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The effect of masseter muscle strength on mandibular cortical bone thickness

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ABSTRACT

Objectives: The purpose of this study is to see the effect of the strength of the masticatory muscle (masseter muscle) on the thickness of the mandibular cortical bone.

Materials and Methods: The method of this study is a correlational research design. Sampling was conducted using a consecutive sampling method with a population of 50 patients aged 20-44 years at RSGM Maranatha Bandung who had panoramic radiography according to the inclusion and exclusion criteria during the period of March to May 2024.

Results: The results of this study involving 50 patients demonstrated a statistically significant correlation between masseter muscle strength and mandibular cortical bone thickness, with a correlation value of 35.16%. Based on the Pearson correlation test, the correlation coefficient was r = 0.593, indicating a moderate positive association. The maximum value of masseter muscle strength was 1.283 millivolts, while the minimum value was 0.00005 millivolts. The maximum mandibular cortical bone thickness value was 0.43, and the minimum value was 0.21.

Conclusion: This study shows that there is an effect of masseter muscle strength on mandibular cortical bone thickness.

Keywords: *Masseter muscle, mandibular cortical bone, surface electromyography, panoramic radiography*
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INTRODUCTION

The masticatory system is a functional unit composed of the neuromuscular system, teeth, temporomandibular joints, maxilla, mandible, tongue, and muscles that support chewing either directly or indirectly, along with blood vessels and nerves as supporting tissues.[1] The chewing process generates chewing force, which serves as an indicator of the functional state of the muscle and jaw activity.[2,3] The magnitude of chewing force varies among individuals.[4] The average maximum human chewing force ranges from 445 to 850 Newtons. Differences in chewing strength among individuals can be influenced by several factors, including craniofacial morphology abnormalities, abnormal anatomy, masticatory muscle strength, gender, age, and food consistency.[5] The human chewing process involves four muscles: the masseter, temporalis, medial pterygoid, and lateral pterygoid muscles.[1,3]

The masseter is the strongest and largest muscle, playing the most significant role in the chewing process.[6] The physiological function or activity of the masseter muscle during chewing can be evaluated using surface Electromyogram (sEMG).[6,7] sEMG is an instrument used to measure the electrical potential generated by muscle activity by placing electrodes near the muscle area on the skin surface without invasive methods. The mandible functions as the attachment site for the teeth. It can move downward and upward, as seen when opening and closing the mouth, and it can also move forward, backward, and side to side during the chewing process.[8] The mandible is innervated by the mandibular nerve, the inferior mandibular nerve, the mental nerve, and the inferior dental plexus. The vascularization system of the mandible is supplied by the internal maxillary artery, the inferior mandibular artery, and the mental artery.[9] The muscles that support the mandible are the masticatory muscles, including the masseter muscle, the medial and lateral pterygoid muscles, and the temporalis muscle.[3,10]

Before the development of panoramic radiography, conventional radiographic techniques had been used in dental radiography since the discovery of X-rays.[11,12] Digital images are created using analog-to-digital conversion (ADC).[13] First, small voltage values in the signal are grouped into a single value. Second, each sampled signal is assigned a numerical value and stored on a computer.[14] Finally, the computer arranges the pixels in their correct positions and displays a grayscale image based on the assigned values, which is then shown on the computer screen.[11] Two-dimensional and three-dimensional digital imaging modalities have been developed to aid in dentomaxillofacial diagnosis, treatment planning, and various clinical applications.[15,16] However, panoramic radiography has now become the most widely used diagnostic tool in dentistry.[17] Panoramic radiography produces an image of facial structures, including the maxillary and mandibular arches, as well as their supporting structures.[18,19] Panoramic radiography serves many purposes, one of which is diagnosing the jawbones, both maxilla and mandible, and evaluating their development.[20]

Panoramic radiography has several quality rating criteria for the images it produces, namely excellent, diagnostically acceptable,[19] and unacceptable.[21] The advantages of panoramic radiographic imaging include its ability to detect jaw fractures, the position of third molars, dental diseases, large lesions, tooth development and eruption (especially in mixed dentition), impacted teeth and root remnants, and to evaluate patients with temporomandibular joint pain. It also offers low radiation exposure and a relatively short imaging time (3–4 minutes) and is particularly helpful for patients who cannot tolerate intraoral procedures well.[11,22] However, the disadvantages of panoramic radiography include its inability to show detailed anatomical structures and its limitation in detecting small carious lesions.[11,23]

Bone-forming cells consist of osteoclasts, which, in dense cortical bone, after the resorption process is complete, divide into mononuclear cells that can be activated into new osteoclasts.[29,31] Osteoblasts have three developmental pathways: they can become quiescent bone cells, be surrounded by the matrix they produce, and become bone cells, or disappear from the site of bone formation due to bone resorption.[29] Osteocytes play a role in calcium and phosphate metabolism in response to stimuli such as parathyroid hormone (PTH), calcitonin, as well as mechanical and electrical stimulation.[8,10]

The condition of the bone can be assessed through its quality, particularly the state of the cortical bone as seen on a panoramic image.[17] Several measurements can be used to evaluate mandibular cortical thickness in panoramic radiography, including the Mandibular Cortical Index (MCI), Mental Index (MI), Panoramic Mandibular Index (PMI), and Gonion Antegonial Index.[17,24] In this study, the Panoramic Mandibular Index (PMI) is used. The PMI is a measurement expressed as the ratio between the thickness of the inferior mandibular cortex in the mental region and the distance from the lower border of the mandible to the lower border of the mental foramen.[17]

Decreased muscle activity and bone quality can lead to imbalances in the masticatory system.[25] A study by Tamut T et al. in 2012 found that high chewing efficiency correlates with high bone density, with the highest efficiency observed predominantly in males.[25] Research by Rizqullah et al. in 2016 showed that Pawon humans had higher cortical bone thickness than modern humans, likely due to consuming harder-textured foods, which placed greater chewing stress on the mandible compared to modern humans.[26] Another study by Fujita Y and Maki K in 2018, conducted through an in-vivo trial on Wistar rats with a soft diet, demonstrated inhibited cortical bone growth in the mandible.[27]

The study population consisted of panoramic radiographs from patients aged 20-44, based on the young adult age range defined by the World Health Organization.[28] Bone growth and development in young adulthood are characterized by peak bone mass and density, so cortical bone thickness does not undergo significant changes due to age. The researchers are interested in investigating whether there is a relationship between the masticatory muscle strength generated by the masseter muscle and mandibular cortical bone thickness.[17]

MATERIALS AND METHODS

This study used a correlational research design with a cross-sectional approach, where data were collected within a specific time frame. The purpose of this study was to determine the effect of masseter muscle strength on mandibular cortical bone thickness using panoramic radiography. The sample consisted of 39 individuals, obtained from patients with panoramic radiograph data at Maranatha Dental and Oral Hospital, Bandung, West Java. Samples were selected based on predetermined inclusion and exclusion criteria.

The inclusion criteria included patients who had agreed to informed consent, had high-quality panoramic radiographs with clearly visible foramen mentale and cortical bone, had a minimum of 28 teeth[4], were aged 20-44 years[29], had no loose teeth[30], and had completed dental treatments such as orthodontics or root canal therapy.[31] The exclusion criteria included patients with a history of mandibular fractures32, those undergoing orthodontic treatment[31,33], patients with parafunctional habits such as bruxism (characterized by occlusal wear on more than 4 posterior teeth)[14], and patients with sensitivity to electrodes. The sampling technique used was consecutive sampling.[34]

The tools used in this study include stationery such as pencils, pens, and paper, as well as a laptop to view radiographic data in softcopy format (.jpg extension) and other data. Detection tools that can be used to see muscle contraction activity in the chewing process in dentistry include Surface Electromyography, Iowa Oral Performance Instrument (IOPI), and Mechanomyography (MMG).[35,36] Surface Electromyogram (sEMG) as a tool used in this study from BIOPAC Systems, Inc., Excel Megastat Ver. 10.6 (2017) software, stopwatch, and AutoCAD software. The materials used include gloves, tissues, alcohol wipes, masks, 5 cm diameter electrode patches, and panoramic radiographic data from patients.

The study population consisted of individuals and digital panoramic radiographic data that met the inclusion criteria from March to May 2024 at Maranatha Dental and Oral Hospital in Bandung. Data processing involved calculating sEMG recordings and panoramic data from the research subjects. Data analysis was performed using Pearson correlation tests for normally distributed data and Spearman correlation tests for non-normally distributed data. Correlation tests were used to determine the significance of the relationship between two variables, and further testing was conducted using t-tests. All data results were presented in table format.

Figure 1. Surface Electromyogram BIOPAC System, Inc. (personal documentation)

Figure 2. Electrode placement on the superficial masseter muscle. (personal documentation). The measurement involves placing electrodes on the skin surface, directly over the muscle to be detected. The electrodes were placed over the masseter muscle at the origin, defined by the posterior border of the zygomatic bone, aligned with the ear, and at the insertion, located at the anterosuperior border of the mandibular angle. One reference electrode was positioned on the sternocleidomastoid muscle.[36] A common signal capture test performed during maximum voluntary contraction involves recording the patient by clenching the teeth as hard as possible for 5-10 seconds.[33] sEMG consists of several components, including patch electrodes, connecting cables, a Biopac device, and a computer[31,37] Masseter muscle strength can be quantitatively assessed using an interval scale obtained through a surface EMG device prototype. The measurements are expressed in terms of signal amplitude and subsequently converted into millivolts (mV).[38,39]

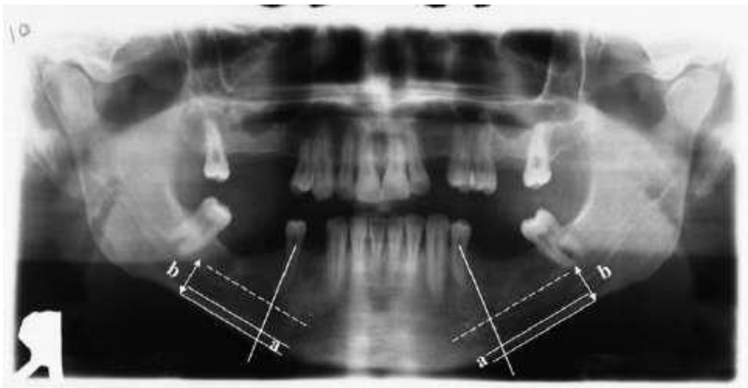

Figure 3. Electrode Panoramic Mandibular Index (a/b) Measurement[28] The measurement was calculated as the ratio of the height of the inferior mandibular cortex (b) to the vertical distance between the inferior border of the mandible and the inferior border of the mental foramen (a).[17]

RESULTS

The study was conducted on 50 subjects who underwent panoramic radiography at Maranatha Christian University Dental and Oral Hospital in Bandung, West Java, during the 2024 period. Subject selection was carried out using a consecutive sampling technique based on the inclusion and exclusion criteria. The age distribution of the study subjects used was young adults aged 20-44 years, according to the World Health Organization, as shown in Table 1.

Table 1. Frequency Distribution of Age in the Study Based on WHO Classification

Age (years)		Frequency	Percentage (%)
Young Adulthood	20-25	22	44
	26-31	12	24
	32-37	11	22
	38-44	5	10
Total		50	100

The distribution of study subjects based on gender shows that 54% were male and 46% were female, as presented in Table 2.

Table 2. Distribution of Study Subjects Based on Gender

Gender	Amount	Percentage (%)
Male	27	54
Female	23	46
Total	50	100

This study involved 50 young adult subjects aged 20-44 years from March to May 2024, who had panoramic radiographic images and integrated medical records that met the inclusion and exclusion criteria. The proportion of male subjects was 54%, higher than the 46% female subjects in the total sample.

The results showed that the minimum masseter muscle strength during maximal biting in male subjects was 0.00015 millivolts, with a maximum value of 1.28326 millivolts. In female subjects, the minimum masseter muscle strength during maximal biting was 0.00005 millivolts, and the maximum value was 1.14434 millivolts (Appendix 6).

The measurement results for mandibular cortical bone thickness from panoramic radiographs showed a minimum thickness of 0.22 millivolts and a maximum of 0.43 millivolts in male subjects. In female subjects, the minimum thickness was 0.21 millivolts, and the maximum was 0.42 millivolts (Appendix 6).

The study was conducted by measuring masseter muscle strength during maximal biting for 5 seconds using a surface electromyography device and measuring mandibular cortical bone thickness from digital panoramic radiographic data. The analysis included correlation and validity tests to determine the effect of masseter muscle strength on mandibular cortical bone thickness at Maranatha Dental and Oral Hospital in Bandung. The correlation analysis was conducted to assess the extent of the influence of masticatory muscle (masseter muscle) strength on mandibular cortical bone thickness, as shown in Table 3.

The effect of masticatory muscle (masseter muscle) strength on mandibular cortical bone thickness was analyzed using Pearson correlation, with an r-value of 0.593, as indicated in Table 3.

Table 3. Results of the Effect of Masticatory Muscle (Masseter Muscle) Strength on Mandibular Cortical Bone Thickness Using the Pearson Correlation Test

Maximum Muscle Strength Value	*Milivolt*	Mandibular Cortical Bone Thickness
Masseter	1,000	
Mandibular Cortical Thickness	(0,593)	1,000

The r-value of 0.593 in this study indicates a strong correlation between masseter muscle strength and mandibular cortical bone thickness. The positive correlation (r) value suggests that as the strength of the masticatory muscle (masseter muscle) increases, the thickness of the mandibular cortical bone also increases.

Table 4. Classification of r-Values Based on Pearson Correlation Test[27]

r-Value	Interpretation
0,00 – 0,25	No relationship or weak relationship
0,26 – 0,50	Moderate relationship
0,51 – 0,75	Strong relationship
0,76 – 1,00	Very strong relationship

Based on Table 4, the calculation of the coefficient using the Pearson correlation test to assess the correlation level in the calibration results shows a strong relationship between masticatory muscle strength (masseter muscle) and mandibular cortical bone thickness, with a correlation coefficient value of 0.593.

Based on the results of the correlation test on the effect of masticatory muscle strength (masseter muscle) on mandibular cortical bone thickness, it can be concluded that the null hypothesis (H0: p = 0) states there is no effect between masticatory muscle strength (masseter muscle) and mandibular cortical bone thickness, and the alternative hypothesis (H1: p ≠ 0) states there is an effect between masticatory muscle strength (masseter muscle) and mandibular cortical bone thickness.

The above hypothesis is tested using the t-statistic test, and the r-value from the Pearson correlation analysis is used to calculate the t-value. The hypothesis is tested using the following formula:

$$t = \frac{r \sqrt{n-2}}{\sqrt{1-r^2}} \sim t_{\alpha/2, n-2\ d.f}$$

Table 5. Results of Hypothesis Test on the Effect of Masticatory Muscle Strength (Masseter Muscle) on Mandibular Cortical Bone Thickness

Variable	*r*	*t-test*	*p-value*	Nature	Correlation	Note
Masseter Muscle Strength and Mandibular Cortical Bone Thickness	0,593	5,10	0,0000	**Significant**	35,16	**Related**

Note: The p-value = 0.0000 < 0.05 indicates a significant relationship.

Based on Table 5, the t-test results show a 35.16% correlation between masticatory muscle strength (masseter muscle) and mandibular cortical bone thickness, which is statistically significant, with a p-value of 0.0000028, indicating that this value is smaller than 0.05. It can be concluded that there is a significant correlation between the effect of masticatory muscle strength (masseter muscle) and mandibular cortical bone thickness. Therefore, the results of this study support the research hypothesis, indicating that there is an effect of masticatory muscle strength (masseter muscle) on mandibular cortical bone thickness.

DISCUSSION

Based on Table 2, the distribution of male subjects is higher than that of female subjects, which is consistent with a study by Kintara in 2022, showing that panoramic and periapical radiography exams were more common in males, with 54.4%.[40] A study by Yunus B et al., in 2020, found that in terms of gender, there were more panoramic data of patients with complete teeth in males (67.5%) compared to females (32.5%).[41]

The sample of this study consisted of young adults aged 20-44 years, according to the World Health Organization.[29] Bone growth and development in adults occur during the peak period of bone mass, resulting in minimal changes in cortical bone thickness due to age.[43] This is supported by data from the Indonesian Ministry of Health in 2022, which found a prevalence of 62% in the age range of 24-35 years.[44] This is further supported by research by Lima KF et al., in 2020, stating that mandibular cortical thickness reaches its maximum growth between the ages of 20 and 40, which can be considered a normal condition.[45]

The study results show that the minimal masseter muscle strength during maximal biting for male subjects was 0.00015 millivolts, with the maximum value reaching 1.28326 millivolts. For female subjects, the minimal value was 0.00005 millivolts, with the maximum value of 1.14434 millivolts. This indicates that the masseter muscle strength in male subjects is higher than in female subjects. This is consistent with Edmonds H's study in 2020, which indicated that adult males have a higher average maximum bite force compared to females.[46] This study is also in line with research by Palinkas M in 2014, which showed that men had about 30% higher chewing muscle strength than women, attributed to the greater muscle mass and testosterone hormone levels in men, resulting in greater bite force.[47]

Several subjects in the study showed both minimal and maximum values of chewing muscle strength (masseter muscle) that tended to be low. Several factors, such as food texture, age, and gender, may influence this. A study by Cladas in 2017 stated that the texture of hard foods increases chewing load, leading to increased muscle activity and, consequently, stronger chewing muscles.[26,39] This finding is in line with research by Rahmadanti B et al., in 2021, which indicated that continuous one-sided chewing increases EMG activity in the chewed side and reduces activity in the non-chewed side.[48] Other research also shows that decreased chewing function can affect chewing muscles, size, and bone mass.[49] Age is another influencing factor, as shown in research by Johnson B in 2016, which found that maximum bite strength increases with age from 25 years onwards and remains constant in younger individuals aged 20 to 40 years, with a decrease in bite strength after 45 years.[50] Reduced masticatory muscle strength has been associated with structural alterations of the mandible, particularly in the inferior cortical region. Experimental studies have demonstrated that atrophy of masticatory muscles, such as the masseter and temporalis, leads to a decrease in cortical thickness and bone density, as observed through three-dimensional radiographic imaging.[51] The underlying mechanism involves a reduction in occlusal force due to decreased muscle activity, which subsequently diminishes mechanical loading on the mandibular bone. This reduction in functional stimulus results in decreased osteoblastic activity and increased bone resorption, ultimately leading to thinning of the inferior mandibular cortex.[51] These findings suggest that masticatory muscle strength plays a crucial role in maintaining mandibular structural integrity, and its reduction may contribute to decreased bone quality, particularly in individuals with additional risk factors such as aging and systemic conditions.[51]

This study had subjects with a minimum of 28 teeth, particularly posterior teeth, in line with research by Choi et al. (2023, which stated that the number of functional tooth units is a major determinant of chewing performance. Maximum chewing force measurements help assess the energy produced by the elevator muscles during activity.[12] Chewing is the activity of mechanically destroying food that occurs in the oral cavity, assisted by the activity of attached muscles.[52]

Based on the research results in Appendix 6, the average cortical bone thickness in male subjects was 0.33, while in female subjects, it was 0.31. The average cortical bone thickness was greater in males than in females, which is consistent with research by Goyushov S in 2020, which stated that mandibular cortical thickness indices are greater in males than in females.[53]

The average results for the left and right sides of cortical mandibular thickness in this study were 0.33, obtained through panoramic radiography measurements. Panoramic radiography can be used as one of the methods for measuring cortical mandibular bone thickness, supported by research by Barunawaty Y in 2020, which stated that panoramic radiography has better technical quality compared to cephalometry.[54]

Data analysis between chewing muscle strength (masseter muscle) and mandibular cortical bone thickness was performed using Pearson's correlation test to determine if there is any correlation. Based on the Pearson correlation test results, an r value of 0.593 was obtained with 50 samples, indicating that there is a correlation between chewing muscle strength (masseter muscle) and mandibular cortical bone thickness. The positive r value (+) indicates a linear correlation, meaning that as masseter muscle strength increases, the cortical mandibular bone thickness also increases. The data was then tested using a t-test to statistically determine if there is a significant correlation between chewing muscle strength (masseter muscle) and mandibular cortical bone thickness.[55]

The results of the t-test indicated a 35.16% correlation that is statistically significant, as shown in Table 5. The p-value of 0.0000, which is smaller than 0.05, indicates that the null hypothesis (H0) is rejected, and the results are statistically significant. This study shows that the cortical mandibular bone thickness is consistent with the function of the force exerted by the chewing muscle (masseter muscle). This study has several limitations. The assessment was limited to a single measurement of the masseter muscle. The measurements were performed only once during the study period, which may not fully represent variations in muscle activity over time. Another limitation lies in the use of surface electromyography (sEMG), in which electrodes are placed on the skin, potentially reducing the accuracy of deep muscle activity assessment. Further studies are required to better elucidate and strengthen the evidence regarding the influence of masticatory muscle activity on mandibular cortical bone thickness.

CONCLUSION

Based on the research results and discussion, it can be concluded that there is an effect of masseter muscle strength on the thickness of the mandibular cortical bone. Some of the benefits of this research from the theoretical aspect are providing information about the magnitude of the influence produced by the masseter muscle strength on the quality of the mandibular cortical bone thickness, providing knowledge to students about the differences in the values produced by the masseter muscle strength in each individual in the masticatory system and as a guideline for further research related to the masticatory system and bone quality in the human jaw. From the practical aspect, it is hoped that this research can be a guide for dentists as a prevention of temporomandibular disorders based on cortical bone thickness and become a reference for a significant relationship between the masseter muscle-mandibular cortical bone relationship that can change the morphology of the jaw shape in the field of dentistry in Indonesia.

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FOOTNOTES

All authors have no potential conflicts of interest to declare for this article.

Ethical approval for this study has been obtained, and all procedures followed are in accordance with the ethical standards set by the responsible committees, both institutional and national. The ethical approval letter number is 063/KEP/V/2024.

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