appropriate screw length for each insertion site.

Materials and methods

Image acquisition and inclusion/exclusion criteria

This study retrieved dental CBCT images collected by the Department of Dentistry at China Medical University Hospital between 2018 and 2023. Suitable samples were selected from these images and imported into Mimics 14.0 (Materialise, Leuven, Belgium) medical imaging software for parameter measurement. The data were statistically analyzed to compare bone thicknesses across different age groups, genders, and screw positions, and the results were compared with those of other relevant studies. The CBCT images were captured using the ProMax 3D Max machine (Planmeca, Helsinki, Finland) with a scanning resolution of 400 μm, a tube voltage of 96 kV, a tube current of 5.6 mA, and an exposure time of 18 s. The retrieved CBCT images corresponded to 208 patients, of which images from 128 patients were selected, corresponding to 64 men and 64 women aged between 20 and 60 years. This study was approved by the Institutional Review Board of China Medical University Hospital (CMUH 111-REC3-205). Patients were included in this study if (a) their age >20 years; (b) they had undergone orthognathic surgery involving Le Fort I osteotomy; (c) their CBCT images had a resolution of 400 μm; and (d) their CBCT images included the entire craniofacial field of view. Patients were excluded from this study if they had (a) a history of orthognathic or craniofacial reconstructive surgery other than the planned Le Fort I osteotomy; (b) maxillary bone defects in the measurement area; (c) supernumerary teeth in the measurement area; (d) severe craniofacial deformities; or (f) severe metal or motion artifacts in their CBCT images.

Assessment of cortical bone thickness in the nasomaxillary and zygomaticomaxillary regions

The CBCT images in the Digital Imaging and Communications in Medicine format were imported into Mimics software, with the minimum threshold set to 480 Hounsfield units and the maximum threshold set to the default setting. The "Region Growing" function was used to select the region of interest, and the "Calculate Part" function was used to reconstruct a three-dimensional cranial image (Fig. 1a), allowing for the definition of screw positions. This study used 8-hole inverted Y-shaped plates (04.511.381-386, DePuy Synthes, Oberdorf, Switzerland) for the nasomaxillary buttress and 6-hole L-shaped plates (DePuy Synthes) for the zygomaticomaxillary buttress. Screws (red dots) were customized and placed according to each patient's bony structure and adjusted slightly after consultation with clinical dentists. Measurement points A–H for the nasomaxillary region and I–N for the zygomaticomaxillary region were marked (Fig. 1b). The "Measure Angle" function was used to find the perpendicular line to the bone surface at the screw site on the transverse plane (Fig. 2a and c), and the "Measure Distance" function was used to measure cortical bone thickness at the screw site (Fig. 2b and d). This study measured the following parameters:

1. Cortical bone thickness in the right nasomaxillary buttress region
2. Cortical bone thickness in the left zygomaticomaxillary buttress region

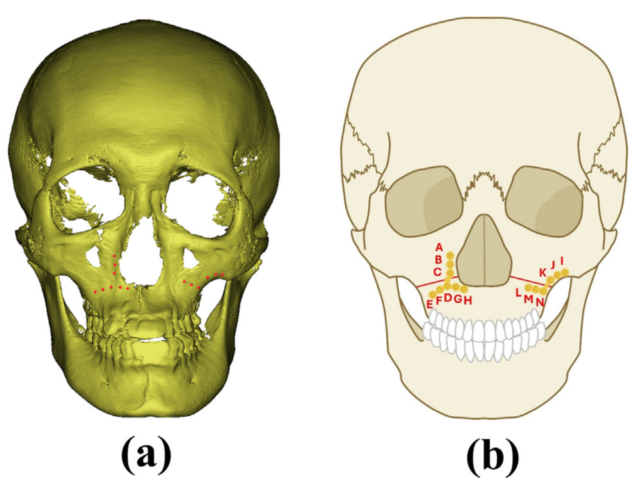


Figure 1 (a) Simulation displaying the positioning of bone screws on the reconstructed three-dimensional cranial model of the patient. (b) Placement of inverted Y-shaped bone plates in the nasomaxillary region (A–H) and L-shaped bone plates in the zygomaticomaxillary region (I–N).

Statistical analysis

The intraclass correlation coefficient was used to analyze intra- and interexaminer consistency. A specific screw position was selected, and the average cortical bone thickness was measured 10 times. The intraclass correlation coefficient analysis revealed an intraexaminer consistency of 0.981 and an interexaminer consistency of 0.949, with a 95% confidence interval, indicating that the measurement results of this study were reliable.

The cortical bone thickness of all samples was described using minimum, maximum, mean, and standard deviation. Independent sample t-test (Student's t-test) was used to determine the thickness differences between the genders. One-way analysis of variance was used to determine thickness differences among age groups, followed by Tukey's post hoc test for further comparisons. The correlation between different screw positions was analyzed using the Pearson correlation coefficient. All statistical analyses were conducted using SPSS version 22 (IBM, Armonk, NY, USA). A *P*-value less than 0.05 was considered statistically significant.

Results

Cortical bone thickness at different screw positions

Table 1 presents the cortical bone thickness data and distribution at measurement points in the nasomaxillary and zygomaticomaxillary regions for all samples ($n = 128$). In the nasomaxillary region, the bone was thinner in the middle vertical section (points B and C) and became progressively thinner toward the mesial region in the horizontal section (points G and H). In the zygomaticomaxillary region, the bone was thicker toward the zygomatic bone in the vertical section (point I) and toward the distal region in the horizontal section (point N).

Different screw positions were compared using Pearson correlation analysis (Table 2). The results indicated that most measurement points in the nasomaxillary region, especially points G and H with other measurement points, shared a moderately positive correlation ($r = 0.3$–0.7), whereas a few points shared a low positive correlation ($r < 0.3$). In the zygomaticomaxillary region, most measurement points were moderately positively correlated with each other, with points M and N exhibiting a high positive correlation ($r > 0.7$), and a few points showing low positive correlations. Negative correlations were not as common between points in the two regions, but they were particularly observed between point K and multiple other points.

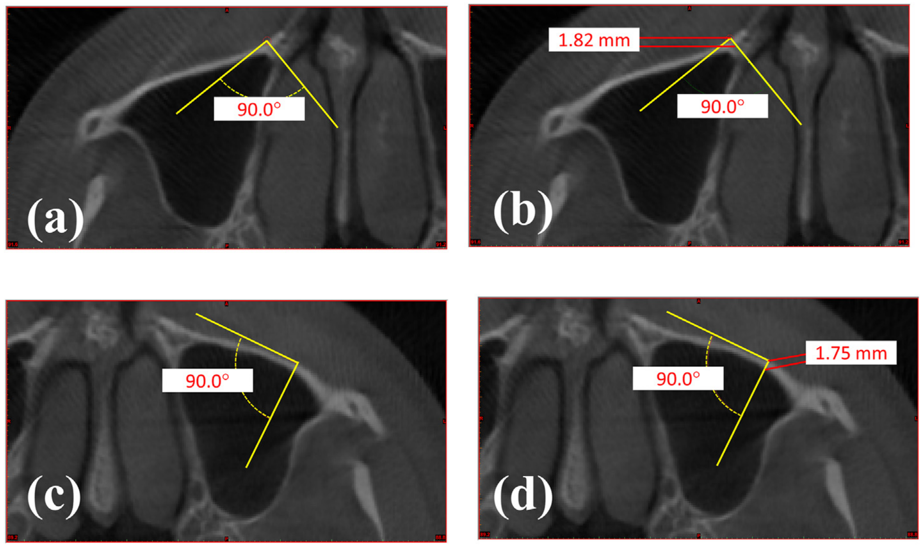
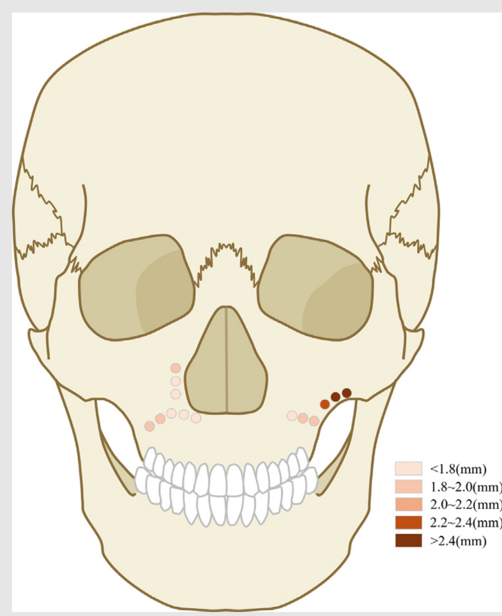


Figure 2 (a) [Nasomaxillary region] Identify the vertical line perpendicular to the bone surface. (b) [Nasomaxillary region] Measure cortical bone thickness along the identified vertical line. (c) [Zygomaticomaxillary region] Identify the vertical line perpendicular to the bone surface. (d) [Zygomaticomaxillary region] Measure cortical bone thickness along the identified vertical line.

Table 1 Cortical bone thickness for all samples.

Position		Mean	SD	Min	Max
Nasomaxillary buttress	A	1.89	0.62	0.77	5.05
	B	1.70	0.46	0.88	3.32
	C	1.77	0.41	1.00	3.18
	D	1.79	0.40	0.96	3.54
	E	1.81	0.42	0.80	2.92
	F	1.81	0.38	1.00	2.80
	G	1.74	0.38	0.94	3.01
	H	1.62	0.31	0.89	2.46
Zygomaticomaxillary buttress	I	2.54	0.76	1.28	5.53
	J	2.50	0.70	1.14	2.64
	K	2.32	0.68	1.36	4.88
	L	1.79	0.38	0.85	2.73
	M	1.82	0.46	0.98	3.50
	N	1.97	0.50	0.94	4.84
	Unit	mm	mm	mm	mm



Differences between genders

Table 3 provides descriptive statistics, the results of independent sample t-tests for men and women, and the thickness distribution. The sample included 64 men and 64 women. Student's t-test results indicated significant differences between the two genders in cortical bone thickness at measurement points B, C, D, E, F, G, and H in the nasomaxillary region. No significant differences were observed at other points.

Table 2 Correlation between different bone screw positions.

Position	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A	—	0.315**	0.274**	0.201*	0.191*	0.198*	0.141	0.123	0.166	−0.034	−0.003	0.103	0.091	0.004
B	0.315**	—	0.545**	0.230**	0.215*	0.103	0.417**	0.327**	0.014	0.122	−0.114	0.138	0.269**	0.242**
C	0.274**	0.545**	—	0.298**	0.352**	0.226*	0.431**	0.385**	−0.028	0.043	−0.221*	0.076	0.147	0.089
D	0.201*	0.230**	0.298**	—	0.386**	0.539**	0.427**	0.335**	−0.013	−0.044	−0.099	−0.028	−0.057	−0.088
E	0.191*	0.215*	0.352**	0.386**	—	0.565**	0.439**	0.367**	−0.036	−0.144	−0.219*	−0.043	−0.004	−0.063
F	0.198*	0.103	0.226*	0.539**	0.565**	—	0.327**	0.264**	−0.084	−0.125	−0.087	−0.129	−0.109	−0.096
G	0.141	0.417**	0.431**	0.427**	0.439**	0.327**	—	0.442**	−0.079	−0.087	−0.209*	0.001	0.026	−0.033
H	0.123	0.327**	0.385**	0.335**	0.367**	0.264**	0.442**	—	0.023	−0.159	−0.208*	−0.171	0.008	−0.072
I	0.166	0.014	−0.028	−0.013	−0.036	−0.084	−0.079	0.023	—	0.379**	0.338**	0.094	0.093	0.018
J	−0.034	0.122	0.043	−0.044	−0.144	−0.125	−0.087	−0.159	0.379**	—	0.554**	0.299**	0.309**	0.218*
K	−0.003	−0.114	−0.221*	−0.099	−0.219*	−0.087	−0.209*	−0.208*	0.338**	0.554**	—	0.343**	0.306**	0.234**
L	0.103	0.138	0.076	−0.028	−0.043	−0.129	0.001	−0.171	0.094	0.299*	0.343*	—	0.565*	0.481*
M	0.091	0.269**	0.147	−0.057	−0.004	−0.109	0.026	0.008	0.093	0.309**	0.306**	0.565**	—	0.739**
N	0.004	0.242**	0.089	−0.088	−0.063	−0.096	−0.033	−0.072	0.018	0.218*	0.234**	0.481**	0.739**	—

$^*P < 0.05$, $^{**}P < 0.01$.

Differences between age groups

The patients in this study were divided into three age groups: early young adults (20–25 years), late young adults (26–30 years), and middle-aged adults (31–60 years). Table 4 presents the cortical bone thickness data and its distribution across the three age groups. The cortical bone thickness at measurement points A and G in the nasomaxillary region significantly differed among the three age groups. No significant differences were found at the other points.

Discussion

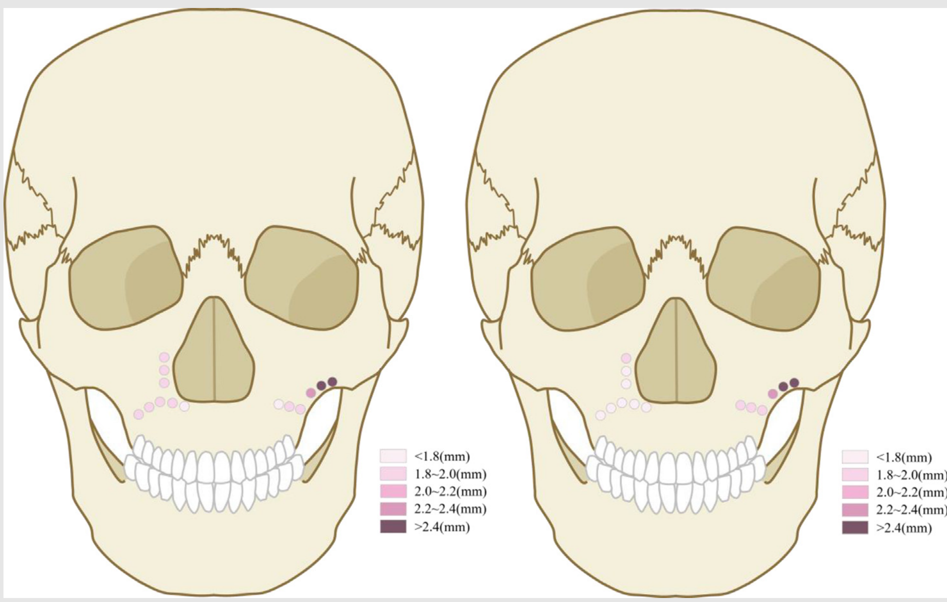
Many studies have measured maxillary bone thickness using CBCT images, CT images, and dry skulls. However, most of these measurements have been in the context of the placement of orthodontic mini-implants and the clinical implications of their use in facemasks and traction devices. To date, only one study has measured bone thickness in the nasomaxillary and zygomaticomaxillary regions in the context of Le Fort I osteotomy for orthognathic surgery. Furthermore, only one study has investigated maxillary bone thickness in Asian individuals, and it was not in the clinical context of orthognathic surgery. Therefore, this is the first study to measure cortical bone thickness at screw implantation sites for Le Fort I osteotomy in Taiwanese individuals. This study measured cortical bone thickness at screw implantation sites in a direction perpendicular to the bone surface in the nasomaxillary and zygomaticomaxillary regions, according to each patient's maxillary bone morphology. The results indicated that cortical bone in the nasomaxillary region was thicker at the sides and thinner toward the center, with thickness increasing distally, whereas cortical bone in the zygomaticomaxillary region was thicker toward the zygomatic end.

Orthognathic surgery involves cutting and repositioning of facial skeleton, followed by fixation with screws to achieve ideal jaw alignment and occlusion, thus enhancing facial balance and harmony. Surgical anchorage of the screws is influenced by their location, their type, bone density, and cortical bone thickness.[16,23] Determining the optimal anchorage site is crucial for the success of the surgery and postoperative stability. Tomohisa et al. noted that optimal stability can be achieved when the screw diameter matches the bone thickness at the implantation site.[24] Therefore, determining maxillary bone thickness and understanding its implications is vital for preoperative planning in orthognathic surgery.

In the nasomaxillary region, the vertical bone thickness tends to decrease toward the center, likely due to the maxillary sinuses on either side of the nasal cavity and below the orbits. This finding aligns with trends observed by Medeiros et al. in the nasomaxillary regions beside the piriform aperture.[16] However, Rossi et al. reported an increasing trend in cortical bone thickness toward the nasal floor,[18] inconsistent with our finding of thicker sides and a thinner center. Horizontally, the thickness tends to increase distally, likely due to variations in occlusal forces at different tooth positions; the maximum occlusal force of molars is greater than that of incisors.[25] A synthesis of data

Table 3 Cortical bone thickness data sorted by gender.

Position		Male (n = 64)		Female (n = 64)		*P*-value
		Mean	SD	Mean	SD	
Nasomaxillary buttress	A	1.93	0.54	1.84	0.69	0.39
	B	1.85	0.49	1.55	0.38	<0.001
	C	1.88	0.42	1.67	0.37	<0.001
	D	1.92	0.38	1.66	0.38	<0.001
	E	1.97	0.42	1.66	0.37	<0.001
	F	1.91	0.41	1.71	0.33	<0.001
	G	1.89	0.32	1.60	0.38	<0.001
	H	1.75	0.33	1.49	0.24	<0.001
Zygomaticomaxillary buttress	I	2.53	0.69	2.55	0.82	0.87
	J	2.51	0.81	2.49	0.57	0.85
	K	2.32	0.75	2.32	0.61	0.98
	L	1.78	0.42	1.81	0.33	0.69
	M	1.82	0.46	1.83	0.47	0.92
	N	1.96	0.48	1.99	0.53	0.70
	unit	mm	mm	mm	mm	mm



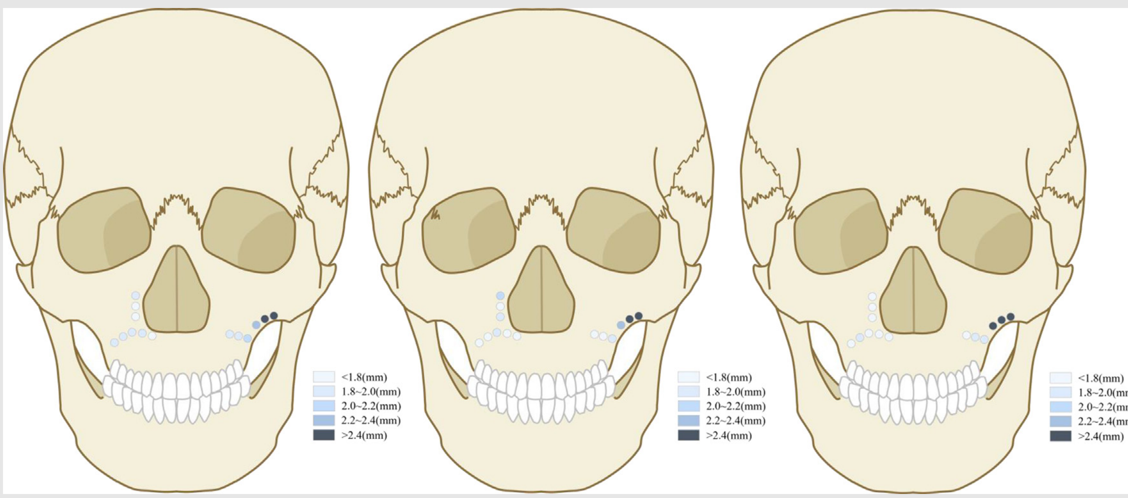
Male Female

from three studies revealed that bone thickness in the nasomaxillary region was largest in Turkish individuals,[14] followed by Brazilian individuals and then Italian individuals (Table 5).[16,18] The vertical thickness values of Taiwanese individuals measured in this study were most similar to those reported for Brazilian individuals, whereas the horizontal thickness values were between those for Brazilian and Italian individuals. Across all literature on bone thickness in the nasomaxillary region, the distribution of vertical thickness data indicate a common trend of thicker sides and a thinner center. However, in the horizontal direction, only Turkish individuals exhibited increasing thickness toward the center, whereas Brazilian and Italian individuals exhibited decreasing thickness toward the center, similar to the trend observed in the Taiwanese individuals in this study.

In the zygomaticomaxillary region, vertical bone thickness tends to increase toward the zygomatic bone. This finding aligns with the findings of Lee et al., who reported that the zygomatic process thickens upward and laterally.[15] In the horizontal direction, the cortical bone becomes thicker distally, a trend that mirrors the horizontal thickness distribution observed in the nasomaxillary region. The overall bone thickness data in the zygomaticomaxillary region, retrieved from three studies representing three ethnic populations, can be ranked as follows: Brazilian individuals had the thickest cortical bone in this facial region,[16] followed by Korean individuals and then Italian individuals (Table 6).[15,18] The vertical and horizontal thickness values reported for Taiwanese individuals in this study fall between the thickness values reported for Brazilian and Korean individuals. The trend observed in this study of vertical thickness increasing toward

Table 4 Cortical bone thickness data sorted by age groups.

Position		20∼25 (n = 55)		26∼30 (n = 38)		31∼60 (n = 35)		*P*-value
		Mean	SD	Mean	SD	Mean	SD	
Nasomaxillary buttress	A	1.84	0.50	2.10	0.77	1.72	0.54	0.024
	B	1.73	0.52	1.73	0.39	1.63	0.44	0.575
	C	1.78	0.38	1.82	0.42	1.72	0.42	0.534
	D	1.80	0.41	1.82	0.40	1.73	0.40	0.566
	E	1.88	0.45	1.75	0.42	1.78	0.38	0.326
	F	1.83	0.37	1.75	0.38	1.85	0.41	0.506
	G	1.84	0.43	1.69	0.30	1.65	0.36	0.042
	H	1.64	0.31	1.65	0.33	1.55	0.30	0.268
Zygomaticomaxillary buttress	I	2.56	0.66	2.49	0.74	2.57	0.92	0.869
	J	2.52	0.67	2.40	0.54	2.59	0.87	0.474
	K	2.27	0.53	2.28	0.69	2.44	0.87	0.492
	L	1.85	0.40	1.76	0.38	1.75	0.34	0.387
	M	1.88	0.53	1.75	0.45	1.80	0.34	0.396
	N	2.06	0.59	1.91	0.45	1.90	0.37	0.214
	unit	mm	mm	mm	mm	mm	mm	mm



Age: 20—25 26∼30 31∼60

the zygomatic region and horizontal thickness increasing distally is replicated in the aforementioned studies on Brazilian, Korean, and Italian individuals.

The average cortical bone thickness in the nasomaxillary buttress region was significantly greater in men than in women at all measurement points except point A, which aligns with the findings of Medeiros et al.[16] This study suggests that this gender-based difference may be due to the greater maximum occlusal force in men compared with women.[26,27] Given that the buttress system is responsible for transmitting occlusal forces, the bone in the nasomaxillary region, which bears more occlusal stress, may have become thicker and denser in men to adapt to the increased occlusal stress. In the zygomaticomaxillary buttress region, the average cortical bone thickness showed minimal nonsignificant differences between genders, consistent with the findings of Medeiros et al.[16] In Korean individuals, the maxillary bone thickness in the zygomaticomaxillary region was reported to be generally greater in men than in women, with the differences becoming more pronounced toward the zygomatic bone. However, only the thickness near the orbit and zygomatic bone showed statistically significant differences between genders, indicating that the data for Korean individuals are more consistent with the trends observed in this study only further from the zygomatic bone.[15]

Past research has not provided specific clinical data for patients of different ages undergoing Le Fort I surgery, so no established age classification was available for reference. This study used dental CBCT images from 128 patients to assess cortical bone thickness at the nasomaxillary and zygomaticomaxillary buttresses before Le Fort I osteotomy. Since most patients receiving Le Fort I osteotomy in Taiwan are under 30 years of age, we classified the patients into three age groups with similar sample sizes: early young adults (20—25 years), late young adults (26—30 years), and middle-aged adults (31—60 years). This classification allowed us to explore potential age-related differences in cortical bone thickness, offering valuable insights for preoperative planning. In the nasomaxillary region, the

Table 5 Comparative studies on bone thickness in the nasomaxillary buttress region.

Country	Turkish			Brazil			Italy			Taiwan
Author	Candan Arman et al.			Y. L. Medeiros et al.			Margherita Rossi et al.			This study
Year	2006			2021			2017			2024
Apparatus	Dry skulls			i-CAT			NA			Promax 3D Max
Resolution	—			0.25 (mm)			NA			0.4 (mm)
Measurement method	—			In parasagittal plane			1. Horizontal plane ∥ the Frankfort horizontal plane 2. Vertical plane ∥ the Midsagittal plane (MSP)			In axial plane
Bone thickness	The most inferior point of infraorbital margin ↓	Y3	Y4	Lower border of infraorbital foramen ↓	C	CM	5 (mm) below infraorbital foramen ↓	2	1	
					3.6	2.8		1.01	3.09	1.89
		2.35	3.31		3.4	2.4		1.21	2.39	1.70
		2.13	3.50		3.1	1.8		1.33	1.34	1.77
		2.16	2.60		3.3	1.9		1.23	1.12	1.81 1.81 1.79 1.74 1.62
		2.02	2.12		4.5	3.4				
		2.32	2.39		7.0	6.4				
		3.45	4.30		8.6	8.6				
	The most inferior point of piriform aperture			Canine root tip						

Table 6 Comparative studies on bone thickness in the zygomaticomaxillary buttress region.

Country	Brazil			Korea				Italy				Taiwan
Author	Y. L. Medeiros et al.			Hyub-Soo Lee et al.				Margherita Rossi et al.				This study
Year	2021			2013				2017				2024
Apparatus	i-CAT			Shimadzu				NA				Promax 3D Max
Resolution	0.25 (mm)			1 (mm)				NA				0.4 (mm)
Measurement method	In parasagittal plane			1. Horizontal plane ⊥ the Midsagittal plane 2. Antero-posterior line ‖ the Midsagittal plane				3. Horizontal plane ‖ the Frankfort horizontal plane 4. Vertical plane ‖ the Midsagittal plane (MSP)				In axial plane
Bone thickness	Lower border of	M	D	↓	AP8	AP6	AP4	5 (mm) below	4	5	6	
	infraorbital	5.5	7.8	↓	1.6	2.3	3.8	infraorbital	0.99	1.23	2.14	2.54
	foramen	4.1	6.8	↓	1.6	2.2	3.6	foramen	0.92	1.19	1.86	2.50
	↓	3.3	6.0	↓	1.5	1.8	2.8	↓	1.02	1.55	1.90	2.32
	↓	2.6	4.9	↓	1.3	1.7	2.4	↓	1.21	1.561.17	1.47	1.79 1.82 1.97
	↓	2.4	3.1	↓	1.2	1.5	2.1	↓	1.16		1.18	
	↓	2.6	2.5	↓	1.4	1.7	2.6	↓				
	↓	4.1	3.8	↓	1.2	1.4	1.8	↓				
	↓			The most inferior border of the zygomatic process				↓				
	Mesiobuccal & Distobuccal roots of the maxillary 1st molar											

cortical bone was generally thicker in early young adults and late young adults than in middle-aged adults. Findings at measurement point A significantly differed between these three age groups, with late young adults having a thicker cortical bone than middle-aged adults at this point. Bone thickness was the highest at measurement point G in early young adults, significantly higher than the thickness at this point in the other two groups. No consistent trend or significant differences in bone thickness were observed across the three age groups in the zygomaticomaxillary region. However, the horizontal cortical bone thickness in this facial region tends to be greater in adults than in middle-aged individuals. This study suggests that tooth loss and bone resorption with aging may lead to thinning of the bone near the roots, resulting in thinner horizontal cortical bone in the zygomaticomaxillary region in middle-aged individuals compared with adults.

Few studies have investigated maxillary bone thickness in the nasomaxillary and zygomaticomaxillary regions or their differences across age groups. Therefore, findings of this study are compared with findings from the literature on alveolar bone thickness by age group, as follows. Fayed et al. evaluated cortical bone thickness between maxillary roots in Swiss individuals, divided into the two age groups of 13–18 years and 19–27 years. The results indicated that the adult group generally had thicker cortical bone than the adolescent group, but the difference was nonsignificant at most measurement points.[28] Cassetta et al. evaluated cortical bone thickness of the alveolar bone in Italian individuals, dividing the patients into an adolescent group (12–18 years) and an adult group (19–50 years). The results showed that cortical bone thickness gradually increased with age, with most groups exhibiting statistically significant differences.[29] Farnsworth et al. evaluated cortical bone thickness at common mini-implant sites in American individuals, dividing the patients into adolescent (11–16 years) and adult groups (20–45 years). Their results demonstrated that adults generally had thicker cortical bone than adolescents, especially in the posterior regions.[30] Sathapana et al. (2013) evaluated the correlation between alveolar bone thickness and age in Australian individuals, dividing the patients into five age groups. The results showed that the thickness of the maxillary cortical bone gradually increased with age.[31]

An analysis of the aforementioned studies indicates that age grouping across different ethnic groups does not reveal a consistent trend in cortical bone thickness. Most studies have indicatesd that cortical bone thickness is generally greater in adults than in adolescents. However, the thickness of the maxillary bone does not vary uniformly with increasing age. This study categorized individuals into the three age groups of early young adults (20–25 years), late young adults (26–30 years), and middle-aged adults (31–60 years). The thickness distribution across age groups revealed that early and late young adults possessed thicker cortical bone than middle-aged adults, as measured at most measurement points. Still, age and thickness did not exhibit a uniform trend, which is consistent with the aforementioned findings from the literature.

Given that orthognathic surgery involves fixating the repositioned jawbones with screws and plates, the quality of the bone at the implantation sites is clinically significant. The bone thickness in these regions affects the number of screws and plates required, the success rate of the surgery, and postoperative stability. Therefore, this study focused on the nasomaxillary and zygomaticomaxillary regions, where screws and plates are most commonly inserted during Le Fort I osteotomy, providing clinical preoperative assessment data and reference samples for orthognathic surgery. This study identified the areas with the best bone thickness and elucidated the distribution and trends of bone thickness in the nasomaxillary and zygomaticomaxillary regions across different genders and age groups. Clinically, this information can guide the placement of screws and plates in the most optimal locations, ensuring ideal stability with a reasonable number of screws and achieving the best fixation effect by selecting appropriate screw lengths.

This study has some limitations. The fixation effect and stability in orthognathic surgery are closely related to the patient's bone quality, thickness, and density. However, this study only discusses maxillary bone thickness across different genders and age groups. Future research could further investigate the density of the maxilla. Moreover, because most patients receiving orthognathic surgery are young adults, this study focused on individuals aged 20–25 years, with patients more than 30 years old being grouped together in a single age group. This uneven sample distribution may have led to statistical errors. Future studies could include more late adult and middle-aged samples and regroup them by age to facilitate further discussion. Lastly, the findings of this study may not be generalizable outside the Taiwanese population.

This study presents the following conclusions: (1) In the nasomaxillary region, the vertical distribution of cortical thickness is characterized by thicker on the superior and inferior ends and thinner in the middle due to the presence of maxillary sinuses. Horizontally, the bone thickness decreases from the distal to the mesial region, a trend related to variations in occlusal forces at different tooth positions. (2) In the zygomaticomaxillary region, cortical thickness increases in the vertical direction from the alveolus toward the zygoma, suggesting the closer to the zygomatic bone is more suitable for the placement of screws and plates. Horizontally, bone thickness increases from the mesial to the distal region, a pattern influenced by differences in occlusal forces at various tooth positions. (3) The average cortical bone thickness in the nasomaxillary region is significantly greater in men than in women, attributed to the higher maximum occlusal force in men. In the zygomaticomaxillary region, the difference in average cortical bone thickness between men and women is minimal and nonsignificant. (4) In the nasomaxillary region, early young adults (20–25 years) and late young adults (26–30 years) exhibit thicker cortical bone compared with middle-aged adults (30–60 years). In the zygomaticomaxillary region, thicker horizontal cortical bones were observed in early young adults (20–25 years). However, vertical thickness distribution showed no statistical differences among the three age groups. The clinical guidance from this study, the surgeons using screw length of more than 5 mm for fixation of routine Le Fort I osteotomy would be meaningless. In comparison, companies manufacturing osteosynthesis hardwares are strongly advised to offer options of screw length less than 5 mm.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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