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Volumetric Assessment of TMJ Spaces and Its Correlation with the Age and Gender of The Patient. A Retrospective Cone Beam Computed Tomographic Study.

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KEYWORDS

Vitamin D deficiency, socioeconomic status, pregnancy, maternal nutrition.

ABSTRACT:

Background: Cone-beam computed tomography (CBCT) enables the three-dimensional assessment of TMJ spaces, which can enhance our understanding of the pathophysiological changes that impact the TMJ spaces throughout various stages of growth.

Objectives: Evaluation of volume of temporomandibular joint space across gender and various age groups.

Method: A retrospective analysis of CBCT scans from 64 patients (128 TMJ spaces) was carried out using a semiautomatic segmentation technique with the "ITK-Snap" program. The total and the mean TMJ space volume was then calculated according to age group, gender, and laterality.

Results: The right total TMJ space volume was found to be significantly larger than the left irrespective of gender and age groups. Males had a larger TMJ space volume than females but the differences were not statistically significant. The volume of the total TMJ spaces was highly significant in 51-60 years of age compared to all other age groups.

Conclusion: An accurate assessment of TMJ space volumes using CBCT can lead to early diagnosis for TMJ disorders related to malocclusions, trauma, or remodelling. The collected data could be of clinical importance in establishing baseline values of TMJ space volume in the Indian subcontinent.

Introduction

The temporomandibular joint (TMJ) is classified as "ginglymoarthrodial" a term derived from the Greek words "arthrodia" and "ginglymus." [1] The TMJ can experience morphological and histological changes due to aging and functional factors.[2] The volume of the TMJ space varies across different age groups and genders. The remodelling of different components of TMJ to accommodate developmental differences, malocclusion, trauma, can cause changes in the TMJ space.[3] Radiographic imaging of the TMJ is essential for identifying abnormalities and bony changes affecting the joint.[4] By analyzing the normal TMJ space volume, it is possible to detect risk factors for conditions such as disc displacements and changes caused by arthritis.[5]

Cone-beam computed tomography (CBCT) provides valuable data not only for diagnosing pathologies but

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also for performing volumetric analysis through 3D image extraction with specialized software. By evaluating the normal volume of TMJ spaces, abnormalities can be identified earlier, assisting in diagnosis and treatment planning. This study aimed to evaluate the TMJ space volume using CBCT and a semi- automatic augmentation technique in a specific subset of the Indian population.

Methodology:

The study was conducted in the Department of Oral Medicine and Radiology, D Y Patil University- School of dentistry, Nerul, Navi Mumbai.The Institutional Research and Ethical Board, (IREB/2024/OMR/02) has approved the study. This is a retrospective observational study that includes scans obtained from 64 patients-128 right and left TMJ spaces taken from the archives from 1/11/2023 to 30/4/2024.

Sample size estimation:

The following formula was used for sample size calculation using OpenEpi software version 3.01:

Total sample size = N = $[(Z\alpha+Z\beta)/C]^2 + 3$

where $Z\alpha$ is the z variate of alpha error i.e. a constant with value 1.96, $Z\beta$ is the z variate of beta error i.e. a constant with value 0.84

C = 0.5 * ln[(1+r)/(1-r) Approximate estimates:

1. 80% power
2. Type I error to be 5%
3. Type II error to be 20%

Minimum correlation between the 2 variables as 0.35.

Study design:

The CBCT scans were recorded using Carestream CS-9600 unit. The scans were obtained in Dicom Imaging and Communications in Medicine (DICOM) format and were viewed on HP Notebook-15-ay009ne. The study participants were categorized according to their age into 4 groups-18-30 years, 31-40 years, 41-50 years, and 51-60 years. To measure the volume of TMJ spaces, the "opensource software ITK-SNAP" was used. ITK-SNAP demonstrates slices in axial, coronal, and sagittal view. In sagittal view, most anterior, superior, and posterior points of glenoid fossa were used as anterior, superior, and posterior boundary respectively. Superior surface of mandibular condyle was taken as the inferior boundary.

Semiautomatic segmentation tool was first used to delineate the joint spaces in sagittal, coronal, and axial views and then manual brush segmentation was performed to ensure accurate segmentation and volumetric measurement. The software automatically determined the TMJ spaces volume under the category of volume and statistics in mm^3.Each side of the TMJ space volume was determined individually. [Figure 1].

This volume was additionally categorized into anterior and posterior TMJ volume on sagittal sections and medial and lateral TMJ volume on coronal sections.

The results to be assesses twice by the same operator at an interval of 7 days to assess intra-operator reliability. The mean TMJ space volume was then determined based on gender, age and laterality.

INCLUSION CRITERIA

1. CBCT scans of patients evaluated for maxillofacial pathology showing normal TMJ morphology from the Department of Oral Medicine and Radiology, D.Y. Patil University- School of Dentistry, Navi Mumbai.
2. Patients of either gender between 18- 60 years.

EXCLUSION CRITERIA

1. CBCT scan of patients with a prior history of orthodontic treatment, TMJ disorders, bone disorders.
2. CBCT scans showing any TMJ pathology such as fractures of the condyle, ankylosis, congenital disorder, etc.

After collecting all the necessary data, the findings were tabulated in a master chart and statistical analysis was undertaken using Statistical package for social sciences (SPSS v 26.0, IBM).

Results:

This study included CBCT scans of 128 TMJ space analysis from 64 patients. The distribution of study participants according to the age groups was 18-30 years (25%), 31-40 years(25%), 41-50 (25%) years

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and 51-60 years (25%). The analysis investigated CBCT scans of 32 males

(50%) and 32 female (50%) participant.

The minimum and maximum value obtained in right total TMJ space volume was 1256.0 mm^3 and 2180 mm^3. The minimum and maximum value obtained in left TMJ space volume was 1200.0mm^3 and 2150.0 mm^3. The overall mean value of right TMJ space volume was 1687.4 mm^3 and left TMJ volume was 1651.90 mm^3. The difference was found to be statistically significant (p=0.0).

The mean volume and std. deviation of the right TMJ space in various age groups was found to be as follows 18-30 years = 1433.50 mm^3 (SD=160.862 mm^3), 31-40 years=1538.06mm^3 (SD=124.560mm^3); 41-50 years = 1722.88mm^3 (SD=54.638mm^3), 51-60 years = 2055.19mm^3 (SD=54.543mm^3).

The mean volume and std. deviation of the left TMJ space in various age groups was found to be as follows 18-30 years = 1433.50 mm^3 (SD=160.862 mm^3), 31-40 years=1538.06mm^3 (SD=124.560mm^3); 41-50 years = 1722.88mm^3 (SD=54.638mm^3) , 51-60 years = 2055.19mm^3 (SD=54.543mm^3).

The volume of the right side TMJ space among the various age groups was compared using Tukey's post-hoc test. On comparing the right TMJ space volume in the age group of 18-30 years among the various groups i.e., 31-40 years, 41-50 years, and 51- 60 years, mean difference in the volume was found to be -104.56mm^3, -289.37mm^3 and -621.688mm^3 respectively. For age group 31-40 years was compared to other older groups, the difference in the mean values was found to be -184.813 mm^3, and -517.125 mm^3 respectively.

Age group 41-50 years when compared with the other groups for volumetric differences the mean values were as follows -167.68 mm^3, -114.35 mm^3 and -40.95 mm^3 respectively. On comparing the fourth age group of 51-60 years among the other groups, the difference in the mean TMJ volume was found to be -126.72 mm^3 in 18-30 years, -114.35 mm^3 in 31-40 years and 40.95 mm^3 in 41-50 years. The overall results were statistically significant on using ANOVA. (F=3.191; p=0.026*). [Table 1]

Left TMJ volume of 18-30 years when compared with 31-40 years, the mean difference was found to be -107.438 mm^3, with 41-50 years the mean difference was found to be -281.563 mm^3 and with 51-60 years the mean difference was found to be -628.5 mm^3 respectively. On comparing the left TMJ space volume of the age group of 31-40 years with that of 41-50 years, the mean difference was found to be -174.125 mm^3**.** On comparison of age group 31- 40 years with 51-60 years, the mean difference was found to be -521.063 mm^3Age group 41- 50 years when compared with the other groups for volumetric differences, the mean value was found to be -346.938 respectively.[Table 2]

This data of intergroup evaluation for right TMJ volume was not found to be statistically significant on using ANOVA. (F=2.397; p=0.071).

Mean TMJ space volume values were calculated by using Unpaired t-test according to gender. The mean right TMJ space volume in males and females was 1711.88 mm^3 (SD=263.8 mm^3);

and 1662.94 mm^3 (SD =259.4 mm^3) respectively which was statistically insignificant (p- value = 0.75). The mean right TMJ space volume in males and females respectively was 1674.34 mm^3 (SD =266.881mm^3) and 1629.53 mm^3(SD =263.796 mm^3) that was larger in males as compared to females but the difference was not statistically significant (p-value = 0.76). [Table 3]

One-way ANOVA was applied to evaluate the difference in TMJ space volumes of right and leftsides in the various age groups. In the age group of 18-30, the mean right TMJ space volume was 1433.5 and the mean left TMJ space volume was 1397.5 mm^3. No statistical significance was noted bilaterally in this age group (F=0.101, p=0.751)

Similarly, on comparing the right and left TMJ space volume of age group of 31-40 yearsthe mean values were 1538.06 mm^3 and 1505.00 mm^3 respectively. The difference was not statistically significant (F=0.021, p=0.885).

In age group of 41-50 years, the mean right TMJ space volume was 1722.88 mm^3; as against the left which was 1679.12 mm^3 No statistical significance could be established. (F=0.004, p=0.952). In age group of 51-

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60, the right and left TMJ space mean volume was 2055.19 mm^3 and 2026.06 mm^3 respectively that was statistically significant (F=0.211, p=0.648).

On evaluation of the overall data, the right total TMJ space volume in all age groups was larger than the left TMJ volume that was statistically non-significant except for males in the age range of 51-60 year.

The overall mean value of the posterior-to-anterior ratio on right side was 2.718 mm^3 (SD =0.384) and left side was 2.677 mm^3 (SD=0.308). The difference was found to be statistically not significant (p=>0.05). The different distribution of TMJ volumes was statistically not relevant bilaterally. (p>0.05). The overall mean value of the medial-to-lateral ratio on right side was 1.134 mm^3 (SD =00.202) and left side was 1.138 mm^3 (SD=0.106). The difference was found to be statistically not significant (p=>0.05). The different distribution of TMJ volumes was statistically not relevant bilaterally. (p>0.05).[Table 4]

Unpaired t-test was used to evaluate the mean posterior-to-anterior volume and medial-to-lateral volume according to gender. The mean posterior-to-anterior ratio in males and females was found to be statistically insignificant. (p-value >.0.05)

Discussion

The etiology and management of TMD over a while have always been controversial. The normal values and position of different TMJ components that can be evaluated on 2D and 3D imaging has also been a matter of debate over the years. Pathological changes can alter the morphology of the TMJ components causing increase or decrease in the TMJ spaces. To detect these changes, it is necessary to know the normal morphometric and volumetric values of TMJ spaces. A radiographic evaluation for morphological studies of the TMJ spaces have been done in the past using 2D imaging that solely provides dimetric measurements.

According to study conducted by T A Larheim et al, Osteoarthritis has been reported as one of the major degenerative diseases accompanying aging, wherein its image appearance is characterized by joint space narrowing. Ankylosis may lead to alteration in the joint cavity volume which can be assessed using CBCT.[6] According to study done by Wenjing Yu et al, disc displacement is possible to diagnose on a CBCT in cases where the calculated posterior-anterior ratio is altered.[7] Hence it is valuable to evaluate the normal TMJ volume in different age groups and genders. In this study, we have analysed and calculated TMJ volume from CBCT of patients without any history of TMD.

3D imaging has provided us insight into the volumetric analysis of the TMJ spaces and CBCT has made it easier by providing finer details at high resolution and lower exposure in a small field of view. Bayram et.al found CBCT to be a reliable tool for volumetric assessment of TMJ spaces.[8] Volumetric analysis of bone isdone using various techniques and software such as ImageJ, Mimics, ITK-SNAP, CTAn, VWorks, InVesalius etc.[8-13]

Of the various techniques, semi-automatic method is the most acceptable as the region of interest can be manually outlined along with the precision of automatic segmentation.In this study, we have used semi-automatic segmentation program ITK-SNAP, a highly validated method for volumetric measurements in medicine and is being used in various studies in dentistry.[14] It is important to learn about the normal morphology and volume to understand what can beclassified as normal.

This study was similar in lines by Shivam et. Al in which he evaluated, the total TMJ space volume between 11-15 years of age in relation to gender, laterality, posterior to anterior ratio, and medial to lateral ratio of TMJ spaces using Dolphin software.[15] This study was conducted to evaluate the total volumeof TMJ spaces between 18-60 years in relation to gender, laterality, posterior to anterior ratio, and medial to lateral ratio of TMJ spaces using ITK SNAP software.

The results were assessed twice by the same operator at an interval of 7 days to assess intra-operator reliability which were statistically similar(p=0.000). This indicated that there was high reliability in all the measurements and they were valid.

In the present study, we included 64 patients in total which equated to 128 TMJ spaces. The patient sample consisted of the age groups 18-30 years (25%), 31-40

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years (25%), 41-50 years (25%), 51-60 years (25%). The differences in the distribution of study participants according to age was not significant due to inclusion of approximately equal number of participants in each age group. The distribution of study participants according to gender was also not significant (p-value=1.00) as we included equal number of participants in both groups to reduce errors.

The overall mean volume of left and right TMJ spaces was found to be 1651.90 mm^3 and 1687.4 mm^3 respectively. While the mean value obtained for right TMJ spaces volume of the entire sample (N=128) was higher than that of the left, it was found to be statistically significant (p-value=0.0). This is in accordance with the studies performed by Shivam et. Al, Tecco et. Al, Safi et. Al, Saccucci et. Al and Shetty SR et. Al [15 9 16 9 17]

Studies performed by Nota et. Al, he found the right side to be larger than the left however the difference was not statistically significant.[18] Literature states that the presence of a preferred side for mastication as well as basic human asymmetry may help to explain the difference in volume of right and left side. Thus, it can be said that the right TMJ spaces in the general population is larger than the left, whether the difference is significant or not.

We also found that the mean right TMJ space volume was larger in males as compared to females but the difference was notstatistically significant (p-value = 0.75). This was in accordance to the study performed by Al-Koshab et. Al in 2015 in which mean values in males were higher compared to females in 18-45 years of age.[19] There was a statistically highly significant difference for males seen for the values in the age group 51-16 years ($p<0.01$).

The different TMJ space distribution was not significantly different on right and left side and in different genders ($p>0.05$, table). This is partly in accordance with the study performed by Zahra Dalili et. Al[28] in 2012 in which he found out that there is statistically significant difference between two sides but not between those sexes.[20]

The distribution of TMJ space was consistent on both the medial and lateral sides from the center of condyle. However, in cases of TMD, the condyle may shift, potentially resulting in an imbalance in the medial and lateral TMJ volumes.

Our results reveal that anterior TMJ volume was significantly less than posterior TMJ volume in both males and females. The ratio of posterior to anterior TMJ volume demonstrated that posterior TMJ volume was 2.5 times larger than the anterior TMJ volume. This is partly in accordance with the study performed by Wenjing et al in 2023 that showed no gender predilection between these spaces but posterior to anterior joint space ratio was 1:1.6.[7] This is most likely attributed to the thickest portion of the disc in the posterior region causing larger joint space in normal patients without TMD. For patients in which disc displacement is suspected, altered values of posterior to anterior ratio will help in diagnosis.

Shivam et al in his study along with TMJ space volume, condylar ad glenoid fossa morphology is important for comprehensive evaluation of the joint.[15] Saccucci et. Al studies TMJ components in different classes of skeletal malocclusion and found that the condyle volume is larger in class III patients.[9] This study can form a basis for further studies wherein similar parameters can be evaluated taking into consideration different classes of malocclusions.

CONCLUSION

This study was performed to evaluate TMJ volume on CBCT using semi-automatic segmentation technique in a subset of Indian population. Until, now, the literature regarding normal and abnormal changes in TMJ volumes has been very minimal. The information obtained can be clinically useful in establishing the diagnostic criteria for TMJ volume among the Indian population. In patients with TMJ disorders due to pathological or physiological changes, an accurate study of the TMJ space volume with CBCT by semiautomatic segmentation can help in early diagnosis and treatment. A further study is deemed necessary with a bigger sample size to confirm the findings of this study.

Limitations of the study

A limited number of samples were used for the study. The different malocclusions were not considered which could affect the morphology of the TMJ spaces

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due to adaptations.

Future scope:

The findings can act as a baseline for further larger studies toconfirm the results. These results can be help to assess pathophysiological alterations in TMJdisorders at an earlier stage, before the onset of symptoms thus allowingfor early diagnosis and treatment of the same.

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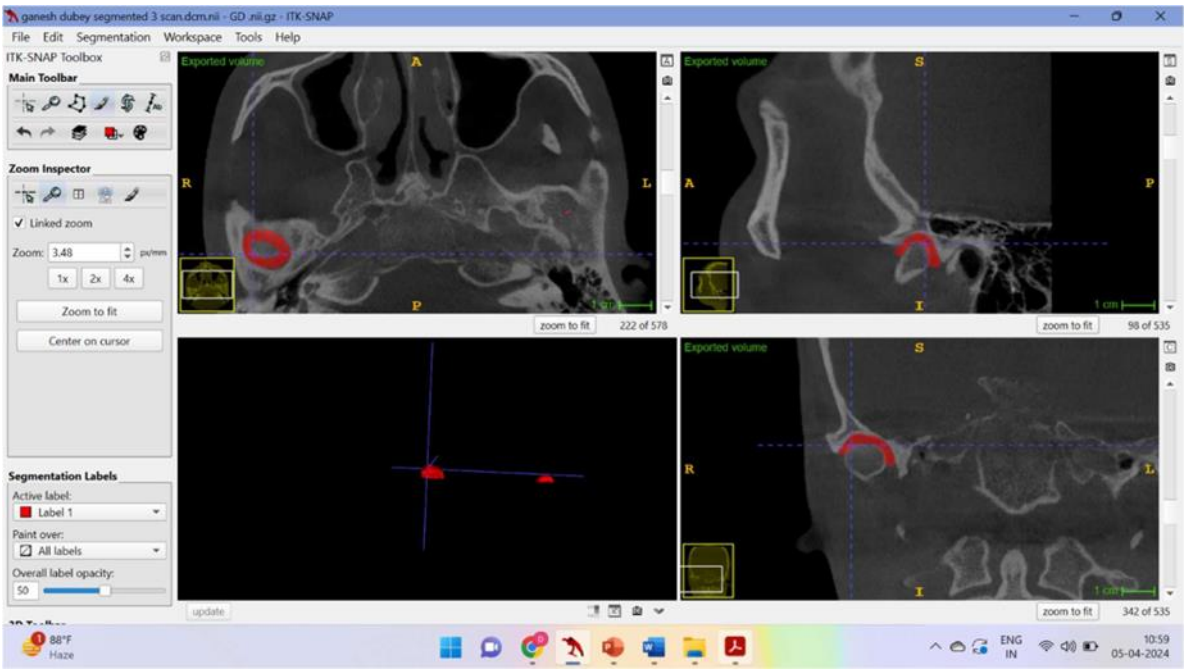

Figure 1: Volumetric analysis performed i.r.t right and left TMJ spaces.

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Dependent Variable	(I) Age groups	(J) Age groups	Mean Difference (I-J)	Std. Error	p value	95% Confidence Interval	
						Lower Bound	Upper Bound
Total Tmj vol mm3 Rt	1	2	-104.563*	38.468	.042*	-206.21	-2.91
		3	-289.375*	38.468	.000**	-391.03	-187.72
		4	-621.688*	38.468	.000**	-723.34	-520.04
	2	3	-184.813*	38.468	.000**	-286.46	-83.16
		4	-517.125*	38.468	.000**	-618.78	-415.47
	3	4	-332.313*	38.468	.000**	-433.96	-230.66

*p-value statistically significant <0.05

Table 1: Comparison between right side mean and standard deviation volume score according to age using Analysis of Variance and Tukey's post hoc test

Total Tmj vol mm3 left	1	2	-107.438*	39.929	.044*	-212.95	-1.93
		3	-281.563*	39.929	.000**	-387.07	-176.05
		4	-628.500*	39.929	.000**	-734.01	-522.99
	2	3	-174.125*	39.929	.000**	-279.64	-68.61
		4	-521.063*	39.929	.000**	-626.57	-415.55
	3	4	-346.938*	39.929	.000**	-452.45	-241.43

*p-value statistically significant <0.05

Table 2: Comparison between left side mean and standard deviation volume score according to age using Analysis of Variance and Tukey's post hoc test.

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Gender	N	Mean	Std. Deviation	Std. Error Mean	T value	p-value
Male	32	1711.8	263.8	32.1145	0.758	0.75
Female	32	1662.9	259.4	24.5208		

Table 3: Comparison between different gender for the mean and standard deviation volume score using unpaired t-test

Side		Posterior to anterior ratio	Medial-to-lateral ratio
Right	Mean	2.718	1.134
	N	32	32
	SD	0.384	0.202
Left	Mean	2.677	1.138
	N	32	32
	SD	0.308	0.106
Total	Mean	2.697	1.136
	N	64	64
	SD	0.346	0.160

Table 4: Comparison between overall left and right mean posterior to anterior ratio and medial to lateral ratio.