12-1986

Pre-Orthodontic Radiography of the Temporomandibular Joint

Stephen G. Tracey

Abstract

PRE-ORTHODONTIC RADIOGRAPHY OF THE TEMPOROMANDIBULAR JOINT

by

Stephen G. Tracey, D.D.S.

The dental profession has given increased attention to temporomandibular joint problems in recent years. Many orthodontists have shown professional concern by taking pretreatment lateral tomograms to assess developmental abnormalities, previous injury, pathology, and condylar position. The purpose of this study was to determine the consistency of orthodontists in evaluating lateral tomograms and panoramic films, particularly when used prior to treatment. Lateral tomograms and panoramic films of 60 single joints were evaluated by 4 orthodontists on two separate occasions. A questionnaire was completed for each radiograph observed and responses were compared for interobserver and intraobserver aggreement. Statistically, results showed little to no interobserver agreement, regardless of the type of radiograph used, though a trend of agreement did exist more predominantly with tomograms. There was a greater trend for intraobserver agreement than interobserver agreement on each question. Because of the apparent lack of interobserver agreement, the use of corrected tomograms prior to orthodontic treatment must be questioned.

LOMA LINDA UNIVERSITY

Graduate School

PRE-ORTHODONTIC RADIOGRAPHY OF THE TEMPOROMANDIBULAR JOINT

by

Stephen G. Tracey, D.D.S.

A Manuscript Submitted in Partial Fulfillment

of the Requirements for the Degree Master of Science

in Orthodontics

December 1986

Each person whose signature appears below certifies that this manuscript in his/her opinion is adequate, in scope and quality, in lieu of a thesis for the degree Master of Science.

J. Milford Anholm, Associate Professor of Orthodontics, Chairman

Stanton Appleton, Associate Professor of Oral Diagnosis, Radiology and Pathology

Helene Engstrom, Associate Professor of Oral Diagnosis, Radiology and Pathology

Gary G. Morikone, Associate Professor of Orthodontics

INTRODUCTION

The dental profession has given increased attention to temporomandibular joint (TMJ) problems in recent years and many theories concerning the etiology and progression of TMJ pathology have been advanced.[1-4] Orthodontists have shown professional concern by taking pretreatment lateral tomograms of the TMJ in order to assess developmental abnormalities, previous injury, present pathology, and condylar position. This usually involves one tomographic slice of each temporomandibular joint and a submento-vertex radiograph which is used to determine condylar angulation and depth of the cut at which the tomograms are to be taken. Since the work of Ricketts (1953)[5], the tomographic technique has been used routinely on children undergoing orthodontic treatment in many practices throughout the United States.[6-8]

Radiographic evaluation of TMJ pathology has been discussed in a number of articles.[9-11] It has been stated that the tomographic technique shows true pathology to a greater extent than the transcranial, panoramic or transmaxillary projections, especially if there are questions concerning the joint space.[12-17] Evalution of any changes in the soft tissue part of the joint requires the use of arthrography, double contrast arthrography,[18-20] computed tomography,[21-23] or magnetic resonance.[24-26] Lateral corrected tomography provides good radiographic information regarding morphology and pathology of the bony components of the temporomandibular joint and has been discussed by numerous investigators.[27-30] Rather

than using average measurements, a submento-vertex radiograph is taken to try to more accurately determine condylar angulation and the depth of cut at which the tomograms are taken. Though the technique produces a more reliable, higher quality tomogram, it also means an increased amount of radiation exposure for the patient, especially in the area of the thyroid, which is positioned higher and considered more radiosensitive in children than in adults.[31,32]

Normally, three to five tomographic slices of each condyle are considered necessary to adequately evaluate bony structural abnormalities of the temporomandibular joint. One slice of the condyle, such as with the tomograms routinely used for pre-orthodontic TMJ screening, will only show joint space and bony abnormalities in the region of that slice, which hopefully is taken in the central portion of the condyle since the central two-thirds of the joint region is the area considered most clearly reproduced tomographically.[13] Using a one slice tomographic technique assumes that the lateral pole and the medial pole are normal or abnormal to the same extent as the region of the slice. However, it has been shown that condylar pathology is more frequently found in the lateral pole.[33] Another questionable assumption is that the condylar position demonstrated in a one slice tomogram is truly representative of its actual position in the fossa. These limitations seem to suggest that patients may be exposed to an increased amount of radiation for a questionable amount of information, and point to the fact that a panoramic film may be just as adequate as a

pre-orthodontic TMJ screening film as one slice tomography.

The panoramic film can be considered a curved surface laminagraph. However, angulation as well as the depth and width of the cut at which the radiograph is taken are usually based upon the teeth, not the TMJ. This means that unless the patient is positioned accurately, a consistent, reliable slice of the joint is not obtained on each film. Also, with most routine dental panoramic films the teeth are placed in an end-to-end bite while the film is being taken so as to assure that both the maxillary and mandibular dentition are in focus. This protrusive position makes it nearly impossible to make any definitive judgements about condylar position. If the evaluation of joint position is of primary importance, a panoramic film can be taken with the patient in centric occlusion, but the approximation of the condyle to the fossa would still be distorted due to differences between the angulation of the x-ray beam and the angulation and slope of the condyle and fossa. However, in spite of its limitations, panoramic films may be used to screen for condylar abnormalites and pathology. Additionally, since the panoramic film is routinely used by both the general dentist and the specialist in all phases of dentistry, no additional radiation exposure need be incurred by the patient. The thyroid absorbed dose of a panoramic film is only about 0.259 mGy when a protective lead collar is worn by the patient[32] versus approximately 15 mGy from a conventionally collimated submento-vertex radiograph, with which a lead collar cannot be worn, plus approximately

0.04 mGy from two lateral tomographic films.[34]

It is generally accepted that dental radiographs cannot be interpreted with the degree of precision, predictability, or objectivity that dental practitioners would like.[35] Even though it has been commonly accepted that persons trained in the analysis of radiographs would be better able than the untrained to agree among themselves, endodontic studies have shown that complete agreement among clinicians regarding whether or not an area of pathosis is radiographically observable is around 50% at best.[36-38] Considering that the radiographs must be of good quality, we can still only say whether or not an abnormality is apparent from radiographic evidence. We cannot say with any certainty whether or not an abnormality actually exists.

Abnormalities that can be revealed by TMJ radiography in adults are considered under the headings: 1) Congenital and acquired developmental conditions, 2) Acute trauma, 3) Nontraumatic and degenerative arthritis, 4) Bony ankylosis of the joint, 5) Generalized disorders of the bone, 6) Abnormalities of function, and 7) Postural derangements.[9]

OBJECTIVE

Any diagnostic test must exhibit both validity and reliability to be maximally useful. To establish a correct diagnosis, the diagnostic test must be reliable; that is, multiple examiners must be able to arrive at the same diagnosis when presented with the same diagnostic data, and the same examiner must agree with himself/herself on repeated readings. This is not to say that agreement alone constitutes a correct diagnosis. The diagnostic test must also be valid; that is, the data must accurately reflect the physiologic conditions present,[38] and the examiners must have sufficient expertise to make a correct diagnosis.

Though both the panoramic and single slice tomographic techniques have been widely used, to the best of the author's knowledge, there has been no study evaluating the reliability, that is agreement between multiple examiners, of findings on one slice tomograms and panoramic films, and their effect on future orthodontic treatment.

The objective of this study was to assess whether it is possible for orthodontists, using these radiographs, to consistently agree on findings dealing with joint pathology, developmental abnormalities, and condylar position, and whether or not these findings would alter initial orthodontic treatment plans.

METHODS AND MATERIALS

Tomograms and panoramic films were obtained from 30 charts of asymptomatic (at initial exam) orthodontic patients at the LLU School of Dentistry Graduate Orthodontic Clinic and 30 charts of symptomatic TMJ patients at the LLU Medical Center TMJ Clinic. The radiographs displayed varying degrees of radiographically observable TMJ abnormalities and/or pathology. A total of 120 radiographs (60 tomograms, 60 panoramics with TMJ only visible) showing 60 single joints, right or left, were accurately reproduced on photographic slides.

Standardized 35 mm. slide reproduction of the radiographs was accomplished as follows: A radiographic illumination box was constructed measuring approximately 14 inches high by 14 inches wide by 24 inches deep. For maximum internal light reflection the inside was painted white while the outside was painted black to minimize external glare. Ventilation holes were placed for heat dissipation away from the light source which was a 3200° K incandescent bulb. The illumination surface onto which the radiographs were affixed was 1/8 inch thick white translucent plexiglass. The photographic equipment consisted of a Pentax ME Super 35 mm. camera body with a Kiron 105 mm. macro lens. Magnification was approximately 1:2.5 to allow for accurate size reproduction of the radiographic image at observation. The slides were further standardized by matting each joint film with black construction paper containing a 45 mm. by 55 mm. opening so that only a uniform area including and surrounding the joint was visible. Exposure

settings consisted of an F-stop of 2.8 with additional light transmission provided by setting the exposure-adjustment control at 1/4 x. The camera's aperture-priority mode was used to automatically set shutter speed, therefore allowing compensation for the variation in film densities of the radiographs. Accurate color balance was achieved by using Kodak Ektachrome 160 Tungsten film and a 0.05 Cyan gelatin filter mounted in a Cokin Systems lens holder. A tripod was utilized for stability during the photographic process.

A Kodak Carousel 5600 slide projector with built in Slide Scan screen was used for observation of the slides. The Slide Scan screen was adjusted and focused in such a way that the projected image duplicated the size of the original radiographic image to the nearest 0.5 mm.

The slides were organized at random and then evaluated separately by four orthodontists who diagnose and treat TMJ related problems. Each orthodontist was asked to complete a questionnaire (Attachment 1) for each slide assessed. Allotted time to assess all of the slides was approximately 2 hours for each orthodontist.

At a later date (at least one day), the same orthodontists repeated the procedure as outlined above; viewing the same slides (but in reverse order) and completing the same questionnaire for each slide. Both observations were utilized to study interobserver and intraobserver agreement.

Observers marked their answers for each question on a line exactly 10 cm. long. Since the line represented a range of

responses, marks were to be made anywhere on the line corresponding to each observer's personal assessment of the question as it related to the radiograph being observed. Scoring of the responses was based upon the lines being divided into 1 cm. increments, 0 through 10, from left to right. Responses were scored to the nearest centimeter increment, up or down.

Statistics: Each of the questions were analyzed for all tomograms and panoramic views, both together and separately, across the five observers for interobserver agreement using Analysis of Variance. Intraobserver agreement for both types of radiographs separately was analyzed utilizing the Paired T-test.

RESULTS

Statistical results for each question, numbered 1 through 9, will be reported as follows: First summaries of interobserver agreement for panoramics and tomograms together, panoramics, and tomograms will be made followed by summaries of intraobserver agreement for panoramics and tomograms. Unless otherwise noted, there was a complete range of responses given by all observers for each question.

1. WHAT IS THE CONDYLAR POSITION (ANTERIOR/POSTERIOR)?

Interobserver Agreement

Panoramics and tomograms together:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 4.7 for Observer 4 to 7.0 for Observers 2 and 3 representing a central to anterior average condylar position. Observers 2 and 3 showed apparent agreement with like mean scores of 7.0. (Table 1)

Panoramics:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged rather uniformly from 5.1 for Observer 4 to 9.0 for Observer 3, representing a central to anterior average condylar position. (Table 2)

Tomograms:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, p <

0.01). Mean scores ranged from 4.3 for Observer 4 to 6.6 for Observer 2 representing an approximately central average condylar position. Observers 1 and 4 showed near agreement with scores of 4.5 and 4.3 respectively. (Table 3)

Intraobserver Agreement

Panoramics:

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 1, showed a statistically significant difference (Paired T-test, $p < 0.01$) with a mean score of 6.3 for the first observation verses 7.1 for the second observation. This represented a shift of average condylar position to a more anterior position. (Table 4)

Tomograms:

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 2, showed a statistically significant difference (Paired T-test, $p < 0.01$) with a mean score of 5.6 for the first observation verses 7.5 for the second observation moving from a central to an anterior position. (Table 5)

2. WHAT IS THE CONDYLAR POSITION (VERTICAL DIMENSION)?

Interobserver Agreement

Panoramics and tomograms together:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 4.6 for Observer 2 to 7.6 for Observer 3 representing a central to inferior average condylar position. Observers 2 and 4 showed near agreement with respective mean scores of 4.6 and 5.1. (Table 1)

Panoramics:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 4.2 for Observer 2 to 8.2 for Observer 3 representing an approximately central to inferior average condylar position. (Table 2)

Tomograms:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 4.9 for Observer 2 to 6.9 for Observer 3 representing a central to inferior average condylar position. Observers 2 and 3 showed near agreement with mean scores of 4.9 and 5.1 respectively. (Table 3)

Intraobserver Agreement

Panoramics:

There was no statistical difference from observation 1 to observation 2 for any of the observers (Paired T-test, $p < 0.01$). (Table 4)

Tomograms:

As with the panoramic films, all four of the observers showed no statistically significant difference from observation 1 to observation 2 (Paired T-test, $p < 0.01$). (Table 5)

3. IS THE CONDYLAR POSITION WITHIN NORMAL LIMITS?

Interobserver Agreement

Panoramics and tomograms together:

As a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$), with mean scores ranging from 3.3 for Observer 3 to 5.8 for Observer 4 indicating a spread of responses in the No to Uncertain area. (Table 1)

Panoramics:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$) with mean scores ranging from 1.5 for Observer 3 to 4.9 for Observer 4. Observers 1, 2, and 4 show near agreement with mean scores of 4.6, 4.0, and 4.9 resectively, representing Uncertain responses with Observer 3's score of 1.5 representing a No response. (Table 2)

Tomograms:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$) with mean scores ranging from 4.2 for Observer 2 to 6.6 for Observer 4 indicating responses of Uncertain.

Observers 1 and 3 seemed to agree with mean scores of 5.1 and 5.2 respectively. (Table 3)

Intraobserver Agreement

Panoramics:

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 1, showed a statistically significant difference (Paired T-test, $p < 0.01$) with a mean score of 5.0 for the first observation verses 4.2 for the second observation, remaining essentally Uncertain but slightly more in the No direction. (Table 4)

Tomograms:

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 4, showed a statistically significant difference (Paired T-test, $p < 0.01$) with a mean score of 6.3 for the first observation verses 6.9 for the second observation, indicating a shift in the Yes direction. (Table 5)

4. DO YOU SEE ANY CONDYLAR PATHOLOGY?

Interobserver Agreement

Panoramics and tomograms together:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 3.9 for Observer 4 to

5.1 for Observer 1, representing slightly No to Uncertain responses. Observers 2, 3, and 4 showed relatively good agreement with mean scores of 4.2, 4.0, and 3.9 respectively. (Table 1)

Panoramics:

No statistical difference was seen among the four observers (ANOVA, $p < 0.01$) with mean scores ranging from 4.0 for Observers 2 and 3 to 5.2 for Observer 1 representing responses that could be classified as Uncertain. (Table 2)

Tomograms:

As with the panoramics, agreement was seen among the observers (ANOVA, $p < 0.01$). Mean scores ranged from 3.7 for Observer 4 to 5.1 for Observer 1 also representing responses from slightly No to Uncertain. (Table 3)

Intraobserver Agreement

Panoramics:

Of the four observers, two showed no statistically significant difference from observation 1 to observation 2 while two, Observers 3 and 4, showed a statistically significant difference (Paired T-test, $p < 0.01$) with mean scores changing from the first observation to the second observation, from 4.5 to 3.5 for Observer 3 and from 4.3 to 3.9 for Observer 4. (Table 4)

Tomograms:

Three of the four observers showed no statistically

significant difference from observation 1 to observation 2 while one, Observer 2, showed a statistical difference (Paired T-test, $p < 0.01$) with a change of mean scores from the first observation to the second observation in the No direction from 5.6 to 3.2. (Table 5)

5. DO YOU SEE ANY FOSSA PATHOLOGY?

Interobserver Agreement

Panoramics and tomograms together:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 1.6 for Observer 2 to 4.8 for Observer 1, representing responses from No to Uncertain. Observers 1, 3, and 4 seemed to show better agreement with respective mean scores of 4.8, 3.6 and 4.2. (Table 1)

Panoramics:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 1.5 for Observer 2 to 5.2 for Observer 4, again representing responses from No to Uncertain. Observers 1, 3, and 4 seemed to show agreement with respective mean scores of 4.8, 4.9, and 5.2, representing responses particularly Uncertain. (Table 2)

Tomograms:

When viewed as a group, statistically significant

difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged with a relatively uniform spread from 1.7 for Observer 2 to 4.9 for Observer 1, representing scores from No to Uncertain. (Table 3)

Intraobserver Agreement

Panoramics:

No statistically significant difference from observation 1 to observation 2 was seen for any of the four observers. (Paired T-test, $p < 0.01$). (Table 4)

Tomograms:

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 2, showed a statistically significant difference (Paired T-test, $p < 0.01$) from a mean score of 2.7 for the first observation to a definite No response of 0.6 for the second observation. (Table 5)

6. DO YOU SEE ANY DEVELOPMENTAL ABNORMALITIES?

Interobserver Agreement

Panoramics and tomograms together:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 0.6 for Observer 1 to 4.9 for Observer 4, representing responses from definite No to Uncertain. Observers 1 and 4 seemed to show agreement with mean scores of 4.7 and 4.9 respectively.

Interestingly, Observer 4 marked this question Uncertain for every radiograph on the second observation. (Table 1)

Panoramics:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 0.6 for Observer 2 to 5.0 for Observer 4 again representing responses from definite No to Uncertain. Observers 1 and 4 seemed to show agreement with respective mean scores of 4.9 and 5.0 although Observer 1 showed a complete range of responses for both observations of 0 to 10, while Observer 4 marked only Uncertain, or a score of 5, for every radiograph on the second observation. (Table 2)

Tomograms:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 0.7 for Observer 2 to 4.9 for Observer 4, representing responses from definite No to Uncertain. Observers 1, 3, and 4, and in particular Observers 1 and 4, seemed to show better agreement with respective mean scores of 4.5, 3.7 and 4.9. Again, while the other observers marked a complete range of responses from No to Yes for both observations, Observer 4 marked only Uncertain, or a score of 5, for all radiographs on the second observation. (Table 3)

Intraobserver Agreement

Panoramics:

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 3 showed a statistically significant difference (Paired T-test, $p < 0.01$) with mean scores moving in the No direction from 4.3 for the first observation to 3.2 for the second observation. (Table 4)

Tomograms:

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 2, showed a statistically significant difference (Paired T-test, $p < 0.01$) with mean scores becoming more definite in the No direction from 1.2 for the first observation to 0.3 for the second observation. (Table 5)

7. IS THE JOINT SYMPTOMATIC?

Interobserver Agreement

Panoramics and tomograms together:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged with a relatively uniformly from 4.7 for Observer 4 to 6.2 for Observer 2, representing of what would appear to be resonses from approximately Uncertain to slightly Yes. Interestingly, Observer 2 showed a range of actual responses of only

Uncertain to Yes, or scores from 5 to 10, for all radiographs on the second observation. (Table 1)

Panoramics:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores again ranged with a rather uniform spread from 5.0 for Observer 1 to 6.1 for Observer 2, also representing responses from Uncertain to slightly Yes. For this question, Observer 2 showed a range of actual scores of only 5 to 10, representing responses from Uncertain to Yes, for the panoramics alone on the second observation. (Table 2)

Tomograms:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). The mean scores ranged from 4.2 for Observer 4 to 6.4 for Observer 2 representing responses from slightly No to slightly Yes, with Observers 1 and 3 most closely agreeing with respective mean scores of 5.1 and 5.4 representing Uncertain responses. As with the panoramics, for this question, Observer 2 showed a range of actual scores of only 5 to 10, representing responses from Uncertain to Yes, for the tomograms alone on the second observation. (Table 3)

Intraobserver Agreement

Panoramics:

Three of the four observers showed no statistically

significant difference from observation 1 to observation 2 while one, Observer 2, showed a statistically signigicant difference (Paired T-test, $p < 0.01$) with a mean score of 5.4 for the first observation verses 6.7 for the second observation displaying a trend away from Uncertain in the Yes direction. (Table 4)

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 1, showed a statistically significant difference (Paired T-test, $p < 0.01$) with a mean score of 5.9 for the first observation verses 4.8 for the second observation, basically remaining in the Uncertain area but moving slightly in the Yes direction. (Table 5)

8. IF THIS JOINT WAS ASYMPTOMATIC, WOULD FINDINGS ON THIS X-RAY ALTER YOUR TREATMENT IN ANY WAY?

Interobserver Agreement

Panoramics and tomograms together:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 2.6 for Observer 3 to 4.4 for Observer 2, representing of what would appear to be a general clinical agreement of No to Uncertain. Observers 1, 3, and 4 seemed to show closer agreement, particularly Observers 1 and 4, with respective mean scores of 3.1, 2.6, and 3.0. (Table 1)

Panoramics:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 2.0 for Observer 1 to 3.6 for Observer 2, also representing of what would appear to be a general clinical agreement of No to Uncertain. Observers 1, 3, and 4 seemed to show closer agreement, particularly Observers 1 and 4, with respective mean scores of 2.0, 2.7, and 2.2. (Table 2)

Tomograms:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). The mean scores ranged rather uniformly from 2.5 for Observer 3 to 5.3 for Observer 2 representing responses in the No to Uncertain region. (Table 3)

Intraobserver Agreement

Panoramics:

Two of the four observers showed no statistically significant difference from observation 1 to observation 2 while two, Observers 1 and 2, showed a statistically significant difference (Paired T-test, $p < 0.01$). While Observer 1 moved in the No direction with a change in mean scores from observation 1 to observation 2 of 3.4 to 0.7, Observer 2 moved in the Yes direction, from No to Uncertain, with a change in mean scores from observation 1 to observation 2 of 1.7 to 5.5. (Table 4)

Tomograms:

Three of the four observers showed no statistically significant difference from observation 1 to observation 2 while one, Observer 2, showed a statistically significant difference (Paired T-test, $p < 0.01$) with a mean score of 7.1 for the first observation verses 3.5 for the second observation, showing a change in the No direction. (Table 5)

9. IF THIS JOINT WAS SYMPTOMATIC (CLICKING, PAIN, ETC.), WOULD FINDINGS ON THIS X-RAY ALTER YOUR TREATMENT IN ANY WAY?

Interobserver Agreement

Panoramics and tomograms together:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 2.5 for Observer 4 to 5.4 for Observer 2, representing a range of responses in the No to Uncertain region. Observers 1 and 2 seem to show closer agreement in the Uncertain area with mean scores of 4.6 and 5.4 respectively, while Observers 3 and 4 seem to show closer agreement in the No directon with respective scores of 2.9 and 2.5. (Table 1)

Panoramics:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 2.3 for Observers 1 and 4 to 4.3 for Observer 2, representing responses for the most part in the No region. Closer agreement was seen

among Observers 1, 3, & 4 with mean scores of 2.3, 2.8, and 2.3, respectively. (Table 2)

Tomograms:

When viewed as a group, statistically significant difference was seen among the four observers (ANOVA, $p < 0.01$). Mean scores ranged from 2.5 for Observer 4 to 6.9 for Observer 1, representing a range of responses from No to Yes. Observers 1 and 2 seemed to show closer agreement in the Yes region with respective scores of 6.9 and 6.5, while Observers 3 and 4 seemed to show closer agreement in the No region with respective scores of 2.9 and 2.5. (Table 3)

Intraobserver Agreement

Panoramics:

Two of the four observers showed no statistically significant difference from observation 1 to observation 2 while the other two, Observers 1 and 2, showed a statistically significant difference (Paired T-test, $p < 0.01$). While Observer 1 moved in the No direction with a change in mean scores from observation 1 to observation 2 of 3.8 to 0.8, Observer 2 moved strongly in the Yes direction, from No to Yes, with a change in mean scores from observation 1 to observation 2 of 1.8 to 6.8. (Table 4)

Tomograms:

Three of the four observers showed no statistically significant difference from observation 1 to observation

2 while one, Observer 2, showed a statistically significant difference (Paired T-test, $p < 0.01$) with a mean score of 8.9 for the first observation verses 4.2 for the second observation representing a strong shift from Yes to Uncertain/slightly No. (Table 5)

SUMMARY OF RESULTS

Statistically significant interobserver difference (ANOVA, $p < 0.01$) was seen for the observers on all questions for panoramics and tomograms together, and all questions except question number 4 regarding condylar pathology for the panoramics and tomograms separately. A much greater trend for intraobserver agreement was seen for both panoramics and tomograms with statistically significant difference (Paired T-test, $p < 0.01$) being seen on relatively few questions for either radiograph, varying from no difference on any of the questions regarding tomograms for Observer 3 to statistically significant difference on 6 questions regarding tomograms for Observer 2.

TABLE 1

INTEROBSERVER AGREEMENT- PANORAMICS & TOMOGRAMS

	Average Means				Sig. Difference
	Observer 1	Observer 2	Observer 3	Observer 4	
Horizontal Condylar Position	5.6	7.0	7.0	4.7	*
Vertical Condylar Position	6.0	4.6	7.6	5.1	*
Condyle w/i Normal Limits	4.9	4.1	3.3	5.8	*
Condylar Pathology	5.1	4.2	4.0	3.9	*
Fossa Pathology	4.8	1.6	3.6	4.2	*
Developmental Abnormalities	4.7	0.6	3.8	4.9	*
Is Joint Symptomatic	5.2	6.2	5.4	4.7	*
If Asymptomatic, Tx Altered	3.1	4.4	2.6	3.0	*
If Symptomatic, Tx Altered	4.6	5.4	2.9	2.5	*

* $p < 0.01$, Analysis of Variance

TABLE 2

INTEROBSERVER AGREEMENT- PANORAMICS

	Average Means				
	Observer 1	Observer 2	Observer 3	Observer 4	Sig. Difference
Horizontal Condylar Position	6.7	7.4	9.0	5.1	*
Vertical Condylar Position	5.9	4.2	8.2	5.1	*
Condyle w/i Normal Limits	4.6	4.0	1.5	4.9	*
Condylar Pathology	5.2	4.0	4.0	4.1	
Fossa Pathology	4.8	1.5	4.9	5.2	*
Developmental Abnormalities	4.9	0.6	3.8	5.0	*
Is Joint Symptomatic	5.0	6.1	5.7	5.2	*
If Asymptomatic, Tx Altered	2.0	3.6	2.7	2.2	*
If Symptomatic, Tx Altered	2.3	4.3	2.8	2.3	*

* $p < 0.01$, Analysis of Variance

TABLE 3

INTEROBSERVER AGREEMENT- TOMOGRAMS

	Average Means				
	Observer 1	Observer 2	Observer 3	Observer 4	Sig. Difference
Horizontal Condylar Position	4.5	6.6	5.1	4.3	*
Vertical Condylar Position	6.1	4.9	6.9	5.1	*
Condyle w/i Normal Limits	5.1	4.2	5.2	6.6	*
Condylar Pathology	5.1	4.4	4.1	3.7	
Fossa Pathology	4.9	1.7	2.4	3.3	*
Developmental Abnormalities	4.5	0.7	3.7	4.9	*
Is Joint Symptomatic	5.4	6.4	5.1	4.2	*
If Asymptomatic, Tx Altered	4.2	5.3	2.5	3.7	*
If Symptomatic, Tx Altered	6.9	6.5	3.0	2.7	*

* $p < 0.01$, Analysis of Variance

TABLE 4

INTRAOBSERVER AGREEMENT- PANORAMICS

Mean, Observation 1 / Standard Deviation
Mean, Observation 2 / Standard Deviation

	Observer 1	Observer 2	Observer 3	Observer 4
Horizontal Condylar Position	6.3 / 2.2 *	7.5 / 2.2	9.2 / 2.1	5.1 / 0.5
	7.1 / 1.9	7.3 / 2.5	8.8 / 2.3	5.1 / .04
Vertical Condylar Position	5.6 / 1.8	3.9 / 2.0	8.1 / 3.3	5.1 / 0.5
	6.2 / 2.2	4.6 / 2.7	8.3 / 3.0	5.1 / 0.5
Condyle w/i Normal Limits	5.0 / 1.5 *	4.2 / 1.9	1.5 / 2.7	4.9 / 0.6
	4.2 / 1.7	3.8 / 3.4	1.4 / 2.4	4.9 / 0.5
Condylar Pathology	5.0 / 2.0	3.1 / 3.6	4.5 / 3.9 *	4.3 / 1.9 *
	5.3 / 2.1	5.0 / 4.2	3.5 / 3.6	3.9 / 2.0
Fossa Pathology	4.7 / 1.7	1.3 / 2.7	5.2 / 2.4	5.1 / 0.7
	4.9 / 1.9	1.7 / 3.0	4.6 / 2.1	5.2 / 0.8
Developmental Abnormalities	5.0 / 1.1	0.6 / 1.8	4.3 / 3.8 *	4.9 / 0.5
	4.8 / 1.2	0.6 / 1.8	3.2 / 3.3	5.0 / 0.0
Is Joint Symptomatic	5.0 / 1.1	5.4 / 1.5 *	5.8 / 2.0	5.3 / 0.8
	5.0 / 1.2	6.7 / 2.1	5.5 / 1.5	5.2 / 0.7
If Asymptomatic, Tx Altered	3.4 / 2.6 *	1.7 / 3.6 *	3.1 / 4.0	2.5 / 2.7
	0.7 / 2.0	5.5 / 4.9	2.3 / 3.5	2.0 / 2.5
If Symptomatic, Tx Altered	3.8 / 2.8 *	1.8 / 3.8 *	3.2 / 4.0	2.6 / 2.9
	0.8 / 2.3	6.8 / 4.7	2.4 / 3.5	2.1 / 2.5

* $p < 0.01$, Paired T-test

TABLE 5

INTRAOBSERVER AGREEMENT- TOMOGRAMS

Mean, Observation 1 / Standard Deviation
Mean, Observation 2 / Standard Deviation

	Observer 1	Observer 2	Observer 3	Observer 4
Horizontal Condylar Position	4.5 / 2.4 4.6 / 2.7	5.6 / 2.9 * 7.5 / 2.8	5.2 / 3.0 5.0 / 2.9	4.3 / 1.5 4.4 / 1.4
Vertical Condylar Position	5.7 / 2.5 6.5 / 2.3	4.8 / 2.9 5.1 / 2.1	6.7 / 3.2 7.1 / 2.8	5.0 / 1.1 5.1 / 1.1
Condyle w/i Normal Limits	5.4 / 3.4 4.9 / 3.4	3.8 / 3.9 4.6 / 2.8	5.1 / 4.3 5.3 / 4.1	6.3 / 2.3 * 6.9 / 2.3
Condylar Pathology	4.9 / 3.6 5.3 / 3.0	5.6 / 3.4 * 3.2 / 3.8	4.4 / 4.0 3.8 / 3.6	3.9 / 2.4 3.5 / 2.1
Fossa Pathology	4.8 / 3.3 4.9 / 2.9	2.7 / 3.1 * 0.6 / 1.8	2.4 / 3.6 2.4 / 3.0	3.3 / 2.1 3.2 / 2.1
Developmental Abnormalities	4.7 / 2.1 4.3 / 2.5	1.2 / 2.5 * 0.3 / 1.3	3.8 / 4.0 3.7 / 3.2	4.8 / 1.1 5.0 / 0.0
Is Joint Symptomatic	5.9 / 1.9 * 4.8 / 2.2	6.6 / 2.1 6.1 / 1.7	5.1 / 2.9 5.1 / 2.1	4.4 / 2.3 4.0 / 2.2
If Asymptomatic, Tx Altered	4.1 / 3.6 4.4 / 3.9	7.1 / 3.9 * 3.5 / 4.6	3.0 / 4.2 1.9 / 3.5	3.9 / 3.6 3.5 / 3.4
If Symptomatic, Tx Altered	6.6 / 3.0 7.2 / 2.8	8.9 / 2.6 * 4.2 / 5.0	3.5 / 4.2 2.5 / 3.6	2.8 / 3.2 2.5 / 2.9

* $p < 0.01$, Paired T-test

DISCUSSION

Increased public awareness of temporomandibular joint problems and demand for treatment has resulted in a significant increase in TMJ procedures being done nationally as well as internationally by both the medical and dental professions,[1,2] including orthodontists who have shown professional concern by taking pretreatment lateral tomograms of the TMJ in order to assess pathology, condylar position, etc.

While lateral tomography has been demonstrated to be superior to other radiographic techniques (transcranial, panoramic, and transmaxillary projections) for assessment of condylar position and disclosure of structural changes in hard tissue,[12-17] it has been shown in various studies that observer variation in assessment of radiographs is routinely quite high. Kopp and Rockler[39] observed that the assessment of commonly used radiographic signs of temporomandibular joint lesions using oblique lateral, axial, and transmaxillary projections, varies substantially when made on different occasions by one single observer, and that despite preceeding training, observers still differ substantially in their interpretation of changes in radiographs of the temporomandibular joints. Liedberg, et al[40] concluded that both inter- and intraobserver variation in radiographic assessment of condylar position using transcranial projections and corrected lateral tomograms must always be expected to a certain extent, even if the radiographs are obtained by standardized procedures. They also pointed out that this weakness in interpretation must be added to the

limitation of radiographic techniques in correctly depicting the condylar position. Various endodontic studies[35-38] have also shown a high percentage of observer disagreement. Studies such as these seem to pose the question that if these radiographs cannot be read with a good degree of reliability, how valuable are they in actually influencing future treatment. It was with this in mind that this study was undertaken.

The objective of this study was to assess whether orthodontists, using panoramics or corrected tomograms, could consistently agree with each other, and themselves, on findings dealing with joint pathology, developmental abnormalities, and condylar position, and whether or not these findings would alter orthodontic treatment plans.

The results of this study seem to support the literature documenting lack of observer agreement with regards to evaluation of radiographs. In panoramic films and lateral tomograms, the interobserver variation was substantial. When panoramics and tomograms were analyzed together, no interobserver agreement for the group as a whole was seen (Analysis of Variance, $p < 0.01$). When panoramics were analyzed alone, the observers agreed as a group on only one question, that is question number 4, "Do you see any condylar pathology?" with corresponding mean responses of Uncertain (ANOVA, $p < 0.01$). Similar results were seen for the same question when tomograms alone were analyzed (ANOVA, $p < 0.01$). It should be noted however, that although statistically the panoramics and tomograms faired the same, a trend was seen for

more agreement with the tomograms.

As with other studies regarding observer agreement, reduction in the number of observers may have resulted in better agreement. In many instances, two or three of the observers showed near agreement while an outlyer altered the final results. However, with 9 questions, enough diversity was seen that no one observer could be identified as being the predominant outlyer. So while selective reduction of the number of observers might have improved agreement for specific questions, removing any one observer from the entire study would have produced an only questionable increase in the amount of interobserver agreement for the study as a whole.

Intraobserver agreement was much better. For panoramics one observer, number 4, showed a statistically significant difference with himself from the first observation to the second observation (Paired T-test, $p < 0.01$) on only one question (Paired T-test, p , 0.01), question 4, regarding the presence of condylar pathology. Clinically this difference seemed small. Another observer, number 3, statistically disagreed with himself on only two questions, question 4 regarding the presence of condylar pathology, and question 6 regarding the presence of developmental abnormalities. Again the differences seemed small in a clinical context. Observer 2, showed disagreement on three questions, 7, 8 and 9, and Observer 1, on four questions, 1, 3, 8 and 9, both with varying amounts of difference.

For tomograms, intraobserver agreement (Paired T-test, p <

0.01) was even better for three of the four observers. Observer 3 showed no statistically significant difference with himself on any of the questions and Observers 1 and 4 disagreed with themselves on only one question each. Observer 1 disagreed with himself on question 7 regarding whether or not the joint was symptomatic, and Observer 4 on question 3 about whether the condylar position was within normal limits. In both instances the differences seemed small in a clinical context. Somewhat puzzling was the fact that Observer 2 disagreed with himself on six out of the nine questions, showing no statistical difference on only three questions; question 2 regarding vertical condylar position, question 3 regarding condylar position within normal limits, and question 7 regarding whether or not the joint was symptomatic. It appeared that he became more committed to a yes or no answer on the second observation moving in a direction away from Uncertain in every instance with regards to position and pathology, etc. Interestingly, on both questions regarding whether or not findings on the tomograms would alter treatment, a shift was seen from Yes to No. Whether or not this reflected a difference in what was seen on the tomograms or a shift in his approach to the study following the first observation is not known.

The results of this study, showing such a lack of interobserver agreement, seem to question the degree of impact that corrected tomograms and panoramics have on proposed orthodontic treatment. These findings seem to in general

reflect the position being taken by many orthodontists as of late, including the observers in varying degrees. One orthodontist who was asked to participate in this study declined, stating that there is too much normal radiographic variation from patient to patient to significantlly alter treatment, and that his treatment was for the most part, based upon clinical findings. Quantrill and Lewis[9] stated that the interpretation of radiographs is difficult because of the wide variation in the normal anatomy as well as in the width of the normal joint space, and that there is also considerable asymmetry and variation in the broad functional range of normal joints. They go on to warn that one must guard against tailoring the radiographic evidence to fit the clinical symptoms.

The radiographic variation in a "normal" population has been shown, particularly for condylar position, by Larheim[41] who stated that because of the high prevalence of asymmetric joint spaces, great care should be taken when using narrowing or widening of the joint space as a diagnostic criterion in children with juvenile rheumatoid arthritis. Pullinger et al[42] concluded that since all condylar positions were found in their functionally normal population, a diagnosis of dysfunction cannot be based solely on radiographic observation of nonconcentric condyle-fossa relationships.

In retrospect, this study would have been improved with the addition of more radiographs. It should be pointed out that while every attempt was made to utilize quality

radiographs, standardization of the films was not attempted. Both panoramics as well as tomograms were taken in more than one place with both linear and polycycloidal tomograms being used in the study.

Also, the use of categorical responses, allowing observers to make choices from specific categories such as "Definite No", "Uncertain No", "Uncertain Yes", "Definite Yes", etc., and percentage statistics would have made comparison with other studies regarding observer agreement more meaningful. Use of statistics such as Analysis of Variance and Paired T-test required far fewer radiographs but permitted less "error" or difference on the part of the observers. Although the statistics were valid, this should be realized when applying the results in a clinical context.

After considering the lack of interobserver agreement seen in this study, one might question the need for corrected tomograms, especially if only one slice is to be observed. As pointed out by Carlsson[31] and Myers et al[32] the thyroid is positioned higher and considered more radiosensitive in children than adults. The conventionally collimated submento-vertex radiograph used to determine condylar angulation and depth of the cut at which a corrected tomogram is taken imparts a thyroid absorbed dose of approximately 15 mGy. This represents a thyroid absorbed dose 750 times that of a single tomographic slice at .02 mGy[34]. Logic seems to dismiss the statement made by Beckwith et al[29] that use of the submento-vertex radiograph for tomographic correction reduces

radiation exposure to the patient by eliminating the "shotgun" approach in which several radiographs at different depth of cut settings are taken to obtain a clinically acceptable laminagraph. By eliminating the submento-vertex radiograph and using average measurements for selection of tomographic slices, an increased amount of information could be gained by taking multiple slices rather than a single slice of each joint, while still reducing radiation to the thyroid. Such an approach needs to be evaluated as a possible alternative to corrected tomograms prior to orthodontic treatment. Further refinement of present radiographic techniques and/or development of new ones that would increase the amount of useable information available to the orthodontist, while decreasing cost and radiation to the patient may offer other alternatives.

While orthodontists will continue to take pretreatment corrected tomograms for medico-legal reasons, whether it be to document presence or lack of TMJ pathology or to conform to an accepted standard of care, the practice requires careful study.

Since good intraobserver agreement by orthodontists has been shown, one might assume that with similar advanced education with regards to radiographic evaluation and diagnosis, increased interobserver agreement may be possible. Avenues for such education should be explored. Standardization of such education could be initiated first at the orthodontic faculty level so that orthodontic students could be similarily educated.

The orthodontic profession should be applauded for its

concern and efforts regarding diagnosis and treatment of temporomandibular joint disorders. However, constant evaluation and reevaluation of present techniques, including the use of pretreatment TMJ radiographs, must be performed so that the best interest of the patient is firmly maintained.

SUMMARY

The purpose of this study was to determine the consistency of orthodontists in evaluating lateral tomograms and panoramic films. Lateral tomograms and panoramic films of 60 single joints, 30 asymptomatic and 30 symptomatic, were evaluated by 4 orthodontists on two separate occasions, utilizing questionnaires requiring information about condylar position, condylar and fossa pathology, developmental abnormalities, possible symptomaticity of the joint, and decisions regarding the alteration of treatment based upon radiographic evidence.

Statistically, results showed little to no interobserver agreement, regardless of the type of radiograph used, though a trend of agreement did exist more predominantly with tomograms. There was a greater trend for intraobserver agreement than interobserver agreement on each question.

Because of the demonstrated diversity in observer assessment of these temporomandibular joint radiographs, coupled with possible patient risk due to the relatively high thyroid absorbed dose of radiation received with a submento-vertex radiograph, the use of corrected tomograms prior to orthodontic treatment must be questioned, and possible alternatives should be explored. Such alternatives could include use of average correction tomograms, refinement of present radiographic techniques and/or the development of new ones, and improved, standardized education so that a maximum amount of useable information can be obtained with only minimal risk to the patient.

ORTHODONTIC TMJ TOMOGRAM/PANORAMIC STUDY

Observer ID _____

X-ray ID _____

EACH LINE REPRESENTS A RANGE OF REPONSES RELATED TO THE CORRESPONDING QUESTION. THEREFORE, A MARK MAY BE MADE ANYWERE ON THE LINE FOR EACH QUESTION.

1. What is the condylar position? (anterior/posterior)	Posterior	Central	Anterior
2. What is the condylar position? (vertical dimension)	Superior	Central	Inferior
3. Is the condylar position within normal limits?	Definite No	Uncertain	Definite Yes
4. Do you see any condylar pathology?	Definite No	Uncertain	Definite Yes
5. Do you see any fossa pathology?	Definite No	Uncertain	Definite Yes
6. Do you see any developmental abnormalities?	Definite No	Uncertain	Definite Yes
7. Do you think this is a symptomatic joint?	Definite No	Uncertain	Definite Yes
8. If this joint was asymptomatic, would findings on this x-ray alter your treatment in any way?	Definite No	Uncertain	Definite Yes
9. If this joint was symptomatic (clicking, pain, etc.), would findings on this x-ray alter your treatment in any way?	Definite No	Uncertain	Definite Yes

Attachment 1. Questionnaire utilized for radiographic study. (Response lines reduced for publication)

REFERENCES

1. Solberg WK, Clark GT, Pullinger AG: The troubled temporomandibular joint: New challenges in teaching, research and clinical management. J Ca Dent A 12(12):36-42, 1984.

2. Moffit M: The TMJ: Can dentistry really help? Contact Point 63(1):10-15,30, 1984.

3. Weinberg LA: The etiology, diagnosis, and treatment of TMJ dysfunction-pain syndrome. Part 1: Etiology. J Prosthet Dent 42(6):654-64, 1979.

4. Weinberg LA: The role of stress, occlusion, and condyle position in TMJ dysfunction-pain. J Prosthet Dent 49(4):532-45, 1983.

5. Ricketts RM: Laminagraphy in the diagnosis of temporomandibular joint disorders. J Am Dent A 46:620-48, 1953.

6. Dr. Robert Ricketts, Pacific Palisades, CA, Personal Communication, 1986.

7. Dr. Roland Walters, Dept. Chairman - Orthodontics, LLU School of Dentistry, Personal Communication, 1986.

8. Mr. Allen Starczyk, Wilson Radiographic Lab, Van Nuys, CA, Personal Communication, 1986.

9. Quantrill JR, Lewis JES: The interpretation of temporomandibular joint radiographs. S Afr Med J 48:1905-12, 1974.

10. Lindvall AM, Helkimo E, Hollender L, Carlsson GE: Radiographic examination of the temporomandibular joint. A comparison between radiographic findings and gross and microscopic morphologic observations. Dentomaxillofac Radiol 5(1-2):24-32, 1976.

11. Kopp S, Rockler B: Relationship between clinical and radiographic findings in patients with mandibular pain or dysfunction. Acta Radiol (Diag) 20(3):465-77, 1979.

12. Klein IE, Blatterfein L, Miglino JC: Comparison of the fidelity of radiographs of mandibular condyles made by different techniques. J Prosthet Dent 24:419-52, 1970.

13. Eckerdal O: Tomography of the temporomandibular joint. Correlation between tomographic image and histologic sections in a three-dimensional system. Acta Radiol, Suppl 329, 1973.

14. Bean LR, Omnell KA, Oberg T: Comparison between radiologic observations and macroscopic tissue changes in temporomandibular joints. Dentomaxillofac Radiol 6:90-106, 1977.

15. Eckerdal O, Lundberg M: The structural situation in temporomandibular joints. A comparison between conventional oblique transcranial radiographs, tomograms and histologic sections. Dentomaxillofac Radiol 8:42-49, 1979.

16. Larheim TA: Comparison between three radiographic techniques for examination of the temporomandibular joints in juvenile rheumatoid arthritis. Acta Radiol (diag) 22(2):195-201, 1981.

17. Pullinger A, Hollender L: Assesment of mandibular condyle position: A comparison of transcranial radiographs and linear tomograms. Oral Surg, Oral Med, Oral Pathol 60(3):329-334, 1985.

18. Blaschke DD, Solberg WK, Sanders B: Arthrography of the temporomandibular joint: Review of current status. J Am Dent A 100:388-95, 1980.

19. Katzberg RW, Keith DA, Guralnick WC, Manzione JV, Ten Eick WR: Internal derangements and arthritis of the temporomandibular joint. Radiology 146(1):107-12, 1983.

20. Westesson P-L, Rohlin M: Diagnostic accuracy of double-contrast arthrotomography of the temporomandibular joint: Correlation with postmortem morphology. AJR 143(3):655-60, 1984.

21. Kaban LB, Bertolami CM: The role of the CT scan in diagnosis of TMJ ankylosis: report of case. J Oral Surg 39(5):370-2, 1981.

22. Helms CA, Morrish RB Jr, Kircos LT, Katzberg RW, Dolwick MF: Computed tomography of the meniscus of the tempormandibular joint: preliminary observations. Radiology 145(3):719-22, 1982.

23. Thompson JR, Christiansen E, Hasso AN, Hinshaw DB Jr: Temporomandibular joints: high resolution computed tomographic evaluation. Radiology 150(1):105-10, 1984.

24. Katzberg RW, et al: Magnetic resonance imaging of the temporomandibular joint meniscus. Oral Surg, Oral Med, Oral Pathol 59:332-35, 1985.

25. Harms SE, Wilk RM, Wolford LM, Chiles DG, Milam SB: The temporomandibular joint: Magnetic resonance imaging using surface coils. Radiol 157:133-36, 1985.

26. Katzberg RW, et al: Normal and abnormal temporomandibular joint: MR imaging with surface coil: Radiol 158:183-89, 1986.

27. Williamson EH, Wilson CW: Use of a submental-vertex analysis for producing quality temporomandibular joint laminagraphs. Am J Orthod 70(2):200-205, 1976.

28. Rozencweig D, Martin G: Selective tomography of the TMJ and the myofacial pain-dysfunction syndrome. J Prosthet Dent 40(1):67-74, 1978.

29. Beckwith PJ, Monfort DR, Williams BH: Accurate depth of cut in temporomandibular joint laminagraphs. Angle Orthod 50(1):16-22, 1980.

30. Williams BH: Oriented lateral temporomandibular joint laminagraphs: Symptomatic and nonsymptomatic joints compared. Angle Orthod 53(3):228-33, 1983.

31. Carlsson C: Integral absorbed doses in roentgen diagnostic procedures. I The dosemeter. Acta Radiol Ther Phys Biol 3:310-26, 1965.

32. Myers DR, Shoaf HK, Wege WR, Carlton WH, Gilbert MA: Radiation exposure during panoramic radiography in children. Oral Surg 46(4):588-93, 1978.

33. Westesson P-L: Double-contrast arthrography and internal derangement of the temporomandibular joint. Swed Dent J Suppl. 13, 1982.

34. Borglin K, Petersson A, Rohlin M, Thapper K: Radiation dosimetry in radiology of the temporomandibular joint. Br J Radiol 57:997-1007, 1984.

35. Gelfand M, Sunderman E, Goldman M: Reliability of radiographical interpretations. J Endodon 9(2):71-75, 1983.

36. Goldman M, Pearson A, Darzenta N: Endodontic success-who's reading the radiograph. Oral Surg 33:432-7, 1972.

37. Antrim D: Reading the radiograph: a comparison of viewing techniques. J Endodon 9(11):502-5, 1983.

38. Zakariasen K, Scott D, Jensen J: Endodontic recall radiographs: how reliable is our interpretation of endodontic success or failure and what factors affect our reliability? Oral Surg 57(3):343-7, 1984.

39. Kopp S, Rockler B: Variation in interpretaion of radiographs of temporomandibular and hand joints. Dentomaxillofac Radiol 7:95-102, 1978.

40. Liedberg J, Rohlin M, Westesson P-L: Observer performance in assessment of condylar position in temporomandibular joint radiograms. Acta Odontol Scand 43:53-8, 1985.

41. Larheim TA: Temporomandibular joint space in children without joint disease. Acta Radiol (Diag) 22(1):85-8, 1981.

42. Pullinger AG, Hollender L, Solberg WK, Petersson A: A tomographic study of mandibular condyle position in an asymptomatic population. J Prosthet Dent 53(5):706-13, 1985.

43. Syrjanen SM: The temporomandibular joint in rheumatoid arthritis. Acta Radiol (Diag) 26(3):235-43, 1985.

44. Brooks SL, Lanzetta ML: Absorbed doses from temporomandibular joint radiography. Oral Surg, Oral Med, Oral Pathol 59(6):647-52, 1985.

45. Goldman SM, Taylor R: Retrospective radiographic evaluaton of 100 temporomandibular joint patients. J Prosthet Dent 53(4):566-9, 1985.

46. Larheim TA, Johannessen S: Transpharyngeal radiography of mandibular condyle. Comparison with other conventional methods. Acta Radiol (Diag) 26(2):167-71, 1985.

47. Katzberg RW: Preliminary evaluation of Hexabrix for temporomandibular joint arthrography. Invest Radiol 19(6 Suppl):S387-8, 1984.

48. Mejersjo C, Hollender L: Radiography of the temporomandibular joint in female patients with TMJ pain or dysfunction. A seven year follow-up. Acta Radiol (Diag) 25(3):169-76, 1984.

49. Preti G, Arduino A, Pera P: Consistency of performance of a new craniostat for oblique lateral transcranial radiographs of the temporomandibular joint. J Prosthet Dent 52(2):270-4, 1984.

50. Weinberg LA: Practical evaluation of the lateral temporomandibular joint radiograph. J Prosthet Dent 51(5):676-85, 1984.

51. Manzione JV, Tallents R, Katzberg RW, Oster C, Miller TL: Arthrographically guided splint therapy for recapturing the temporomandibular joint meniscus. Oral Surg, Oral Med, Oral Pathol 57(3):235-40, 1984.

52. Gusching AC: Frontal tomography of articulating temporomandibular joint surfaces. Angle Orthod 53(3):234-9, 1983.

53. Preti G, Fava C, Pera P: Accuracy and repeatability of a new procedure for temporomandibular joint laminagraphy. J Prosthet Dent 49(5):715-25, 1983.

54. Hellsing G, Isberg-Holm A, McWilliam J: A comparitive study of two techniques for recording centric relation. Dentomaxillofac Radiol 12(1):5-12, 1983.

55. Larheim TA, Tveito L, Dale K, Ruud AF: Temporomanibular joint abnormalities in rheumatoid arthritis: comparison of different radiographic methods. Acta Radiol (Diag) 22(6):703-7, 1981.

56. Lysell L, Petersson A: The submento-vertex projection in radiography of the temporomandibular joint. Dentomaxillofac Radiol 9(1):11-7, 1980.

56. Eckerdal O, Lundgerg M: Temporomandibular joint relations as revealed by conventional radiographic techniques. A comparison with the morphology and tomographic images. Dentomaxillofac Radiol 8(2):65-70, 1979.

57. Kundert M: Limits of perceptibility of condyle displacements on temporomandibular joint radiographs. J Oral Rehabil 6(4):375-83, 1979.

58. Eckerdal O, Ahlqvist J: Thin bony walls of the temporomandibular joint. Morphologic properties and tomographic reproduction. Acta Radiol (Diag) 20(2):385-92, 1979.

59. Mikhail MG, Rosen H: The validity of temporomandibular joint radiographs using the head positioner. J Prosthet Dent 42(4):441-6, 1979.

60. Markovic MA, Rosenberg HM: Tomographic evaluation of 100 patients with temporomandibular joint symptoms. Oral Surg, Oral Med, Oral Pathol 42(6):838-46, 1976.

61. Stanson AW, Baker HL Jr: Routine tomography of the temporomandibular joint. Radiol Clin North Am 14(1):105-27, 1976.

62. Shorten DL, Farman AG, George DI, Sharma S, Wilson D: Radiation exposure to critical structures during transfacial and transcranial TMJ radiography. Dentomaxillofac Radiol 14:93, 1985.

63. Bankvall G, Hakansson HAR: Radiation-absorbed doses and energy imparted from panoramic tomography, cephalometric radiography, and occlusal film radiography in children. Oral Surg 53(5):532-40, 1982.