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Original Research Article

Evaluation of the Role of the Bonwill Triangle in Temporomandibular Disorders: A Retrospective Analysis

Temporomandibular Bozukluklarda Bonwill Üçgeninin Rolünün Değerlendirilmesi: Retrospektif Analiz

Kübra Öztürk[1], Hikmetnur Danışman[2], Rıdvan Akyol[3]

ABSTRACT

Aim: The aim of this study was to evaluate the role of the Bonwill triangle in temporomandibular disorders (TMDs).

Materials and Method: This study was conducted using 1880 cone beam computed tomography (CBCT) images obtained from the Department of Oral, Dental, and Maxillofacial Radiology Clinic at Nuh Naci Yazgan University Faculty of Dentistry between June 2020 and February 2024.

Results: A total of 154 patients were included in the study, with ages ranging from 18 to 45 years (mean age: 24.9 ± 5.8 years). Of these, 70 were male (45.5%), and 84 were female(63.0%). The control and TMD groups each comprised 77 patients. In the analyses, no statistically significant difference in the measurements examined was found between the TMD and control groups ($p > 0.05$). In males, the distance between the center of the right condyle and the center of the right mandible (IC-R) was found to be significantly higher compared to females ($p < 0.001$). Similarly, the distance between the center of the left condyle and the center of the left mandible (IC-L) was found to be significantly higher in males than in females ($p < 0.001$). Additionally, the intercondylar distance measurement was found to be significantly higher in males compared to females($p < 0.001$). However, there was no statistically significant difference in the IC-R (right and left) and intercondylar distance measurement between the control and TMD groups ($p > 0.05$).

Conclusion: Limited information exists in the literature about the impact of the Bonwill triangle on TMD. Our findings suggested that TMD did not have a significant effect on these anatomical features. However, gender was found to have a significant effect. These results underscore the need for further research to develop a more comprehensive understanding of the pathophysiology of and treatment strategies for TMD.

Keywords: Cone beam computed tomography; Dental occlusion; Temporomandibular joint disorder

ÖZET

Amaç: Bu çalışmanın amacı, Bonwill üçgeninin temporomandibular bozukluklar (TMB) üzerindeki etkisini değerlendirmektir.

Gereç ve Yöntem: Nuh Naci Yazgan Üniversitesi Diş Hekimliği Fakültesi'nde Haziran 2020 ile Şubat 2024 tarihleri arasında elde edilen 1880 konik ışın bilgisayarlı tomografi (KIBT) görüntüsü kullanılarak bu çalışma yürütülmüştür.

Bulgular: Çalışmada, toplam 154 hasta incelenmiştir, yaşları 18 ila 45 arasında değişmekte olup ortalama yaşları 24.9 ± 5.8'dir. Bu hastaların 70'i erkek (%45.5) ve 97'si kadındır (%63.0). Kontrol grubunda 77 hasta bulunurken, TMD tanısı alan grubunda da 77 hasta bulunmaktadır. Yapılan analizlerde, TMD grubu ile kontrol grubu arasında incelenen ölçümlerde istatistiksel olarak anlamlı bir farklılık bulunmamıştır ($p > 0.05$). Erkeklerde, sağ kondilin merkezi ile sağ mandibular merkez arasındaki mesafe (IC-S) kadınlara göre istatistiksel olarak anlamlı derecede yüksektir ($p < 0.001$). Benzer şekilde, sol kondilin merkezi ile sol mandibular merkez arasındaki mesafe (IC-S) erkeklerde kadınlara göre anlamlı derecede yüksektir ($p < 0.001$). Ayrıca, interkondiler mesafe ölçümü erkeklerde kadınlara göre anlamlı derecede yüksektir ($p < 0.001$). Kontrol grubu ile TMD grubu arasında ise IC-S (sağ ve sol) ve interkondiler mesafe ölçümlerinde istatistiksel olarak anlamlı bir farklılık bulunmamıştır ($p > 0.05$)

Sonuç: Bonwill üçgeninin TMD üzerindeki etkisi hakkında literatürde sınırlı bilgi bulunmaktadır. Bu çalışmanın sonuçları, TMD'nin bu anatomik özellikler üzerinde belirgin bir etkisi olmadığını göstermektedir. Ancak cinsiyetin bu ölçümler üzerinde belirgin bir etkisi olduğu bulunmuştur. Bu bulgular, TMD'nin patofizyolojisi ve tedavi stratejileri üzerine daha derinlemesine bir anlayış geliştirmek için daha fazla araştırmanın gerekliliğini vurgulamaktadır.

Anahtar Kelimeler: Diş oklüzyonu; Konik ışınlı bilgisayarlı tomografi; Temporomandibular eklem bozuklukları

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İletişim: Dr. Kübra Öztürk
Ertuğrul Gazi Mah. Kuzey Çevre Yolu Nuh Naci Yazgan Üniversitesi Yerleşkesi Diş Hekimliği Fakültesi 38170 Kocasinan Kayseri, Türkiye
E-mail: kbrozturk89@gmail.com, kozturk@nny.edu.tr
[1] Assoc. Prof., Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Nuh Naci Yazgan University, Kayseri, Türkiye
[2] Asst. Prof., Department of Orthodontics, Faculty of Dentistry, Nuh Naci Yazgan University, Kayseri, Türkiye
[3] Asst. Prof., Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Nuh Naci Yazgan University, Kayseri, Türkiye

INTRODUCTION

Temporomandibular dysfunction, also known as temporomandibular joint (TMJ) dysfunction or temporomandibular disorder (TMD), is a common condition affecting individuals of all age groups.[1] It encompasses a range of musculoskeletal conditions that occur in the temporomandibular region that lead to symptoms like pain, clicking, crepitus, and limitations in mandibular movement.[2] TMD presents with headaches, TMJ pain, and other related symptoms.[3] The relationship between the mandible and the skull is crucial in the context of TMD: The mandible plays a significant role in mastication and speech, and any dysfunction in the TMJ can lead to limitations in mandibular movement and orofacial pain.[4] TMD can be influenced by various factors, including parafunctional behaviors like bruxism, which may contribute to tooth wear but may not always have a significant relationship with TMJ dysfunction.[5]

An equilateral triangle, described by the American dentist G. Bonwill in 1858, formed the basis of Bonwill's theory of occlusion. Bonwill created this theory by measuring 6000 skulls and 4000 living individuals.[6] The Bonwill triangle is formed by drawing lines between the mandibular incisors and the right and left mandibular condyles. This equilateral triangle shows that the ideal arch is symmetrical. The distance between the mandibular incisors and condyles, or the distance between the right and left condyles, varies significantly between men and women.[7] The Bonwill triangle has significant effects on complete dentures, dental occlusion, articulation, and mandibular fractures. However, Bonwill's theory is rarely used since it contains a statement about simpler methods to correct problems with the mandible. Specifically, this theory states that the lengths of the teeth are in constant relationship with the other bones of the skull and the entire anatomical structure of the body, as well as the distance of the sides of the triangle.[6]

Proper occlusion is essential for maintaining the stability of the dental arch and distributing functional loads evenly across the TMJ. When there is a correct relationship between the maxillary bone and the jaw, with uniform and simultaneous dental contacts, the jaw gains maximum stability, and the TMJ remains asymptomatic. Conversely, occlusal imbalances can lead to increased loads on TMJ structures, potentially contributing to TMJ disorders.[8]

A literature review revealed that there was no study examining the relationship between occlusion and TMDs through the lens of the Bonwill triangle theory, which forms the basis of occlusion and is recommended for use in assessing mandibular problems. The aim of this study was thus to compare the Bonwill triangles of patients diagnosed with TMDs with those of healthy individuals.

MATERIALS AND METHOD

Sample Selection

This study was conducted using 1880 cone beam computed tomography (CBCT) images obtained from the Department of Oral and Maxillofacial Radiology at the Faculty of Dentistry between June 2020 and February 2024. The Ethics Boards and Commissions approved this work (2024/003-04).

The CBCT images of patients who presented with TMJ complaints and underwent TMJ tomography for further examination, as well as the CBCT records of patients who underwent tomography before third molar surgery, were randomly selected from the records.

The diagnosis of temporomandibular joint dysfunction is determined by oral and maxillofacial surgeons using the DC/TMD diagnostic criteria. The decision to perform tomography is made based on the DC/TMD diagnostic decision tree. In accordance with the inclusion and exclusion criteria of the study, CBCT scans were retrospectively analyzed, and the tomographic images of 154 patients were included in the study.

The inclusion criteria were as follows:

1. Patients had to be aged 18 years or older.
2. Patients had to have undergone TMJ tomography (research group), or they had to have undergone tomography for third molar extraction without TMJ complaints (control group).

Exclusion criteria included:

1. Patients with systemic muscle–joint diseases.
2. Patients with autoimmune disorders.
3. Patients who received radiotherapy to the head and neck region.
4. Patients who had undergone prolonged steroid therapy.

5. Patients who had undergone surgery in any joint of the body.
6. Patients with a history of orthognathic surgery and orthodontic treatment.
7. Patients whose CBCT images obtained for measurements lacked clarity in certain sections.

Acquisition of Images

The same X-ray technician performed all CBCT scans. Standing and biting on the positioning rod, the patient was placed such that their head was in neutral position, their midline was in the middle, and their horizontal plane was parallel to their cantho-meatal plane during the X-ray. To obtain the CBCT images, a 3D digital imaging system (KaVO OP 3D Pro, PaloDEx Group Oy, Tuusula, Finland) with pre-set settings and procedures was utilized. The KaVO OP 3D Pro CBCT tomographic scanner was configured with the following exposure settings applied to the chosen saved images in this investigation: 13 x 15 cm field of view, 90 kV exposure setting, 08 mA exposure duration, 17.5 to 26.9 s exposure period, and 0.320 mm voxel size.

Image Analysis

Image reconstruction and measurement were conducted using Cybermed's OnDemand 3D Imaging software (Seoul, South Korea). In the obtained pictures, 1 mm thick slices were made at the cervical vertebral level and the cranial base.

Determination of the Bonwill Triangle

Measurements were conducted following the methodology that Koothati *et al*.[7] described. Accordingly, the axial sections of the CBCT images were used to evaluate the measurements of the Bonwill triangle as follows: Initially, the distance between the central points of the right and left mandibular condyles (C-LR) were measured in millimeters, following which the distance in millimeters between the contact point (IC) of the mandibular central incisors and the central points (R: Right condyle and L: Left condyle) of each condyle were measured (Figure 1).

C-LR, IC-Right, and IC-Left values were measured for each patient (Figure 2).

Figure 1. Determination of the contact point of mandibular incisors

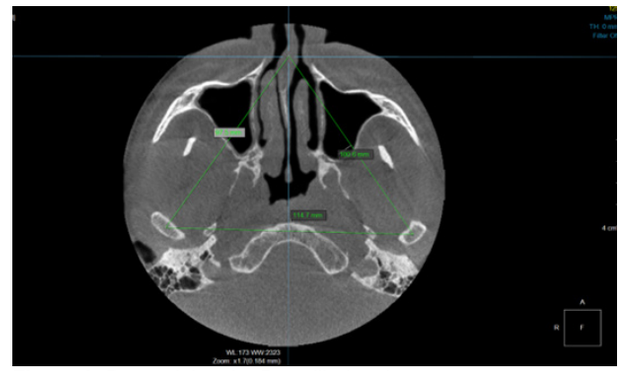

Figure 2. Determining the Bonwill triangle

Statistical Analysis

The ideal sample size was determined using G-Power 3.1.9.7. With an effect size of 0.5 (moderate effect size), a power of 0.90, and an α of 0.05, the sample size was calculated to be 140. Hence, 70 CBCT images were examined for patients with TMJ diagnoses and 70 for patients in the control group.

TURCOSA (Turcosa Analytics Ltd Co, Turkey, www.turcosa.com.tr) online software was used in the statistical evaluation of the data obtained in our research. The existence of a linear relationship between variables was evaluated with Pearson's or Spearman's correlation test, depending on the distribution feature of the variable. Student's t-test was used to evaluate the data in the TMD and control groups. For the analyses, the statistical significance level was acceptable at $p < 0.05$.

RESULTS

Upon conducting an archive search, 90 TMJ CBCT images for the diagnosis of TMD were obtained.

After examining the data, 13 cases with TMJ were excluded from the study due to poor CBCT image

quality in the relevant sections. Subsequently, the records of 77 patients were selected for the TMD group, and the records of another 77 patients were chosen for the control group, and included in data analysis.

The study included a total of 154 patients, with ages ranging from 18 to 45 years and a mean age of 24.9 ± 5.8 years. Of these, 70 were male (mean age 23.8 ± 5.7), and 84 were female (mean age 25.5 ± 5.7), whose CBCT images were included for analysis (Table 1).

Analysis of the IC-Right measurement revealed that the mean value for males (97.1 ± 6) was significantly higher than that for females (91.7 ± 4.7) ($p < 0.001$). Similarly, for the IC-Left measurement, males exhibited a significantly higher mean value (96.2 ± 6.8) than females (91.7 ± 4.8) ($p < 0.001$). Additionally, an analysis of the intercondylar distance measurement showed that the mean value for males (103 ± 6.5) was significantly higher than for females (98.6 ± 5.6) ($p < 0.001$). (Table 2)

However, no statistically significant differences were found in the IC-Right ($p = 0.784$), IC-Left ($p = 0.307$), and intercondylar distance measurements ($p= 0.632$) between the control and TMD groups (Table 3).

Table 1. Descriptive statistics and frequencies of the group of patients with temporomandibular disease and the control group in terms of age and gender

		Control (n=77)	TMD (n=77)	Total (n=154)
Age	Mean ± SD	23.7 ± 4.1	26.1 ± 6.9	24.9 ± 5.8
Gender				
Male	n (%)	34 (48.6)	36 (51.5)	70 (45.4)
Female	n (%)	43 (51.2)	41 (48.8)	84 (54.6)

n: Number of patients, TMD: Temporomandibular disorder, SD: Standard deviation

Table 2. Evaluation of measurement values according to gender

		Male (n=70)	Female (n=84)	p[a]
IC-Right	Mean ± SD	97.1 ± 6	91.7 ± 4.7	**<0.001***
IC-Left	Mean ± SD	96.2 ± 6.8	91.7 ± 4.8	**<0.001***
ID	Mean ± SD	103 ± 6.5	98.6 ± 5.6	**<0.001***

n: Number of patients, SD: Standard deviation, IC-Right: Distance between incisal edge and right condyle center, IC-Left: Distance between incisal edge and left condyle center, ID: Intercondylar distance, [a]: Student-t test, *: $p<0.05$

Table 3. Comparison of measurement values of patients with temporomandibular disease and the control group

		Control (n=77)	TMD (n=77)	p[a]
IC-Right	Mean ± SD	94 ± 6.6	94.3 ± 5.3	0.78
IC-Left	Mean ± SD	93.9 ± 6.5	93.6 ± 5.9	0.76
ID	Mean ± SD	100.9 ± 6.3	100.4 ± 6.5	0.63

n: Number of patients, TMD: Temporomandibular disorder, SD: Standard deviation, IC-Right: Distance between incisal edge and right condyle center, IC-Left: Distance between incisal edge and left condyle center, ID: Intercondylar distance, [a]: Student-t test

DISCUSSION

The aim of this study was to investigate the relationship between occlusion and TMDs through the lens of Bonwill's triangle theory, which serves as the basis for understanding occlusal harmony and mandibular function. Using CBCT images, we compared the Bonwill triangle measurements of patients diagnosed with TMD with those of healthy individuals. Herewith, we aimed to provide insights into the potential association between occlusal parameters and TMDs, clarifying diagnostic and treatment approaches in clinical practice.

The Bonwill triangle's height-to-base ratio reflects the symmetry of the mandible's left and right sides. Bilateral symmetry not only aids in aesthetic, expressive, linguistic, and masticatory oral functions but also helps maintain the stability and health of the entire oral and jaw system by equalizing the stress on the muscles and joints of both sides.[9]

The Bonwill triangle has been evaluated for various purposes related to medicine and dentistry, including gender determination, sex identification in forensic dentistry, anthropological studies, bone grafts, and the evaluation of mandibular fractures.[7,10,11] The triangle has been particularly useful in providing geometric parameters for fractured mandibles and dental procedures.[11] Additionally, research has focused on using Bonwill triangle parameters to determine biological sex via CBCT [7], while it has also been employed to assess occlusal vertical dimension changes in dental articulation studies.[12] In the field of dentistry, the Bonwill–Hawley method has been used for dental crowding measurements, demonstrating its applicability in orthodontic assessments.[13]

Reviewing the literature revealed that an assessment of the Bonwill triangle has been applied in various medical and dental areas; however, the relationship between the Bonwill triangle and TMD has not been explored sufficiently. Therefore, our study aimed to compare the Bonwill triangles of patients diagnosed with TMD and those of patients without TMJ complaints.

When reviewing much older studies, it was determined that the height of the Bonwill triangle is not affected by the selection of condylar reference points.[14] Additionally, research on the impact of the Bonwill triangle on complete dentures has highlighted its significance in prosthetic applications.[15] Based on this information, it has been speculated that the Bonwill triangle may influence TMD in terms of occlusal stability.[16-20]

Our study results showed that there was no statistically significant difference in the anatomical measurements examined between the control group and the TMD group. These results indicate that these measurements were similar between both groups and that TMD did not have a significant effect on these anatomical features.

Ganesh and Mohanraj[6] reported the IC-right distance as 97.8±2.8, IC-left distance as 98.6±3.8, and intercondylar distance as 97.4±3.4 in the measurements they took on 60 dry human mandibles. In this study, we found the IC-right distance as 94.3±5.3, IV-left distance as 93.6±5.9, and intercondylar distance as 100.4±6.5 in patients with TMD. In the control group, we found the IC-right distance as 94±6.6, IV-left distance as 93.9±6.5, and intercondylar distance as 100.9±6.3. Although there was no statistical difference between these two groups in our study, it differs from the results of the study by Ganesh and Mohanraj. Our study has the advantage of providing a comparison between groups such as gender and joint diseases, however, since it is a radiological study, the image distortion factor is not eliminated and therefore it has a disadvantage compared to the one-to-one measurement obtained from the dry human mandible.

Stamm *et al*.[21] made a comparison between skeletal class I, class II and class III patients on radiological data by taking the Bonwill triangle as a reference and found the distance of the incisors to the condyle center as 105.4 ± 5.7 in the Class I group, 92.1 ± 5.3 in the Class II group and 92.9 ± 5.9 in the Class III group. Ye *et al*.[9] made a comparison between individuals with low, medium and high facial profiles by calculating the ratio of the Bonwill triangle to the intercondylar distance correction on radiological images and reached an evaluation regarding occlusion. Since our study was retrospective, we did not have information about the soft tissue profile of the patients. Therefore, we could not make a comparison between the groups according to their facial profiles.

These findings are important for clinical practice and treatment strategies since they can aid in developing a more in-depth understanding of the etiology and treatment of TMD.

Our study results, in line with the literature, show that gender has a decisive effect on these two measurements [11], as well as on joint space measurements.

The primary limitation of our study is the retrospective evaluation of the data. Additionally, multicenter prospective clinical studies are required to generalize the study findings to the broader population.

CONCLUSION

While there is literature providing crucial insights into the impact of gender on anatomical measurements and has underscored the importance of considering gender-based differences in treatment strategies, there is a scarcity of research specifically addressing the Bonwill triangle in TMDs. Some studies have explored the relationship between occlusion and TMD, but the significance of the Bonwill triangle within this context remains relatively unexplored. Existing literature on occlusion and TMD presents conflicting views on the role of dental occlusion as an etiological factor in TMD. Further research is needed to elucidate the role of the Bonwill triangle in TMD pathogenesis and its potential implications for treatment approaches so that more tailored interventions can be formulated for individuals with TMD.

Conflicts of Interest Statement

There is no conflict of interest to declare.

Data Availability Statement

The datasets created and analyzed during the current study are available from the corresponding author upon request.

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