Original Article

Role of Digital Volumetric Tomography in Assessing Morphological Variations in Condyle and Temporal Components of Patients with Asymptomatic Temporomandibular Joint

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Abstract

Background: Radiographic features of remodeling are difficult to analyze. This has led to the popularity of using digital volumetric tomography (DVT) for temporomandibular joint (TMJ) imaging. To understand variations in normal anatomy and morphology of the condyle and temporal components of the TMJ, it is necessary to differentiate normal variant from pathology. **Methods:** A total of 160 condyle and temporal components of TMJ in patients with asymptomatic TMJ were assessed by two observers using orthopantomograph (OPG) and compared with DVT using axial, coronal, and sagittal sections for the different condylar and temporal changes separately. Different relationship between variables were evaluated and statistically analyzed. **Results:** The assessment made by two observers showed agreement between two observers for OPG and DVT ($P < 0.05$). A significant increase in occurrence of remodeling changes was observed with increase in age in both condyle and temporal components. A significant difference was observed between male and female in condylar and temporal changes also among the right and left sides. Remodeling changes were detected more accurately in DVT compared with OPG. The common bony changes seen were flattening followed by concavity and osteophytes. There is a significant difference in detecting these changes. **Conclusion:** Knowledge of morphologic variability in the TMJ is of utmost important to differentiate normal variant from pathology which would help in arriving at proper diagnosis. A more accurate and authentic information on condylar and temporal bony changes were obtained by DVT.

Keywords: Condyle, digital volumetric tomography, orthopantomograph, temporal, temporomandibular joint

Introduction

Temporomandibular joint (TMJ) is an important and unique joint in the body which is formed by the articulation between condylar portion of the mandible and squamous part of the temporal bone.[1] In spite of the detailed descriptions of the several pathologic changes that involve this joint, a very little attention to the appearance of the normal TMJ has been given. A constant process of remodeling occurs throughout all joints which have been revealed by skeletal and histological studies.[2]

Progressive, regressive, and circumferential are the three categories of articular remodeling. Progressive remodeling results in sclerosis caused due to cortical plate thickening. In case of regressive remodeling, there will be cortical plate erosion. Both progressive and regressive remodeling finally result in shape changes with cortical plate which is normal at a newly acquired surface. Peripheral type of remodeling causes appearance of osteophytes. In all these three types of articular remodeling, the crucial factor is that the superior surface stays intact, whereas underneath it follows the possible changes. Sclerosis, osteophytes, and erosion are also evident in osteoarthritis, and hence these features are not distinctively characteristic of remodeling alone.[2]

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The condylar appearance differs to a greater extent among various groups of ages and individuals. Various morphological changes may take place due to developmental variability, remodeling of condyle to adapt various abnormalities, trauma, malocclusion, and other developmental variations and pathologies.[3,4] Remodeling occurring at lesser than 20 years of age is uncommon, but it is very common after that age.[2] However, there is difference of opinion regarding correlation between remodeling changes and age. Studies have shown that there is no direct correlation between age and remodeling, and there is progressive increase in degree of incidence and morphological variation.[5,6]

Various imaging modalities of TMJ evaluation have been reported. But they have shown to have drawbacks due to the complicated TMJ anatomy, its position at the skull base, and limitations in various techniques of radiologic evaluation.[7] Orthopantomograph (OPG) has the benefit of displaying both maxillary and mandibular arches and entire dentition with supporting structures and both TMJ in a single image. Some panoramic machines have specific TMJ programs but they have severe limitations. These do not produce thin image layers and they provide an oblique and distorted view which lowers the image quality. Hence, advanced radiographic imaging is essential.[8,9]

Digital volumetric tomography (DVT) offers high-definition three-dimensional digital radiograph with accurate anatomical details of maxillofacial structures when compared with other radiographic methods that have drawbacks such as distortion, lack of clarity, magnification, and precision in measurements.[10] The bony constituents of TMJ are small often leading to superimposition of skull base resulting in adequate clarity of TMJ outline. This has led to the popularity of using DVT for TMJ imaging.[11] Radiographic features of remodeling are difficult to analyze. Hence, to understand variations in normal anatomy and morphology of the condyle and temporal components of the TMJ, it is necessary to differentiate normal variant from pathology.[9]

The purpose of this study was to evaluate the prevalence of radiologic morphological variations of condylar and temporal components in patients having asymptomatic TMJ. A thorough analysis was made regarding consequence of age on the variation and comparison between genders and also to evaluate the interobserver reliability in assessing condylar and temporal changes using OPG and DVT. In addition, effectiveness of DVT in relation to the OPG in assessing these changes was evaluated.

Materials and Methods

A total of 160 TMJ in 80 patients with asymptomatic TMJ who were willing to participate were assessed for the different condylar and temporal changes in right and left TMJ separately using OPG and DVT which included patients who had condylar or temporal changes in OPG which were advised for various purposes. They were divided into four age groups: 20–29, 30–39, 40–49, and 50–59 years. In each age group, 20 subjects were evaluated both clinically and radiographically using OPG and DVT. The approval from the ethical board was obtained for conducting the study. All the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation.

Informed consent was taken from the patients prior to the history, clinical, and radiographic examination. Age, gender, medical and drug history, dentition status, parafunctional habits, and changes in occlusion were recorded. Subjects on systemic steroids, morbid obese, or patients affected with generalized arthritis were excluded. None of the patients had symptoms relating to the TMJ or any other bone-related pathologies. All the subjects were above 20 years of age.

TMJ variation in OPG was confirmed by taking DVT. KODAK 9000 3D Extraoral imaging system (Carestream Health, Inc., Rochester, NY, USA) was used for obtaining OPG and DVT images. Exposure parameters were as follows: OPG: 70–74 kV, 14.3–15.1 mAs, and scan time 13.9–15.1 s. Radiation exposure to the patient was 0.01 mSv (70–85 mGycm^2); DVT: 70–80 kV, 10–10.8 mAs, and scan time 24 s. Radiation exposure to the patient was 1.02–1.05 mSv (220–235 mGycm^2). As per the National Council on Radiation Protection and Measurements (NCRP) guidelines, the radiation exposure to the patients was below the maximum permissible dose of 2.4 mSv. Radiation safety precautions such as thyroid collar and lead apron were used.

Two observers who were blinded to each other assessed separately both OPG and DVT images. In DVT, images were observed in three sections, that is, axial, coronal, and sagittal views. The radiologic findings were recorded as follows and the definition for the various radiological changes are according to Muir and Goss[2]: (a) osteophyte: a local bony projection along joint margins; (b) erosion: a area which has decreased density in the cortical plate of a joint surface; (c) flattening: a loss of an even convexity or concavity of the joint outlines; (d) sclerosis: a local area with increased density of the cortical bone on a joint surface; (e) concavity: a hollowed-out area on the bony contour; (f) subcortical "cyst": a well-defined, rounded radiolucent local area of bone rarefaction that may be just underneath the cortical plate or deep in trabecular bone; and (g) other changes: bifid condyle. The frequency and site of each feature for each condylar and temporal component of the joint were determined. The various associations between variables were tested and statistically analyzed.

Statistical procedure

Data were collected and subjected to statistical analysis using kappa statistics for agreement between two observers and Chi-square test was applied between two methods on assessment of parameters. The statistical significance was set at 5% level of significance (0.05).

Results

A total of 160 TMJ in 80 patients with asymptomatic TMJ were assessed for different condylar and temporal changes as mentioned in the methodology. All the TMJs were assessed by two observers using OPG and DVT. The agreement between observers in assessing OPG images was carried out using kappa statistic. It clearly shows that there was perfect agreement between two observers in assessment of condyle changes using OPG (anterior, kappa = 94.09%, $P < 0.001$; superior, kappa = 89.70%, $P < 0.001$; posterior, kappa = 92.12%, $P < 0.001$) at 1% level. It means that a perfect agreement was observed between two observers. However, good agreement was also observed between two observers in assessment of temporal changes (anterior, kappa = 94.59%, $P < 0.001$; superior, kappa = 90.54%, $P < 0.001$), but for posterior of temporal the observed and expected agreement was the same and not statistically significant ($P = 0.5467$) using OPG [Table 1].

The agreement between observers in assessing DVT images was carried out using kappa statistic. It clearly shows that there was a perfect agreement between two observers in assessment of condyle changes using DVT (coronal, kappa = 89.41%, $P < 0.001$; sagittal, kappa = 87.84%, $P < 0.001$; axial, kappa = 97.75%, $P < 0.001$) at 1% level. It means that a perfect agreement was observed between two observers. However, good agreement was also observed between two observers in assessment of temporal changes (coronal, kappa = 88.29%, $P < 0.001$; sagittal, kappa = 91.44%, $P < 0.001$; axial, kappa = 91.67%, $P < 0.001$) using DVT [Table 2].

A comparison between OPG and DVT of condyle in each age group was performed and it showed no statistical difference between OPG and DVT of condyle in the age groups 20–29 and 30–39 years ($P > 0.05$) and a significant difference was observed between OPG and DVT of condyle in the age groups 40–49 and 50–59 years ($P < 0.05$) [Graph 1].

A comparison between OPG and DVT of temporal component in each age group was performed and it showed no statistical difference was observed between OPG and DVT of temporal component across all age groups ($P > 0.05$) except in the age group 50–59 years ($P < 0.05$) [Graph 2].

A significant difference was observed between male and female in condylar changes in both OPG and DVT ($P < 0.05$). There was female predominance with most common change seen being flattening followed by concavity [Graph 3]. In temporal component, in OPG there was female predominance in flattening and sclerosis, whereas in DVT there was male predominance. In erosion, there was male predominance in both OPG and DVT ($P < 0.05$) [Graph 4].

In OPG, there was no statistical difference between right and left condyles when compared, the most common being flattening followed by concavity ($P > 0.05$) [Graph 5]. In temporal, a significant more flattening was observed in the left side, whereas erosion on the right side in OPG ($P < 0.05$) [Graph 6]. In DVT, there was statistical difference observed between right and left condyles, the most common being flattening followed by concavity, and also in temporal component ($P < 0.05$) [Graphs 7 and 8].

Overall comparison of OPG and DVT showed no statistical significant difference between OPG and DVT in assessing remodeling changes in condyle [Graph 9] and temporal components [Graph 10].

Table 1: Agreement between two observers by kappa statistic in OPG

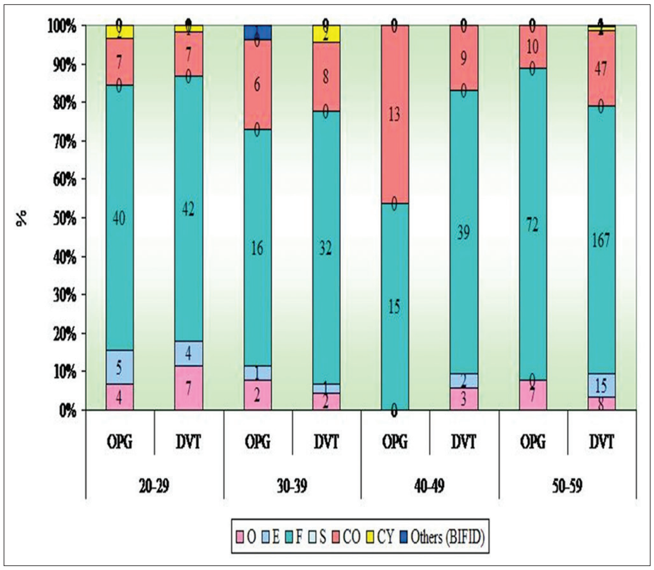
	Agreement	Expected Agreement	Kappa	Std.err.	*Z*	*P*
Condyle						
Anterior	94.09%	74.00%	0.7726	0.0602	12.8400	0.00001*
Superior	89.70%	81.43%	0.4450	0.0597	7.4500	0.00001*
Posterior	92.12%	78.17%	0.6388	0.0648	9.8500	0.00001*
Temporal component of TMJ						
Anterior	94.59%	92.40%	0.2885	0.0662	4.3600	0.00001*
Inferior	90.54%	85.79%	0.3342	0.0675	4.9500	0.00001*
Posterior	98.65%	98.66%	−0.0068	0.0579	−0.1200	0.5467

*P<0.05; OPG: orthopantomograph

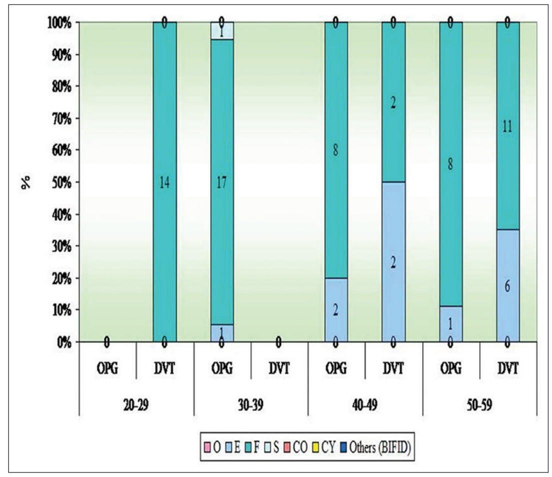
Table 2: Agreement between two observers by kappa statistic in DVT

	Agreement	Expected Agreement	Kappa	Std. err.	*Z*	*P*
Condyle						
Coronal	89.41%	69.97%	0.6475	0.0671	9.64000	0.00001*
Sagittal	87.84%	75.67%	0.5002	0.0583	8.58000	0.00001*
Axial	97.75%	86.68%	0.8309	0.0643	12.9200	0.00001*
Temporal component of TMJ						
Coronal	88.29%	69.60%	0.6148	0.0639	9.6200	0.00001*
Sagittal	91.44%	76.98%	0.6281	0.0626	10.0400	0.00001*
Axial	91.67%	84.70%	0.4554	0.0622	7.3200	0.00001*

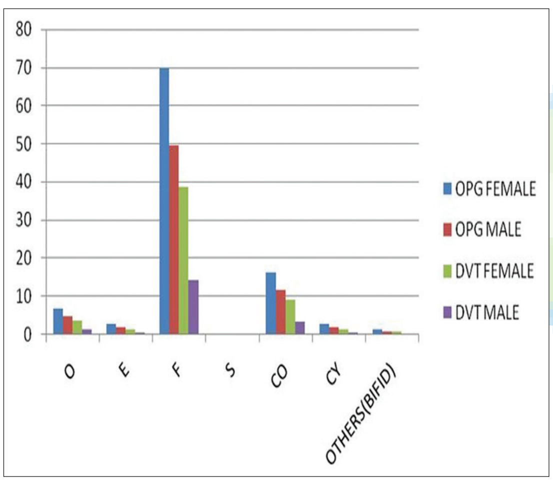
DVT: digital volumetric tomography. *P<0.05



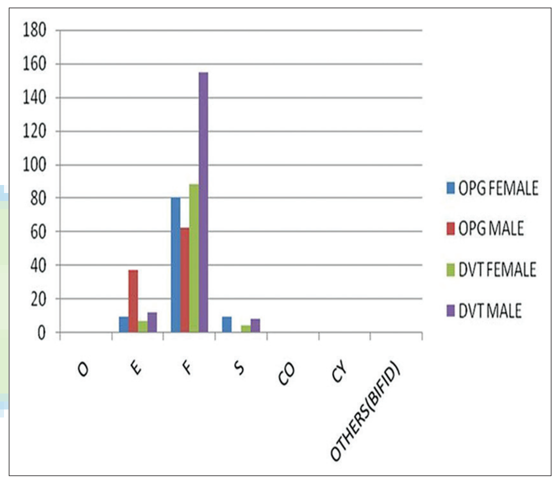
Graph 1: Comparison of OPG and DVT in each age group – condyle. O: osteophyte; E: erosion; F: flattening; S: sclerosis; CO: concavity; CY: cyst



Graph 2: Comparison of OPG and DVT in each age group – temporal. O: osteophyte; E: erosion; F: flattening; S: sclerosis; CO: concavity; CY: cyst



Graph 3: Comparison of OPG and DVT in male and female – condyle. O: osteophyte; E: erosion; F: flattening; S: sclerosis; CO: concavity; CY: cyst



Graph 4: Comparison of OPG and DVT in male and female – temporal. O: osteophyte; E: erosion; F: flattening; S: sclerosis; CO: concavity; CY: cyst

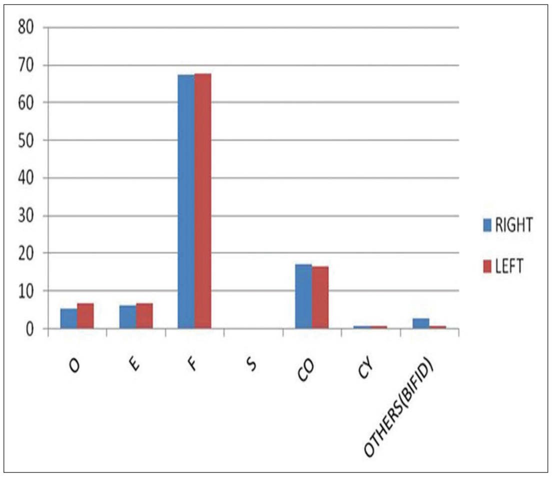
Discussion

Numerous radiographic techniques to determine the changes in the bone that involve the TMJ are used. The superimposition of the neighboring structures of TMJ accompanied with limited mouth opening, artifacts, and movements of the mandible during the examination makes it difficult to get a well-defined image of the TMJ.[7] The most recent radiographic technique to visualize TMJ is DVT or cone beam computed tomography (CBCT).

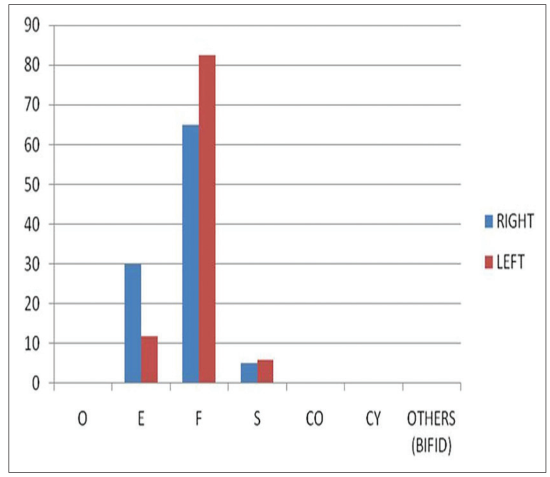
This study was carried out to assess the various bony changes in condyle in patients with asymptomatic TMJ using DVT and OPG. The diagnostic accuracy of DVT and OPG to see the changes in the mandibular condyle was evaluated and compared with each other. In our study, we used KODAK 9000C 3D Extraoral imaging system to take OPG and DVT images. Using this system, a study done by Alqerban *et al*.[12] can be justified, in which the authors concluded that the CBCT system had greater accurateness with no significant differences in detecting the severity of root resorption.

The agreement between observers in assessing condylar and temporal changes using OPG and DVT showed almost perfect agreement. This is in agreement with the observations made by Mathew *et al*.[5] and Crow *et al*.[13] and not in agreement with the observation by Vidra *et al*.[14] where the observer reliability in radiographic assessment was poor for surface and shape of the condyle.

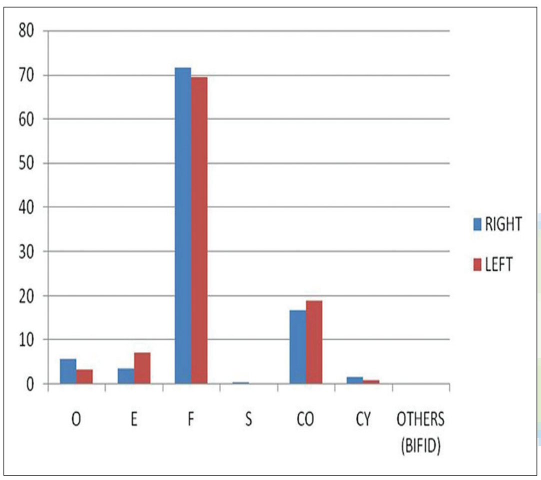
This study indicates that an abundant amount of remodeling of bone takes place in asymptomatic TMJ. This finding is similar to the studies relating to bony remodeling changes in skeletal and histologic.[2] It is paradoxical to the misconception that asymptomatic joints are normal radiographically. The least



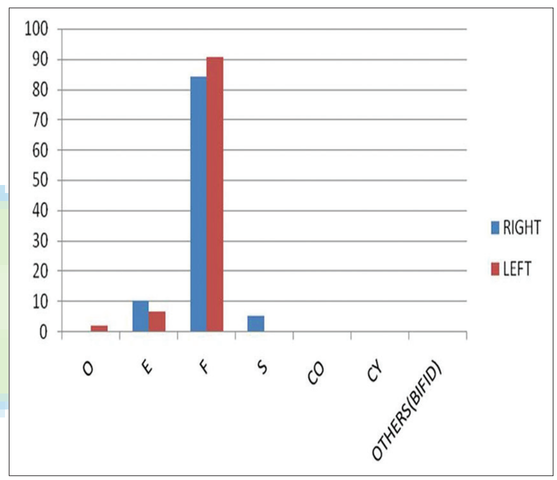
Graph 5: Comparison of right and left condyle in OPG. O: osteophyte; E: erosion; F: flattening; S: sclerosis; CO: concavity; CY: cyst



Graph 6: Comparison of right and left temporal component in OPG. O: osteophyte; E: erosion; F: flattening; S: sclerosis; CO: concavity; CY: cyst



Graph 7: Comparison of right and left condyle in DVT. O: osteophyte; E: erosion; F: flattening; S: sclerosis; CO: concavity; CY: cyst

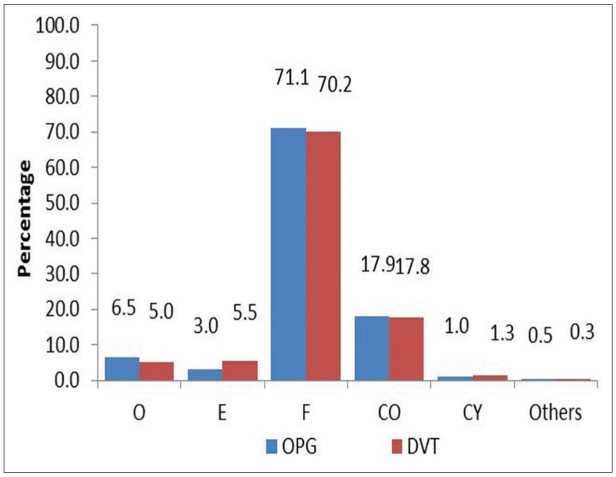


Graph 8: Comparison of right and left temporal component in DVT. O: osteophyte; E: erosion; F: flattening; S: sclerosis; CO: concavity; CY: cyst

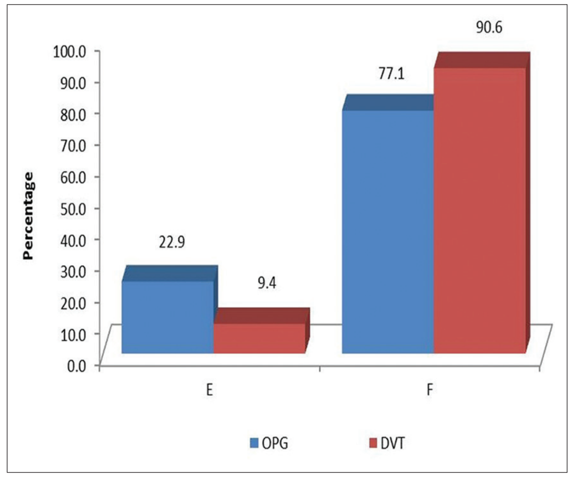
age of 20 years was selected for the study because this is the relative age at which subarticular calcification is completed uniformly in TMJ.[2] Subjects on systemic steroids, morbid obese, or patients affected with generalized arthritis were excluded since the indicated conditions may modify joint morphology.[15]

The prevalence of condylar morphological changes was more in individuals above 40 years when compared with those below the age of 40 years which was statistically significant ($P < 0.05$) and in temporal significant changes seen in those above 50 years of age. It was also observed that as age increased, the condylar and temporal changes were also increased. This observation is in agreement with the observations of Muir and Goss,[2] Mathew *et al*.,[5] Takayama *et al*.,[6] and Pontual *et al*.[7] that morphologic variation was less common in earlier age group and age is a factor which determines the degree of remodeling, although there is no direct relationship. Since the degenerative oradaptive changes in the TMJ appear over a long period of time, it is understandable that the condylar and temporal changes increase with progressing age. However, these findings were not in accordance with the observations of few studies which showed these changes more predominant in younger age groups or in all age groups.[13,16]

In our study, there was no statistical difference between right and left condyles observed in OPG, but in DVT there was a significant difference between right and left condyles in which more number of condylar changes were seen in the right side. This observation is in accordance with the observation by Borahan *et al*.[17] This higher incidence of bony changes on the right side might reflect the chewing pattern of the individual who usually use the right side of the jaw. This observation is not in agreement with the observations by Mathew *et al*.[5] and Takayama *et al*.[6] in which findings were more on the left side. However, in temporal component, there was significant statistical difference between right and left sides observed in OPG and DVT in which more number of temporal changes



Graph 9: Overall comparison of OPG and DVT – condyle. O: osteophyte; E: erosion; F: flattening; CO: concavity; CY: cyst



Graph 10: Overall comparison of OPG and DVT – temporal. E: erosion; F: flattening

were seen in the left side. This could be an incidental observation. Moreover, Crusoe-Rebello *et al*.[18] reported that right and left joints could not be considered separately since one joint influenced the other and thus mandibular movements were coordinated by both joints.

In this study, significant difference was observed between male and female in condylar changes in both OPG and DVT ($P < 0.05$) in which there was female predominance. This finding is in agreement with the observation by Pontual *et al*.[7] It has been suggested that the increased prevalence of bony changes in female reflects hormonal influences of estrogen and prolactin, which might exacerbate the degradation of cartilage and articular bone stimulating immunological responses in that region. However, it is observed that in temporal component, there is no significant difference between male and female in OPG, but in DVT there was statistical significant difference in which there was male predominance. Conversely, Cho and Jung[19] reported no significant gender differences. Moreover, Crusoe-Rabello *et al*.[18] also observed no correlation between male and female, concluding that hormones did not play a role in TMJ derangement.

The reason for using OPG is because they were obtained as part of the initial dental examination and convenience of viewing the entire dentition and both joints on a single image. The glenoid fossa, however, could not be seen in most of the OPG. Features were commonly seen in the condyle than in the temporal. Overall comparison of OPG and DVT showed no statistical significant difference in assessing remodeling changes such as flattening. This is owing to the fact that flattening is gross change and can be easily identified by two dimensional imaging like OPG. DVT could accurately detect changes such as Ely's cyst, bifid, sclerosis, osteophytes, and erosion. In both OPG and DVT, common bony changes in condyle observed were flattening followed by concavity and osteophytes, whereas in temporal components the most common bony changes seen were flattening followed by erosion in both OPG and DVT. Pontual *et al*.[7] observed that the most common finding was flattening followed by osteophyte and stated that the high frequency of flattening denotes an adaptive alteration which is the first change of progressive disease and might be associated with overload of masseter and temporal muscles to the TMJ.

In our study, although there was no statistically significant difference between two imaging modalities, the remodeling changes were more observed in DVT than OPG. This dissimilarity may be due to the advantage of DVT to evaluate the TMJ region over the OPG as there is no superimposition of anatomical structures. Hence, in OPG there may be an illusion due to superimposition of anatomical structures. Thus, TMJ changes found in OPG have been confirmed with DVT.

Conclusion

The clinical implications of this study are that the radiographic appearances of condylar and temporal components of asymptomatic TMJ differ to a greater extent. Remodeling changes are more common, hence the joint without radiographic changes is unusual. To detect gross changes in the bone such as flattening, OPG alone can be used, whereas DVT is useful to detect changes such as Ely's cyst, bifid, sclerosis, osteophytes, and erosion. In our study, in both OPG and DVT, common bony changes were flattening followed by concavity and osteophytes. The frequency of findings was positively associated with age. The total number of findings was more in females than in males in condyle, whereas in temporal there was male predominance.

It is a diagnostic challenge for radiologist and surgeons to distinguish pathology from morphological variations in the TMJ. Thus, a thorough understanding of the TMJ anatomy and morphologic variability is important so that normal variant can be differentiated from a pathological condition. DVT provides more valid and authentic information on condylar and temporal bony changes. The DVT has an added advantage of reducing the size of the irradiated area to the area of interest, thus minimizing the radiation exposure to the patient and cost-effectiveness compared with other specialized technology and could be easily accessible in a dental hospital.

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Conflicts of interest

There are no conflicts of interest.

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