The Assessment of Osseous changes in the Temporomandibular Joint using Cone Beam Computed Tomography

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Dedication

This M.Sc. is dedicated to my family: my wife Godijah, daughters Imaan, Nuhaa and Asmaa. I do everything for you. Thank you for your understanding and support when I spent many nights and weekends with my studies. To my father and mother for their encouragement, my brother Ebrahim and sisters Soraya and Sameera for listening to my complaints and offering advice and clarity.

I love you all.

Abstract

Aim:

To compare osseous changes in the mandibular condyles in patients presenting to the Oral Health Center, Tygerburg Campus, with and without clicking of the temporomandibular joint.

Background

Clicking of the temporomandibular joint (TMJ) is not a normal occurrence in its form or function. A chronic click may lead to the development of osteoarthritis. A clinical finding of clicking of the joint can reflect osseous changes of the bony structures and form part of the early signs of degenerative joint diseases. These osseous changes can be detected on Cone Beam Computed Tomography (CBCT) images. The purpose of this study is to confirm the presence osseous changes of the joint and institute the early management of these patients. Failure to intervene in the early stages could result in disease progression to possible osteoarthritis. CBCT imaging will be used to assess osseous changes in the temporomandibular joints with reference to erosions, flattening, lipping, sclerosis and osteophyte formation.

Materials and methods:

25 patient records were selected for a control group and 25 patients that attended the Oral Health center were screened for asymptomatic clicking of the temporomandibular joints. Osseous changes of the 100 condyles were examined by the author and a senior member of the department. Changes were recorded when consensus was reached on the presence of any changes. Cone Beam Computed Tomography was used to assess the joints in both groups.

Results:

Age and gender showed no statistical significance between the 2 groups. The proportion of 'yes' for the variables showed that sclerosis (right) was statistically significant when comparing case versus control groups (P = 0.002). A chi-squared test applied to the data resulted in observed chi-square = 15.68, df = 1, p-value = 7.501e-05, (<0.0001) confirming that the discrimination is statistically significant.

Conclusion:

Osseous changes were found in both the control and case group. The case group exhibited equal or greater prevalence of osseous changes. Patients with asymptomatic click of the temporomandibular joints demonstrate osseous changes.

Key words: osseous changes, temporomandibular joint, temporomandibular disorders, TMD, CBCT and TMJ.

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List of abbreviations

TMJ	Temporomandibular joint
CBCT	Cone Beam Computed Tomography
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
TMD	Temporomandibular Disorder
RDC/TMD	Research Diagnostic Criteria/ Temporomandibular Disorder
R/r	Right
L/l	Left
U.W.C	University of the Western Cape

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Chapter one

Introduction

There is a misconception by patients and practitioners that a clicking sound of the temporomandibular joint (TMJ) on opening and/or closing does not warrant treatment unless it causes pain. A click is a clinical manifestation of disorders of the TMJ called internal derangement – which relate to an abnormal positional relationship between the mandibular condyle, the articular eminence and the articular disc that separates them. The important consideration is that chronic derangement of the disc frequently results in osteoarthritis (Barghan *et al*. 2012).

A click can present at almost any stages of the normal motion and function of the TMJ and can vary in audibility and severity. The resultant derangement can displace the articular disc in an anterior, posterior, medial or lateral direction. The force of the reduction of the disc, when present, can cause a compensatory or abnormal response of the osseous structures of the TMJ. These structural changes of the osseous components can be examined with radiographic imaging and together with the clinical findings, confirm disease progression.

Imaging procedures that are used to evaluate the TMJ include the panoramic radiograph, tomography, conventional computed tomography (CT), CBCT, and magnetic resonance imaging (MRI).

The possibility exists that a disorder of the TMJ, which is a chronic process, can result in disease progression if left untreated. The importance of diagnosing the early stages of derangement and treating the signs and symptoms could prevent or reduce the chances of degenerative joint diseases, like osteoarthritis, later in life.

This study served to ascertain the importance of using the appropriate imaging modality to detect any osseous changes on the

TMJ and guide the initiation of treatment. The presence of erosions, sclerosis lipping, osteophytes and flattening of the condyle are indicative of an active degenerative process and management thereof may limit disease progression.

Chapter 2

Literature Review

2.a Temporomandibular Disorders

Temporomandibular disorders (TMD) are regarded as the most common cause of non-dental pain affecting the head and neck region (Barghan *et al*. 2012). The clinical picture includes pain involving the muscles of mastication, headache, earache, clicking, limited opening of the mandible or deviation on opening and locking of the jaw. The diagnosis of TMD is considered difficult due the complex aetiopathogenesis, making a standardized diagnosis and treatment protocol hard to follow (Barghan *et al*. 2012).

Epidemiological studies show a female predominance for TMD and onset of the disease from as early as the second decade, with a mean onset between 35 and 45 years old (Manfredini *et al*. 2011).

The clinical examination of the TMD patient is vital and in many cases insufficiently carried out, as full assessment must include the osseous structures as well as soft tissue components (muscle and disc). This can only be achieved by radiographic imaging, as the focus is on evaluating the cortical and trabecular architecture, confirming their integrity, monitor progression of the osseous changes, and finally to evaluate a response to treatment (Barghan *et al*. 2012).

Wiese *et al* (2011) conducted a study to assess the changes in diagnosis and management of TMD patients after radiographic examination. They reported a 27 percent (cited similar studies up to 40% change) alteration in the management of these patients who initially only underwent clinical examination.

Various imaging techniques are currently available that may be used to evaluate remodeling of the TMJ, osteoarthritis, inflammatory arthritis, synovial chondromatosis, internal derangement of the articular disc, trauma, ankylosis, developmental abnormalities of the TMJ, coronoid hyperplasia, and neoplasms. (Barghan *et al*. 2012).

2.b Radiographic imaging techniques to assess the TMJ

A variety of image modalities have been used to study the TMJ. These include panoramic radiography, plain radiography, magnetic resonance imaging (MRI), computed tomography (conventional and computed), cone beam computed tomography, arthrography (Petersson. 2010) and recently also ultrasonography. (Manfredini *et al*. 2011).

i. Panoramic radiography and assessment of the TMJ

Panoramic radiographs may be useful to evaluate gross anatomy or pathology especially late in the progression of the disease. Early changes are not clearly visible on panoramic radiographs and although inexpensive, does not show the entire articular surface, may show some distortion and is limited by superimposition of the zygomatic arches. Hintze et al(2009) also highlighted the flaws of the panoramic radiography in terms of distortion and anatomical overlap. They noted that the shape of the condyles varied on radiographs using different units causing inaccurate diagnoses.

Mawani *et al* (2005) studied condylar shape using panoramic radiography units and conventional tomography. They noted that panoramic views gave an oblique section of the condyle, with the result that the medial pole is sometimes superimposed over the center of the condyle, leaving a view of the lateral pole that appears as medial. Some osseous changes affecting the medial pole are missed in these views. This variation caused the experts to recommend that panoramic radiographs not be the sole image used in diagnosis (Hintze *et al*. 2009).

ii. Plain radiography and assessment of the TMJ

The transcranial TMJ projection, used to view the joint, has become less popular due to the superimposition of adjacent structures. Previously it was the preferred image of choice in adjunct to the panoramic radiographs because it lacked the distortion and showed anatomical accuracy. The variation in accuracy between panoramic radiographs and TMJ tomograms favored the TMJ view but could not be validated. Therefore the TMJ view lost favorability due to the high resources it needed, in comparison to panoramic radiographs (Hintze *et al*. 2009).

iii. Tomography and the assessment of the TMJ

Linear or complex motion tomography became popular in overcoming distortion and superimposition, but these underestimated small bone abnormalities, and limited the diagnostic accuracy. CT provides excellent imaging of the osseous structures and shows changes such as erosions, osteophytes, dislocations, fractures, ankylosis and other abnormalities (Barghan *et al*. 2012). The limiting factor in its use is the high radiation dose, high cost and limited availability.

iv. Magnetic Resonance Imaging (MRI) and the assessment of the TMJ

MRI produces images consisting of thin slices of tissue in the various planes including oblique angles and those found with CT. It was initially used to study the brain and later adapted into dentistry to study pathology including tumours and the TMJ. MRI is traditionally used to observe the soft tissue components of the TMJ (Barghan *et al*. 2012).

v. Cone Beam Computed Tomography (CBCT) and the assessment of the TMJ

The introduction of CBCT and its availability in most hospitals, as well as in dental schools and some private practices helps overcome previous limitations, including the high cost and high radiation dosage of conventional CT. Additional advantages include a high spatial resolution due to the minute voxels used in CBCT. Voxels are like pixels and the smaller and more numerous they are, the greater the detail and definition of the images. (Barghan *et al*. 2012).

2.c Comparison of the Different Views

The different modalities have had their place in the history of diagnosing and monitoring treatment of TMD. Recent advancements in research surrounding CBCT highlight the superiority and advantages as a modality of choice in many aspects of dentistry including TMJ evaluation.

Prior to clinical studies, researchers made use of dry specimens from human and animal cadavers. In one study by Alkhader *et al* (2010) they discussed the role of CBCT as the new modality of choice for detecting osseous changes of the TMJ. They concurred with studies done on dry mandibles that showed high reliability and supreme accuracy. There were similar studies done on camel cadaver jaws to demonstrate the value of computed tomography to study the bony components of the TMJ with regards to accuracy of form and linear measurements of the bony structures (Arencibia *et al. 2012*).

Miracle and Mukherji (2009) reported on similar studies using CBCT on cadavers for the evaluation of TMD with regards to bony defects, sclerotic changes, osteophytes and flattenings. They highlighted the need for more studies using CBCT and concurred with other studies that suggested CBCT as the method of choice for periauricular erosions and osteophytes (Miracle and Mukherji 2009).

Valladares Neto *et al*.(2010) conducted a study measuring the condylar dimensions from age 3 to 20. They found CBCT to be an accurate technique to measure condylar dimensions and to detect any morphological changes that occurred during growth. This study confirmed findings of studies done on cadavers (Valladares Neto *et al*. 2010).

There are limited studies on the assessment of osseous changes in the TMJ and most compare various imaging modalities. Mupparapu *et al* (2011) evaluated morphological changes in the TMJ using submentovertex and complex motion tomography, prior to orthodontic treatment. They studied the joints of 57 patients some with and some without any signs and symptoms of TMD. The age range of their patients extended from 16 to 77. The results of their study showed that 53% of the patients had hard tissue structural abnormalities that showed disease progression. They recommended treatment of disc displacement to reposition the disc prior to orthodontic treatment. This interceptive treatment was important because they found significant changes in cephalometric analysis with disc displacements, which could adversely affect the overall orthodontic management (Mupparapu *et al*. 2011).

Mupparapu *et al*. (2011) also suggested that using CBCT instead of submentovertex and complex motion tomography, could provide significant results that would aid in the management of patients with TMD prior to orthodontic treatment. Of significance was the age range of their patients (16-77) in their study and the alarming aspect that the patients were screened preoperatively and not prioritized as having TMD symptoms. This could underline the need for incorporating a thorough TMJ examination for TMD according to Research Diagnostic Criteria for Temporomandibular disorder (RDC/TMD) guidelines and if need be, the further examination to confirm symptoms and guide treatment.

Alkhader *et al*. (2010) looked at the diagnostic performance of MRI for detecting osseous abnormalities of the TMJ and its correlation with CBCT. They used CBCT as the reference standard and evaluated 55 patients that presented to their hospital manifesting with signs and symptoms of TMD that underwent both CBCT and MRI examination. They concluded that MRI was the most useful technique in assessing soft tissue components of the TMJ but was very limited in detecting osseous abnormalities whereas CBCT was the most reliable for the evaluation of the osseous structures (Alkhader *et al*. 2010).

Both these studies used similar sample sizes over broad age groups comparing different modalities to examine the TMJ, and they both highlighted the importance of early detection of the disease. Mupparapu *et al.* (2011) advised the need to initiate treatment of the TMD as a priority step before the commencement of orthodontic work. Both studies recommended the use of CBCT to assess osseous components of the TMJ.

In a study carried out by Manfredini *et al*. (2011), they acknowledged the popular use of MRI for evaluation of soft tissue changes and the use of CBCT as a valid alternative to CT in evaluating hard tissue changes. A recent introduction in TMD literature was made by Manfredini *et al* (2011) regarding the use of ultrasonography. They also highlighted the need for TMD experts to work with medical legal experts in cases of dental malpractice (Manfredini *et al*. 2011).

In a review by Ribeiro-Rotta *et al*. (2011), they addressed the question of whether CT and MRI would be valuable in treatment planning of TMJ disorders. They mentioned 257 publications and found only one that met their inclusion criteria. The study was a systematic review evaluating the efficacy of MRI in diagnosing TMJ changes such as: disc position and configuration, perforation, joint effusion, osseous changes and bone marrow changes. The remaining studies did not prove to be of therapeutic value and treatment planning as most did not draw any conclusions that MRI examination would result in a better treatment outcome (Ribeiro-Rotta *et al*. 2011).

The various studies regarding the efficacy of MRI confirms its value in evaluating soft tissue components in the TMJ as well as other parts of the body. Petersson (2010) disagreed and deduced in his study that there are insufficient studies to confirm the efficacy of using MRI to diagnose disc displacement. It was also concluded that the literature provides no conclusive evidence whether to employ MRI and suggested the need for more studies on the diagnostic efficacy of MRI.

Petersson (2010) noted the advantages of CBCT compared to conventional CT as being similar in their diagnostic capabilities. He also reported on the lack of conclusive studies comparing CBCT to other image modalities for diagnostic capabilities.

In a study undertaken to determine the usefulness of CBCT as compared to a multidetector CT, it was concluded that more studies were needed for CBCT assessment of the TMJ (Ahmad *et al*. 2009). Early studies like Hussain *et al* (2008) discussed the role of various modalities in assessing TMJ erosions and osteophytes and suggested the use of CBCT as a cost effective and dose effective alternative to conventional CT.

There is an obvious lack of studies comparing CBCT to other reference standard procedures and most radiologists acknowledge the advantages of CBCT. However, these studies are all research based and very few studies are clinical. The important deciding factor when dealing with a clinical situation is a combination of the best available options for the patient that is minimally invasive, cost effective and provides the best efficacy and treatment outcome. The lack of international standardized treatment modalities will always influence TMD imaging prior, during and post treatment and will always be dependent on sound research and bridging the gap between the research and clinical worlds.

2.d Ossoeus Changes of the Condyle

In a retrospective study of 220 patients evaluating CBCT data, Nah (2012) studied the incidence of osseous changes on the condyles. He noted that some changes were only observed in certain plains of view and therefore a comprehensive examination of the data should include all 3 plains of view. He concluded that the increasing use of CBCT requires more specific or detailed guidelines for evaluating osteoarthritis.

Tsuruta *et al* (2004) investigated 26 subjects that presented for orthodontic treatment and who showed clicking of the TMJ with no pain. They used CBCT and reconstructed analysis showed no evidence of sclerosis and cyst formation. They only evaluated for flattening (deviation from convex rounded form), osteophytes (marginal bone outgrowth), and no changes. They highlighted the reliability of CBCT to measure these changes.

Badel *et al* (2009) studied the radiological characteristics of osteoarthritis in TMJ's without any disc displacement. They compared 16 patients that were diagnosed with osteoarthritis and 20 dental students without any signs or history of TMD. They found sclerosis and osteophyte formation were the most common findings in patients with osteoarthritis. They found no statistical difference between degenerative changes of the condyles of TMJ's with and without clinical signs of osteoarthritis.

In this study, osseous changes will be diagnosed according to the image analysis criteria (listed below) for panoramic radiographs, CT, and MRI set out by Ahmad *et al* (2009).

A. No osteoarthritis

i. Normal relative size of condylar head,

ii. No sclerosis or articular surface flattening,

iii. No deformation due to subcortical cyst, surface erosion, osteophyte, or generalized sclerosis.

B. Indeterminate for osteoarthritis

i. Normal relative size of the condylar head,

ii. Subcortical sclerosis with or without articular surface flattening,

iii. Articular surface flattening with or without subcortical sclerosis,

iv. No deformation due to subcortical cyst, surface erosion, osteophyte, or generalized sclerosis

C. Osteoarthritis

i. Deformation due to subcortical cyst, surface erosion, osteophyte, or generalized sclerosis

2.e Summary of the literature

It has now become widely accepted that the modality of choice for the assessment of osseous changes in the TMJ is CBCT. Osseous changes that will be considered for this study include sclerosis of the cortical bone surfaces, flattening of the condyles and erosions of the condyles. These osseous changes imply the possible early signs that one might be able to detect in CBCT images (Alkhader *et al*. 2010). In addition, osseous changes of lipping and osteophyte formation were also recorded.

Chapter 3

3.a - Aim:

We compared osseous changes in the mandibular condyles in patients presenting to the Oral Health Center, Tygerburg Campus, with and without clicking of the temporomandibular joint.

3.b - Null Hypothesis:

No osseous changes occur on the condyles of patients reporting a clicking of the temporomandibular joint(s).

3.c - Objectives:

1. to assess early osseous changes of the condyles using cone beam computed tomography (CBCT), with respect to erosions, flattening, lipping, sclerosis and osteophyte formation of the condyles.
2. compare these features across case and control groups

3.d - Materials and methods:

i. Study design:

The study design was a case - control study.

ii. Sampling:

Inclusion criteria:

Case group

1. Patient had to exhibit a click of the temporomandibular joint.
2. Patients in the age group between 20 and 55 were considered for the study.
3. Patients had to have a minimum of 24 teeth.

Control group

1. Patients must have minimum of 24 teeth. Missing anterior teeth that are being replaced by implant prosthesis were considered.

Exclusion criteria:

1. Pregnant women were excluded.

2. Patients with previous diagnosed TMD were excluded.

3. Patients that presented with acute trauma to the head/neck region.

iii. Sampling process:

Source of case group (group A):

The source of the group A was patients that attended the oral health center, Tygerburg campus for treatment. Patients undergoing a screening or examination procedure when attending for any treatment in the sifting department that presented with clicking of the temporomandibular joints was selected for inclusion. These patients were informed about the study and if willing, asked to provide consent for taking part in the study. 25 patients that presented with clicking of the temporomandibular joint were considered for the study after an additional examination by the researcher.

Additional routine radiographs will be performed for the priority treatment that the patient (group A) is attending for on the day.

Source of control group (group B)

The actual records of all CBCT cases were examined for patients that presented for treatment other than TMD. 25 patients were drawn from the records and analyzed. An attempt was made to match the ages to that of the case group as close as possible.

The patients from group B were contacted telephonically to be informed of the study. They were asked if any clicking noise was heard during opening or closing of the mouth.

If no clicking was noted, patients were informed that this study would include their records to assess the TMJ status.

iv. Ethics clearance:

An application for ethical clearance was submitted to the University of the Western Cape ethics board (Project registration number – 12/10/58). Written informed consent was obtained from each patient in the case group. Anonymity was preserved at all times as the data made use of an assigned patient number and no use of any name, folder number or any identification method that could link the records to the patient. Only the researcher had a copy of the correlated patient identification, and assigned patient number, which was kept in a secure location.

All patients had the right to withdraw from the study at any time and necessary information and risk was explained prior to commencement.

The patients in the control group already had a CBCT exposure and were informed about study, the requested use of their records, and the anonymity of the study. They were given an option to refuse their records from being part of the study.

3.e. Data collection:

Upon achieving consent via a consent form, patients were examined again to confirm an asymptomatic click of the temporomandibular joint.

These patients (group A) were exposed to a low dose, high resolution cone beam computed tomography dose using a Newtom VGI CBCT machine. The field of view used was a minimal 7cm (height) by 12cm allowed for the Newtom CBCT machine that provides a view of the mandible, maxilla and the temporomandibular joints on both sides. The study reconstruction was modified in the NNT version 2.21 software program, to view the right and left temporomandibular joints on the axial, frontal and sagital planes as well as oblique view. A 3-dimentional reconstruction of the condyles was made to examine the shape of both the right and left condyles. This provided a total of 100 joints that were examined.

The author and a senior member of the Maxillofacial Radiology Department examined all reconstructions and consensus on diagnostic criteria was reached. Osseous changes of the condyles that were recorded included: erosions, flattening, lipping, sclerosis and osteophyte formation.

3.f. Data processing and analysis:

The study volumes obtained from the CBCT imaging were reconstructed to provide axial, coronal and sagittal views of the mandible, maxilla and temporomandibular joint. Osseous changes were assessed for positive (yes) or negative (no) findings for flattening, erosions, lipping, sclerosis and osteophyte formation of the condyles. The patient's gender and age was recorded to correlate age and sex with the findings. The author and a senior member of the Radiology Department examined the reconstructed images in batches of five to negate fatigue. Only findings that achieved consensus were reported on. Positive and negative findings were plotted on the Microsoft excel data collection table (appendix 4)

3.g. Statistical analysis

Statistical analysis was done using R – Development Core Team (2012). R: A language of environment for statistical computing. R foundation for statistical computing, Viena, Austria. ISBN 3-900051-07-0

URL - HTTP://www.R-project.org/.

Chapter 4

Results

The proportions of 'yes' responses to the different variables: erosions r (right), erosions l (left), flattening r, flattening l, lipping r, lipping l, sclerosis r, sclerosis l, osteophyte r and osteophyte l were tabulated as prevalence's (figure 1 - graph). P-values were obtained using chi-squared test applied to a cross tabulation for each variable by group. The mean age for the control group was 35.04 years and case group was 30.64 years. Both age and gender demonstrated no statistical significance in analysis. The prevalence of erosions r in the case group was 44% compared to 36% in the control group, erosions l showed 44% versus 32%, flattening r showed 48% compared to 40%, flattening l 72% compared to 56%, lipping r showed 16% and equal 16% in control, lipping l showed 16% compared to 4%, sclerosis r 72% compared to 24%, sclerosis l showed 52% compared to 48%, osteophyte r showed 4% compared to 0 in control and osteophyte l showed 8% compared to 4% in the control group (figure 2 - graph).

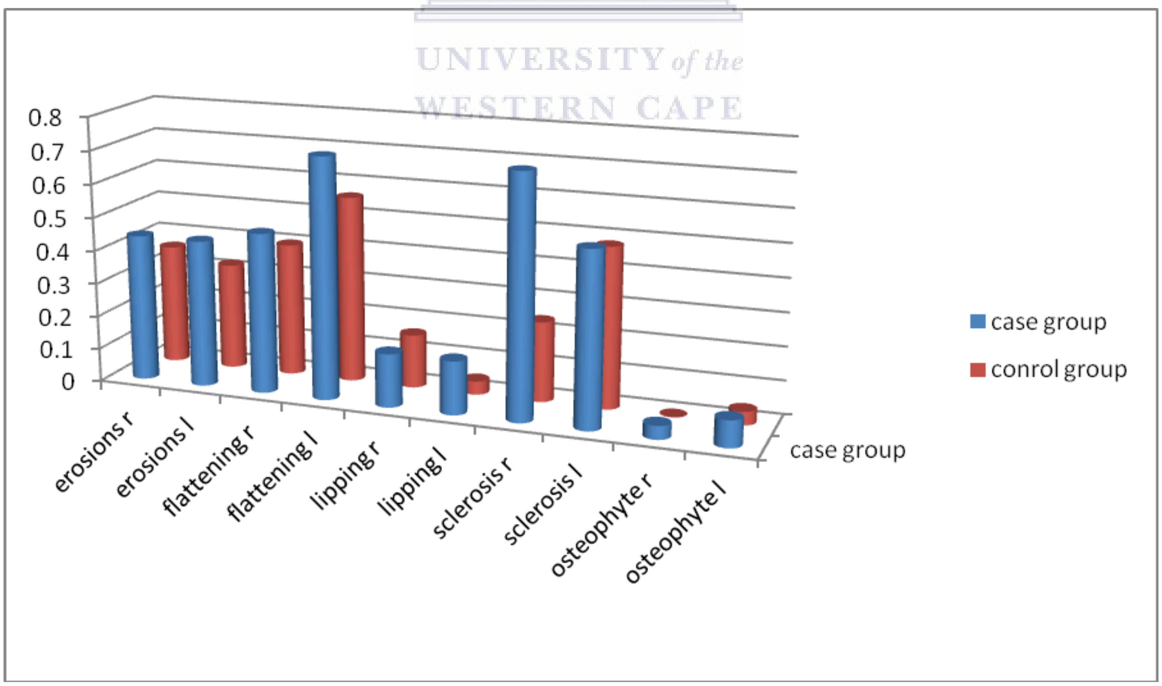

figure 1- graph of proportions of incidence (%) of the various osseous changes observed in case versus control groups

An observation of note is the prevalence of the variables were equal to or greater in the case group than the control group. The only variable that showed statistical significance (figure 2 - graph) between the two groups was sclerosis r (P = 0.002).

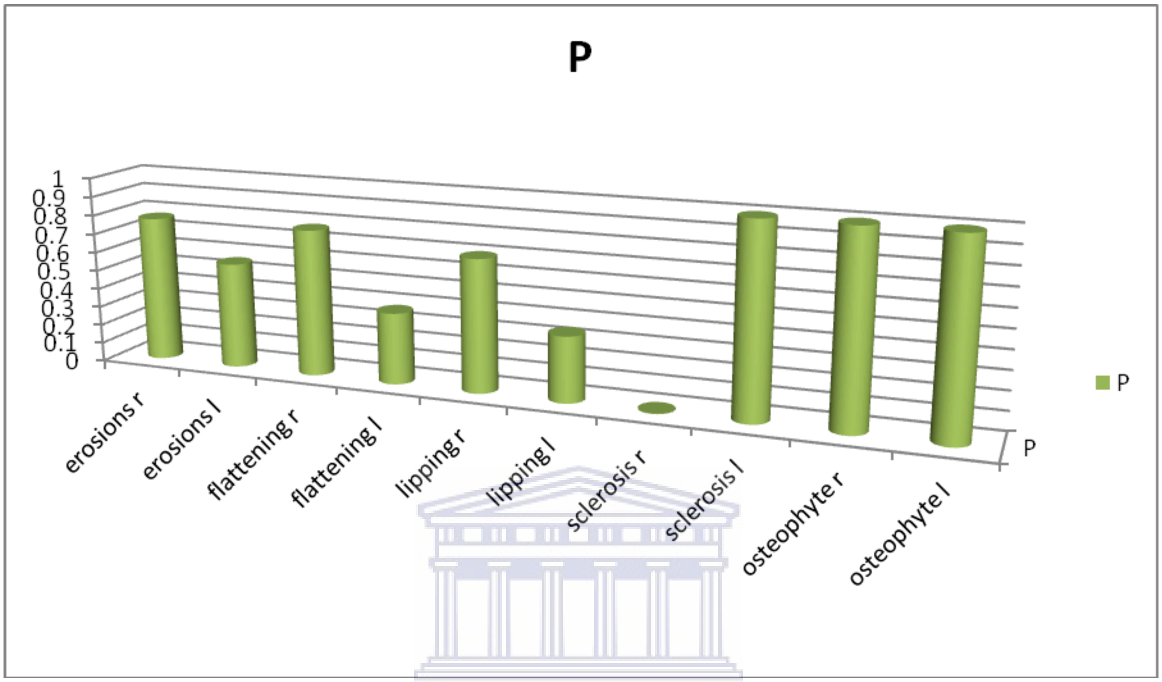

figure 2 - Graph showing the P values between case and control group. Sclerosis r shows statistical significance (P=0.002).

Because the observed prevalence in the Case group is greater than or equal to that in the Control group for every variable, it seems worthwhile to consider a multiple logistic regression of Group on all of the other variables with the view to calculating a predictor of Group membership, or equivalently a function that maximizes the discrimination between groups. The results are summarized in graph 3 below. The abscissa is Group membership, coded 0 = Control, 1 = Case. The ordinate is the predicted probabilities of group membership from the regression. The horizontal line is drawn at the median (0.447) of the predicted probabilities. In the control group the number of points below the line 20. The number above is 5. In the Case group the number below the line is 5 and the number above is 20.

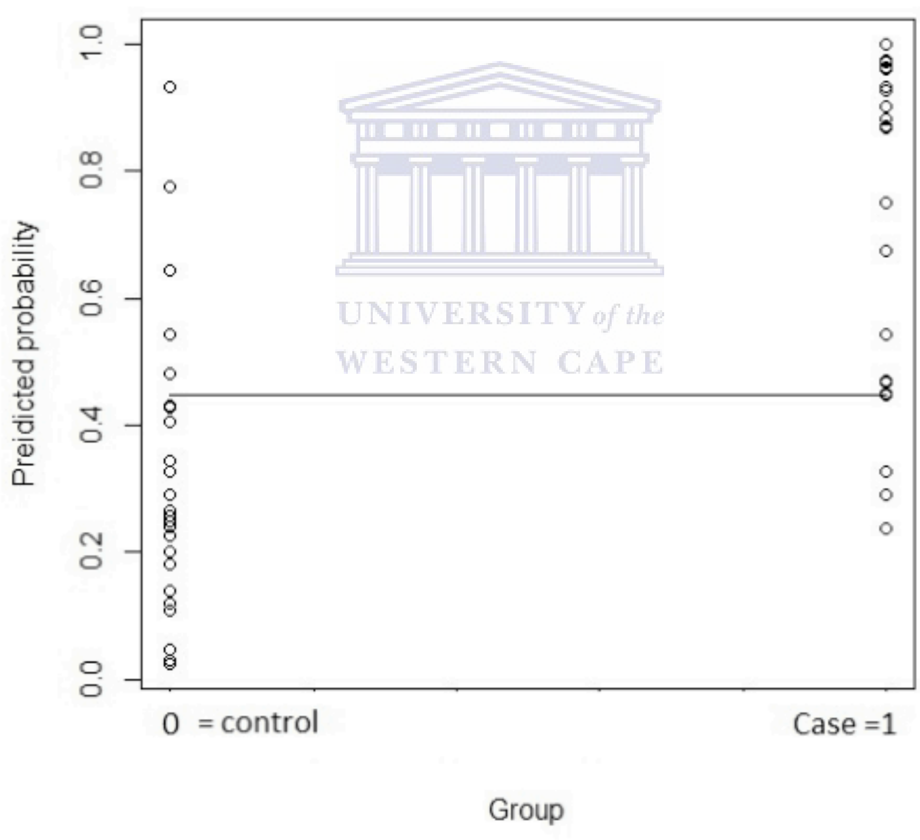

Figure 3 – Graph of predicted probability of osseous changes occurring in control group and case group

A chi-squared test applied to this table gives the result: observed chi-square = 15.68, df = 1, p-value = 7.501e-05, (<0.0001) confirming that the discrimination is statistically significant. A visual comparison of the incidence of osseous changes can be observed in figure 4 and 5. It proved useful to compare the osseous changes in the case versus the control group. Examples of the variables that were assessed: erosions (figure 6,7,8 and 9); flattening (figure 7); lipping (figure 9); sclerosis (figure 6,7,8,9); osteophyte formation (figure 6)

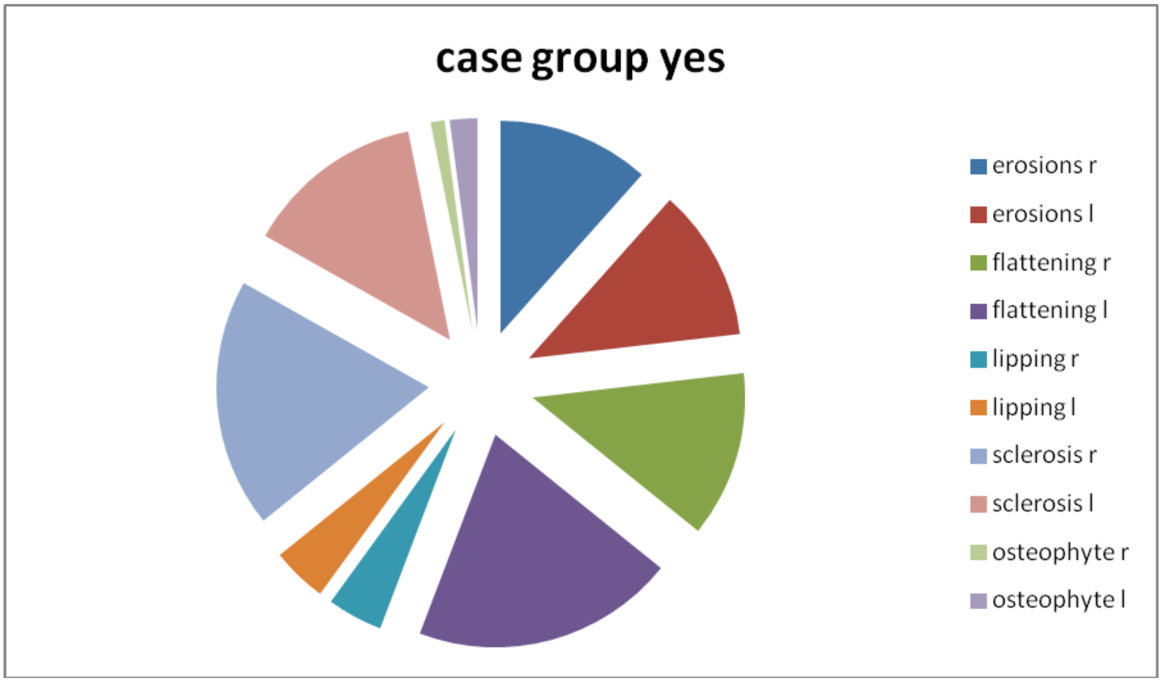

Figure 4 - Pie chart showing percentage of osseous changes in the case group

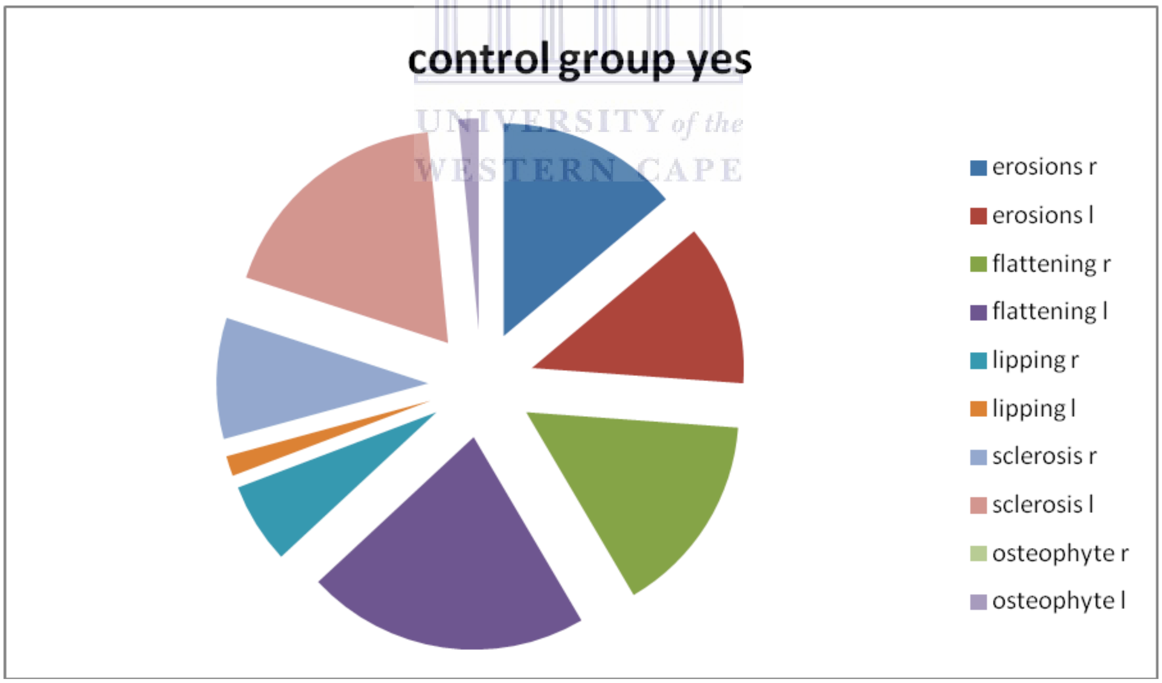

Figure 5 - Pie chart showing the percentage of osseous changes in the control group

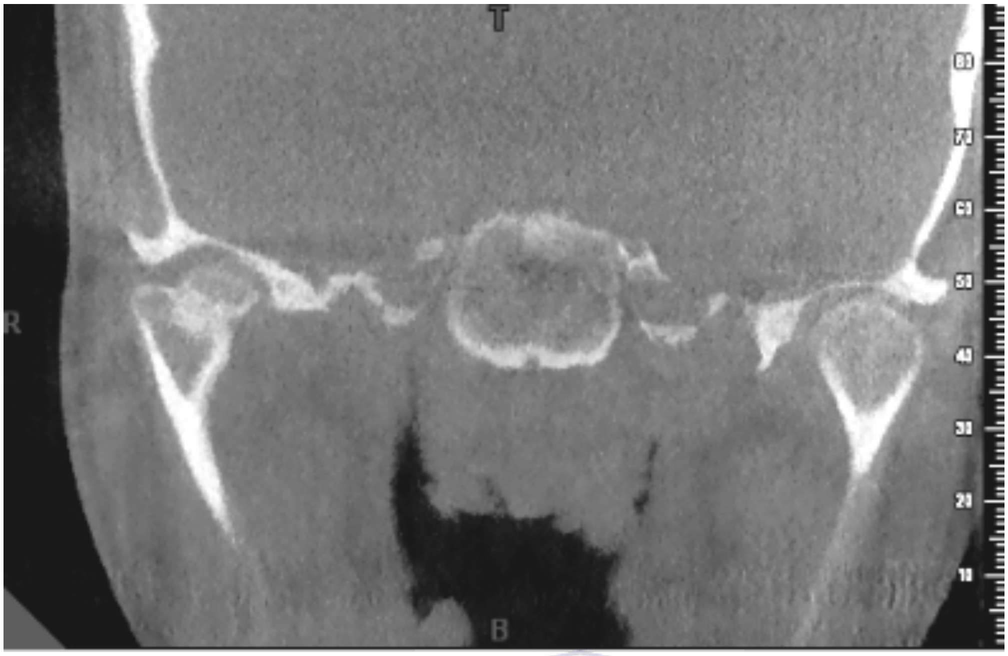

Figure 6 - Axially corrected coronal CBCT view of right and left condyles. right condyle shows subchondral sclerosis and deviation in form with large osteophyte appearance, sclerosis and flattening of the eminence, mild erosion of the left condyle. Patient had asymptomatic click.

Figure 7 - Axially corrected coronal CBCT view of left condyle showing erosion, sclerosis of the subchondral bone and flattening of the superior aspect of the condyle. mild evidence of lipping on medial aspect and erosion of the eminence. Reduced joint space medially.

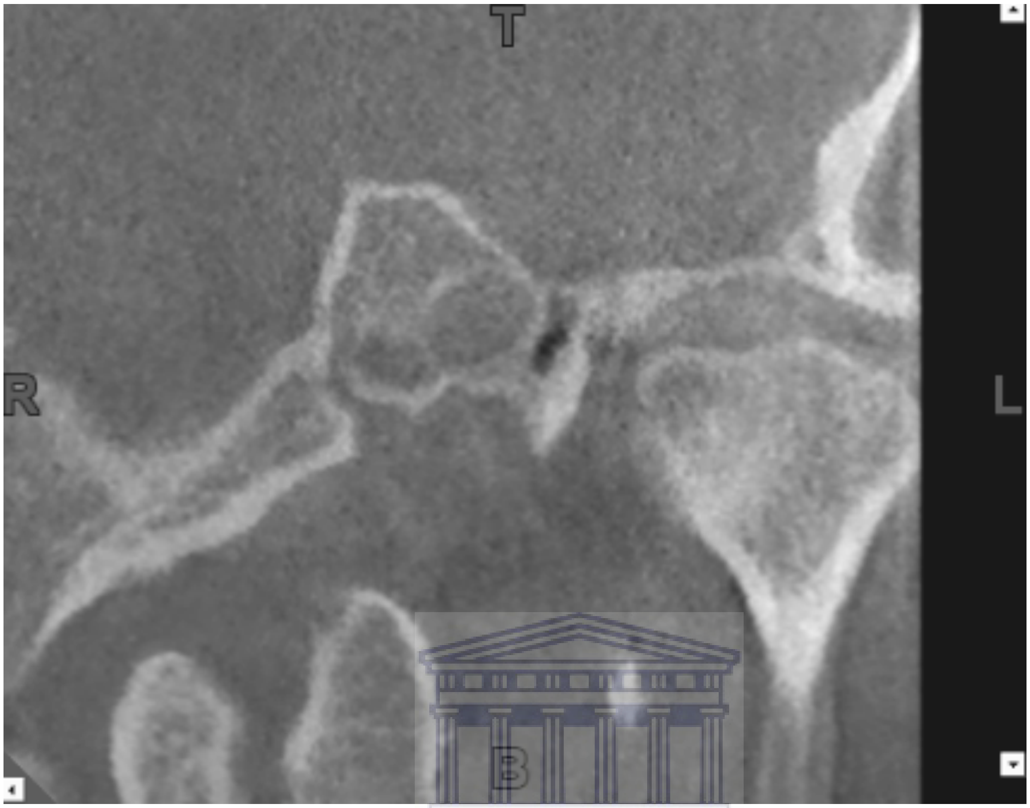

Figure 8 - Axially corrected coronal CBCT view of left condyle showing erosions, subchondral sclerosis and shape deformity. Mild erosion of the eminence also visible.

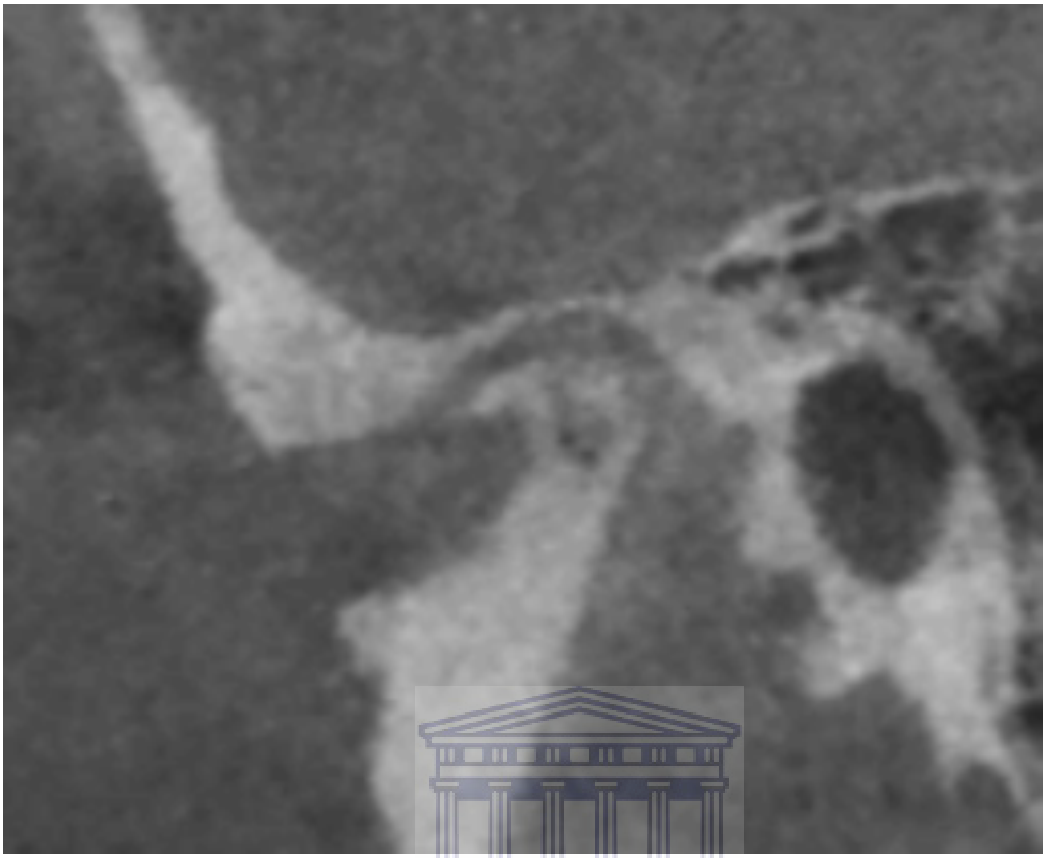

Figure 9- sagittal view showing lipping, erosion and sclerosis of the condylar head, erosions in the glenoid fossa and flattening of the articular eminence.

Chapter 5

a. Discussion

This study varied from those mentioned in the literature review, as it did not compare different imaging modalities, but rather used the most appropriate modality as deduced from the literature, to obtain vital radiographic information. This can then be correlated with clinical symptoms to guide and advice the treatment of early TMD.

The graph in figure 3 gives a clear understanding of the results. The predicted probabilities between the case and control groups can easily be visualized. A median (0.447) through the graph implicitly shows that control group has 20 points below the median and the case group has 20 points above. This also implies a statistical significance between the both group discriminations.

Osseous changes were observed in both the case and the control groups. The proportions of these changes in the case group were equal to or more compared to the control group. Erosions (32% - 44%), flattening (40% - 72%) and sclerosis (24% - 72%) were the more common finding. Lipping was observed in 4% to 16% of the condyles evaluated and osteophyte formation (0 – 8%) was the least occurring change. This reiterates previous notions that some osseous changes are normally found on the condyles, in asymptomatic middle to older patients, due to wear and tear of the joint. Some osseous changes are associated with osteoarthritis; like erosions, lipping, subchondral cyst and osteophyte formation. Snearly (2012) reported that erosion of the condyle is a sign of the earliest manifestation of degenerative changes.

Badel *et al* (2009) did a study comparing the osseous changes in patients (n = 16) confirmed with osteoarthritis and asymptomatic volunteers (20 dental students). They found flattening in 30% of osteoarthritic joints, 30% showed sclerosis and 15% showed osteophyte formation. It is interesting to note that only 2 dental students showed osseous changes. In another study, Nah K.S (2012) reported on a retrospective analysis of CBCT records of 440 TMJs. He observed prevalence for the following variables: sclerosis (30.2%), erosions (29.3%), flattening (25.5%), osteophyte formation (8%), subcortical cyst (5.5%) and deviation in form (13.2%). The incidence of his findings closely mimic those in this study, however were conducted in patients with confirmed TMD and not as incidental findings in undiagnosed patients.

Ossoeus Changes

The variables used to assess the osseous components have been classified by some as normal or associated with disease. The RDC/TMD guidelines classify osseous changes as either normal, indeterminate or osteoarthritis. The use of ”indeterminate” category associates osseous changes with normal wear and tear and does not denote an overt diagnosis of degenerative joint disease or osteoarthritis (Ahmad *et al. 2009*).

i. - Erosions

Surface erosions of the bony components of joints are considered one of the diagnostic features of degenerative joint disorders. It can be considered an important diagnostic feature of osteoarthritis. Early signs confine the erosions to the cortical margins but could easily be misdiagnosed as it can represent a shape distortion or variation. In this study 44 % of right condyles in the case group showed erosions compared to 36% in control group. The left side also showed 44% in case group compared to 32% in the control group. An increased incidence in case group is observed. Advanced disease progression shows erosions of the condyle to exhibit subcortical cyst formation as well. This was only observed in one patient in the control group and was not regarded as a true cyst but rather an area of osseous degeneration.

ii. - Flattening

Flattening of the condyle was not regarded as a diagnostic feature of osteoarthritis, but rather as a sign of remodeling of the TMJ in response to wear and tear of daily function. In the right condyles, 48% showed evidence of flattening compared to 40% in the control group. The left condyle showed 72% in the case group and 56% in the control group. The natural and somewhat complex variation of the head of the condyle can provide a misleading picture for flattening. In some planes the condyle appeared to be flattened. 3D rendition of the condyle and observation in all 3 planes was vital to appropriately diagnose the presence of flattening. One may speculate whether the increase incidence of flattening in the left condyles could be associated with the muscle tone and prominent muscle usage of right-handed people versus left-handed people.

iii. - Sclerosis

Ahmad *et al* (2009) mentioned in the RDC/TMD diagnostic criteria that one-third of patients with subcortical sclerosis presented with pain and TMD. Sclerosis confined to the cortical margins and demonstrating a wider than normal sclerotic bony margin may be considered as normal or variation of normal. This is another feature that was found in normal functional TMJ's. It is difficult to grade the severity of sclerosis of the cortical outline if it is confined to a small part of the condyle. The extent of the sclerosis beyond the cortical margin and into the subchondral space is also difficult to assess as no definitive landmarks are available to differentiate a mild, moderate or severe form. Severe or generalized sclerosis of the condyle is reported as a diagnostic feature of osteoarthritis. (Ahmad *et al*, 2009)

iv. - Lipping

In this study, the right condyles of 16% of the case group showed lipping as well as 16% of the control group. The left condyle showed 16% incidence of lipping whereas the control group incidence was 4%. Lipping of the condyle is considered an advanced diagnostic feature of degenerative joint disease. In some cases the condyle exhibited a classic 'bird-beak' appearance of the anterior condyle. The low incidence of this osseous change confirms that lipping is associated with advanced degenerative disease.

v. - Osteophyte formation

Osteophytes are a common diagnostic feature of osteoarthritis. It Indicates cartilage degeneration and most often is associated with pain. In this study the right condyles of the case group showed an incidence of 4% where the control group showed none. The left condyles showed an 8% incidence and the control group showed 4%.

The RDC/TMD guidelines indicate that osseous changes including erosions, osteophytes, generalized sclerosis and subcortical cyst formation are diagnostic criteria for osteoarthritis. Flattening and sclerosis confined to the cortical margins are considered indeterminate criteria for osteoarthritis (Ahmad *et al* 2009).

In this study, one of the inclusion criteria was the presence of 24 teeth or more. Aly *et al* (2011) compared the morphological changes in 13 patients. 8 of whom had a complete dentition, while the other 5 had bilaterally missing lower posterior teeth. They found no support to their hypothesis that loss off occlusal support caused osseous changes in the TMJ and admitted that they assessed a very small sample size.

The TMJ is regarded as one of the most actively used joints in our bodies and are susceptible to wear and tear. The effects of this daily use can be exhibited by osseous changes that can mimic degenerative joint disease. The results of this study indicated that osseous changes can be observed in patients that have an asymptomatic clicking of the joints. Although changes were observed in the control group, the incidence of bony changes was equal to or greater in the case group. The clicking symptom has been shown to resolve with some non-invasive therapeutic measures or the condition may progress to a degenerative joint disease. Koyama *et al* (2007) followed up on patients with confirmed TMD. They initially examined 1032 joints of 516 patients and then followed up the investigations of 102 joints at intervals between 3 and 18 months (mean 13.4 months). The patients were undergoing conservative treatment such as splint therapy during the follow up period. 63% of the initial joints showed osseous changes and 68.6% of the follow up joints showed osseous changes. There was an increase in number of joints that showed osseous changes and some of the variables observed showed increased prevalence and some variables showed a decrease in prevalence.

b. Conclusion

Osseous changes of the condyles were found in both the case and control groups. The predicted probability of these osseous changes occurring in both groups was statistically significant. A comparison of the incidence between case and control groups showed sclerosis (right condyle) to be the only statistically significant variable. Osseous changes can be found in patients that present with an asymptomatic click of one or both temporomandibular joints. A prolonged clicking of the TMJ warrants a clinical examination and adequate radiographic examination with CBCT, if available.

c. Recommendations

i. There is a lack of clarity in the literature when diagnosis with regards to the severity of the osseous changes on the condyles. Badel *et al* (2009) concluded that minimal bony changes may be considered as normal. The literature is vague about the progression of minor osseous changes to degenerative joint disease. When should a sign or symptom be considered mild, moderate or severe? The early symptom of a progressive disease should not be left to resolve and a non-invasive treatment should be initiated.

ii. We recommend further studies to observe the incidence of osseous changes in right versus left condyles. Some patients in the case group complained of a click on the right side and the observed changes were more prominent on the opposite joint. It will be interesting to deduce if any osseous changes would be correlated to corresponding joints in patients who are right handed or left handed. Does general and dominant muscle tone play a role and which joint will show more changes?

iii. More studies need to be conducted to evaluate the osseous changes of the articular eminence and glenoid fossa of the temporal bone. A progressive remodeling disorder of a joint shows osseous changes of both bones involved.

iv. Similar studies need to be conducted with a larger sample size to make results more meaningful.

v. Cervidanes et al 2010 conducted the first study involving virtual 3D models that precisely quantify condylar morphology. They make use of surface correspondence, a 3D surface mapping technique, with the aid of CBCT to capture the changes of the osseous structures. This has potential for further studies to visually evaluate progression and efficacy of treatment modalities.

There are various treatment options for the management of TMD. Early treatment usually focuses on non-invasive means to treat the clicking. A thorough clinical history together with radiographic examination is warranted in patients with early signs, in this case a persistent click of the TMJ. Patients in this study will be contacted to explain the results and asked to attend the TMJ clinic. Protocols and guidelines specific to these patients need to be drawn up for long term management. These should include physiotherapy as an on-going home exercise, the use of non-steroidal anti-inflammatory medication in patients who show progressive symptoms, the need for evaluation for bite plate therapy and regular follow up visits.

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Appendix 1

Subject information letter – case group

Bone changes of patients with clicking on opening or closing the mouth – on CBCT xrays.

My name is Dr Shoayeb Shaik, and I am a qualified dentist, currently studying further in the Radiology Department of the University of the Western Cape.

You have been asked to take part in this study because one or both of your joints that control the opening and closing of your mouth clicks, either on opening, closing, or both.

Research shows that this click can progress into a disorder of the joint. I am asking you to have a radiograph taken so that I can examine you for any early signs, and direct your treatment if need be. The information I get from this radiograph will help in your treatment and will also be used for research purposes.

Procedure:

I will examine your joint once again to see if the jaw does make a sound when you open or close. If this is confirmed, you will have one Cone Beam Computed Tomography examination. This modern piece of equipment will allow me to see the bones and even allow the conversion of the image into a 3D version.

This will be done in the Radiology Department in this facility. You will be asked to stand in a room in front of an x-ray machine. Your head will be kept in place with a Velcro strap so that you don't move your head. The machine will move around you twice. There is no pain or discomfort in doing this procedure. This procedure will take no longer than 5 minutes.

Possible benefits:

This study will allow us to gain knowledge of the effects of the clicking on the joints. Whilst you may not have any pain or discomfort from this clicking, we will be able to assess if there is early signs of damage. Information gained from this study will allow us to improve the treatment of the joint disorders and maybe save people from pain and discomfort later in life.

Possible Risks:

The radiographs taken in this kind of study generate a total amount of radiation which is less than 1% of the annual dose expected in normal life.

Confidentiality:

Your personal records related to this study will be kept with the utmost confidentiality. Assess to your records will always be restricted. Your name will not be associated in any of the data forms. Any publications of the results obtained from this study will not reflect your name.

Voluntary participation:

Participation in this study will not affect your current treatment in any way.

You are not obligated to take part in this study. You may decline at any time and your continuing treatment will not be compromised. Your participation is of great value and will be appreciated.

Cost:

There is no money given for taking part in this study.

You will not be charged for the cone beam CT but the rest of your treatment will be billed as normal.

Contact information

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Appendix 2 - Consent form

Bone changes of patients with clicking on opening or closing the mouth – on CBCT radiographs.

If you accept to take part, please fill in the following document and sign where applicable. (Please tick next to your answer)

1. Do you understand that you have been asked to take part in a research study? Yes __ No __

2. Have you read and received a copy of the information sheet? Yes __ No __

3. Do you understand the benefits and risks? Yes __ No __

4. Have you had the opportunity to ask questions about the research? Yes __ No __

5. Do you understand that you are free to withdraw at any time and this will not affect your future dental treatment? Yes __ No __

6. Do you understand the confidentiality of your records And understand who will have access to your records? Yes __ No __

The research study was explained to me by ______________________ and I agree to take part in it.

Patients signature: ______________________ Date: ____________________

Printed name: ______________________ Place: ____________________

I believe that the person signing this form fully understands this study and voluntarily agrees to participate.

Signature of researcher: ______________________ Date: ____________________

Printed name: ______________________

Appendix 3

Subject information letter – control group

Bone changes of patients with clicking on opening or closing the mouth – on CBCT radiographs.

Good morning/ afternoon

My name is Dr Shoayeb Shaik, can I please have two minutes of your time. If it is not convenient for you now, can you give me a time to call back that will be more convenient for you?

I am doing a study on the changes in the jaw bone and joint that presents when someone hears a clicking sound when opening or closing the mouth. I need to ask you to come in for a brief examination of your joints. If you are unable to come in, will it be possible for me to come to you, at your convenience.

On examination, if the patient does have a click, it will be suggested that the patient enquire about the temporomandibular joint clinic at the faculty of dentistry and have a practitioner take a closer look.

If no clicking on examination is found, patient will be informed that author will be using their records to do a study that will help us understand these symptoms better, and be beneficial in the treatment of joint disorders. Your name will not be used anywhere and only I will know your details.

You may choose to be withdrawn from this study but I humbly urge you to please consider your inclusion.

Please enjoy your day further and thank you kindly for your time.

Appendix 4 page ___

Data collection form – osseous changes of the temperomandibular joint on CBCT images.

Case: ______ Control: ____

Instructions:

- Positive finding must be indicated with a tick
- Negative finding must be indicated with a X

Patient no.	Erosions		Flattening		Lipping		Sclerosis		Osteophyte		Cyst		Other	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L