Original Articles

VARIATION OF HORIZONTAL AND VERTICAL CONDYLAR ANGULATION AND ITS EFECT ON TMJ TOMOGRAPHIC IMAGING[f]

M.B. Hassanin, BDS, MS, PhD*; A. El-Zanaty, MB, BCh, MS, PhD**;
N. Khan, BS, MS, PhD***, H. Rosenberg, DDS****

أجرى هذا البحث لدراسة تفاوت زاوية الميل الرأسي والأفقي للقمة الفك في مجموعة كبيرة من المرضى وأيضًا لفحص تأثير التعويض غير الدقيق لهذه الزوايا على الفائدة النوعية التشخيصية للصور المقطعية الجانبية.

يظهر الجدول التالي نتائج التحليل الاحصائي لزوايا اللقمة الرأسية والأفقية في ١١٤٣ مريض شملهم هذا البحث:-

مصدر الاختلاف	الزاوية الافقية اليمنى	الزاوية الرأسية اليمنى	الزاوية الأفقية اليسرى	الزاوية الرأسية اليسرى
عدد الحالات	١١٤٣	١١٤٠	١١٤٠	١١٤٠
المدى (التراوح)	-١٥ إلى ٥٢	-١٩ إلى ٢٣	-٧ إلى ٥٣	-١٤ إلى ٤٣
الزاوية المتوسطة	٢٤,٢	٣,٣	٢٥,٣	٤,٥
الخطأ القياسي	٢٨	,١٤	,٢٩	,١٥
الزاوية الموثوق بها (٩٥٪)	٢٣,٧ إلى ٢٤,٨	٣,٠ إلى ٣,٦	٢٤,٧ إلى ٢٥,٩	٤,٢ إلى ٤,٨

يظهر هذا الجدول بجلاء مدى التراوح الواسع لزوايا اللقمة الرأسية والأفقية كما يظهر ان القيمة المتوقعة للزاوية الأفقية في ٩٥٪ من الحالات يقع بين ٢٣,٧ و ٢٥,٩ مقارنة بالزاوية القياسية التي قدرها استانسن وباكر في عام ١٩٧٦ ب ٢٠ درجة.

لتوضيح أثر التصحيح غير السليم للزوايا الرأسية والأفقية للقمة الفك على جودة الصورة الشعاعية استخدمت جمجمة طبيعية بها بروز عظمي واضح على السطح الأمامي للقمة اليمنى. قيس الميل الأفقي والرأسي بطريقة روزنبرج وجرازيك لعام ١٩٨٦ أخذت صور مقطعية جانبية مصححة لمفصل الفك بتعويض الزاوية الصحيحة وزاوية تزيد درجتين أو أربع درجات وزاوية

Received 20/04/94; revised 22/08/94; accepted 18/10/94

*Assistant Professor and Head of Oral & Maxillofacial Radiology, Department of Biomedical Dental Sciences, King Saud University College of Dentistry.

**Lecturer of Anatomy and Cell Biology, College of Medicine, Banha University, Banha, Egypt.

***Biostatistician, Research Center, King Saud University College of Dentistry, P.O. Box 60169, Riyadh 11545, Saudi Arabia.

****Professor Emeritus of Oral Radiology, College of Dentistry, University of Illinois, Chicago, IL, USA.

Address reprint requests to Dr. M.B. Hassanin

t Presented in part to the *8th International Saudi Dental Meeting,* January 1994, Riyadh, Saudi Arabia.

تنقص درجتين أو أربع درجات عن تلك الزاوية الصحيحة وقد وجد أن التعويض غير الدقيق لزاوية الميل بفرق في حدود درجتين يغير من حجم وشكل وموضع البروز العظمي على الصور المقطعية الجانبية المصححة.
تظهر هذه النتائج أهمية التعويض الشخصي لميل الزاوية الرأسية والأفقية للتصوير المقطعي الدقيق لمفصل الفك.

In this study, we examined the variation of the temporomandibular joint (TMJ) horizontal and vertical condylar angles in 1,143 patients who were referred for tomographic evaluation of the TMJ. Both angles showed a wide range of variation with the mean right and left horizontal condylar angles being 24.2 and 25.3 degrees, respectively. The mean right and left vertical condylar angles were found to be 3.3 and 4.5 degrees, respectively. The horizontal and vertical condylar angles were measured on a dry skull with a prominent morphologic landmark (osteophyte). Corrected lateral cephalometric hypocycloidal tomograms were produced by compensation for the true horizontal and vertical condylar angles, and by varying each angle +2, -2, or +4, -4 degrees from the true measured angles. It was found that a slight variation of +2 or -2 degrees in either the horizontal or vertical condylar angles would affect the shape, size and anatomic relationships of the bony components of the TMJ. These results demonstrate the need for individual compensation of the horizontal and vertical condylar angles to obtain high quality diagnostic tomographic images of the TMJ.

Introduction

Radiography is an important tool in achieving a proper diagnosis and planning a successful treatment and follow-up of the TMJ dysfunction. The desire to obtain high quality diagnostic image of the TMJ led to the development of various radiographic techniques. Among these techniques are the transcranial, transorbital and transpharyngeal imaging.[1,12] All attempts were made in these forementioned techniques to eliminate the superimposition of the base of the skull on the joint image. However, these techniques fell short of achieving this vital objective as variable degrees of superimposition were still present on the produced images.[13]

The variability in the morphology of condylar head, as well as in the orientation of its long axis due to the variability of the condylar horizontal and vertical angulations, makes it difficult and nearly impossible to obtain an ideal TMJ image using the transcranial, transorbital or transpharyngeal techniques.[12,13] Tomography, or sectional radiography, produces images of the joint at different places and different sections for thorough evaluation of the joint. While some investigators recommended positioning of the patient's head with a standard 20 degrees horizontal angle,[14] others recommended individual compensation of the horizontal angle of each condyle[15,16] while a third group of researchers considered the vertical angulation of the condylar axis.[12,13,15,17]

To fulfill the objective of producing reproducible images of the TMJ, tomography was modified to compensate for the specific morphology of the condyle and its axis. Corrected lateral cephalometry was developed as early as 1961 by Yale and Rosenberg[15] at the University of Illinois in Chicago. This technique was based on the compensation for the individual right and left horizontal and vertical condylar angulation for each patient. It was further modified in 1986 by Rosenberg and Graczyk[17] by the introduction of corrected anteroposterior cephalometric tomography of the TMJ. This modified technique was based on positioning the patient's head in a specially-designed cephalostat according to the previously measured horizontal and vertical angle of each condyle. This technique produced maximum diagnostic and reproducible radiographs of the joint.[17]

The present study was designed with two objectives. First, to study the variation of both horizontal and vertical condylar angulation in a large group of patients who presented for corrected lateral tomographic examination of the TMJ. Second, to evaluate the importance of individual correction of the horizontal and vertical condylar angles and its effect on the diagnostic quality of the produced tomographic images.

Materials and Methods

The records of corrected lateral cephalometric hypocycloidal tomographic images of the TMJ of

1,143 patients examined at the Department of Oral Radiology, College of Dentistry, University of Illinois in Chicago between 1982 to 1992 were reviewed. In all of these patients, the individual right and left condylar horizontal and vertical angles were measured prior to the tomographic examination according to the technique described by Rosenberg and Graczyk in 1986.[17] A submental vertex (SMV) radiograph was produced by positioning the patient's Frankfort plane parallel to the film and perpendicular to the X-ray central beam. On the SMV view, three lines were constructed [Fig. 1]. The first line *{line A-A)* connected the metal markers within the earposts "intermeatal line". The second line *{line B-B)* represents an arc determined by the radius of the intermeatal line and the third line *{line C-Q* was drawn from the visible condylar long axis to intersect with the intermeatal line. The angle formed between the condylar axis and the intermeatal line represents the horizontal condylar angle. An AP tomogram was produced by positioning the patient's Frankfort plane in the frontal plane and perpendicular to the X-ray film. On the AP tomogram, the intermeatal line, an arc representing the radius of the intermeatal line and a third line representing the long axis of the condyle were drawn. The angle formed by the intersection of the long axis of the condyle with the intermeatal line represents the condylar vertical angle [Fig. 2]. For each patient, age, sex and right and left horizontal and vertical condylar angles were recorded. Data were analyzed using statistical analysis system (SAS) and a main frame computer [IBM 3083 of KingSaud University] to calculate the range, mean, standard error, and 95% confidence interval for the right horizontal, the right vertical, the left horizontal and left vertical angles separately.

To correlate the relationship between the true horizontal and vertical condylar angles and the quality and image clarity of the condyle and other bony components of the TMJ (fossa and eminence), a dry skull with a prominent bony osteophyte on the anterior aspect of the right condyle was used in this study. To prevent the movement of the mandible during the investigation, the right and left condyles were kept in the center of their respective fossae. The upper and lower teeth were kept in maximum occlusion and were fixed in such position using sticky wax. The horizontal and vertical angles for the right and left condyles were measured separately according to the corrected lateral cephalometric technique mentioned above. Corrected lateral tomograms were made for each joint, using the true measured horizontal angle and varying the vertical angle by +2, -2, +4 and -4 degrees from the actual vertical angle. Another set of tomograms was also made for each joint by correcting for the true measured vertical angle and varying the horizontal angle by +2, -2, +4 and -4 degrees, respectively. The produced tomograms were examined and evaluated for any changes in the relationship between the bony components of the TMJ and image clarity.

Results

The age and sex distribution of the 1,143 patients included in the present study are summarized in

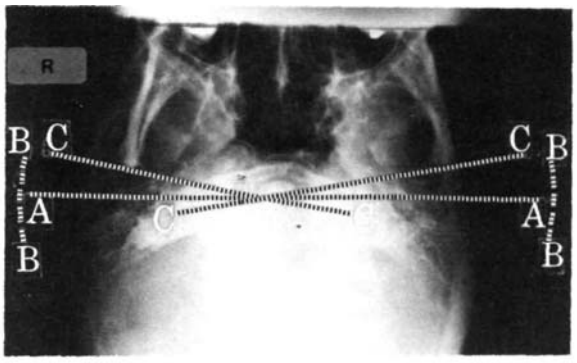

Figure 1. A SMV radiograph to measure the horizontal condylar angle. *Line A-A* intermeatal line. *Line B-B,* arc determined by radius of intermeatal line. *Line C-C,* condylar long axis.

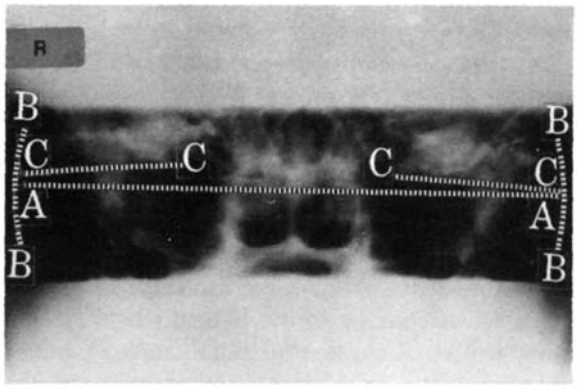

Figure 2. An AP tomograph to measure the vertical condylar angle. *Line A-A,* intermeatal line. *Line B-B,* arc determined by radius of intermeatal line. *Line C-C,* condylar long axis.

Table 1. Over 80% of these cases were female patients and the rest were males. Age-range was 3 to 81 for male patients with a mean age of 31.5 years while the range for female patients was 7 to 80 years with a mean age of 30.7 years. The majority of the patients were in the age-range of 11 to 45 years. Variation of the right horizontal angle is shown in Figure 3 and ranges from -15 to 52 degrees. Majority of the patients showed a right horizontal angle in the range of 11 to 40 degrees with a mean right horizontal angle of 24.2 degrees. The right vertical angle [Fig. 4] ranged from -19 to 23 degrees with the majority of patients showing a range from -4 to 10 degrees and with a mean of 3.3 degrees. The left horizontal angle [Fig. 5] ranged from -7 to over 53 degrees with most of the patients falling in the range of 11 to 40 degrees with a mean of 25.3 degrees. The distribution of the left vertical angle [Fig. 6] showed a range from -14 to 43 degrees with the majority of patient having a range from -4 to 10 degrees with a mean of 4.5 degrees.

Table 2 summarizes the statistical analysis of the variation of horizontal and vertical angles in this study.

As for the dry skull studies, Figure 7 shows a photograph of the skull from the frontal and lateral views. The anterior, medial and lateral aspects of the right condyle are shown in Figure 8, which clearly demonstrates the bony osteophyte on the anterior aspect of the right condyle. The right condylar angles of this dried skull measured 15 degrees horizontally and 5 degrees vertically. The corrected tomographic image of the right condyle made by varying the horizontal angle is shown in Figure 9, while that made by varying the vertical angle is shown in Figure 10. The corrected tomographic image with the actual horizontal and vertical angles clearly reveals the osteophyte in its position. The position, size and angulation of this bony structure were altered by changing either the horizontal or vertical angle by +2 or -2 degrees. Changing either the horizontal or vertical angles by +4 *or-4* degrees resulted in a higher degree of superimposition, and image distortion making it difficult to separate different structures. The photographic appearance of the left condyle of the dried skull is shown in Figure 11. The horizontal and vertical angles of the left condyle of the dried skull measured 17 and 7 degrees, respectively. The tomographic images of the left condyle made by varying the horizontal angle and vertical angle are shown in Figures 12 and 13, respectively. Both figures illustrate the changes in the shape, size and density of the condyle by varying either the horizontal or vertical angle. They also show the obvious change in the density, size and shape of the fossa and eminence. The horizontal condylar angles for the dried skull were measured on the SMV image and the vertical angles were measured on antero-posterior tomographic views that were made for the patients.

Table 1. Distribution of patients in the study according to age and sex.-

Age Range	Male	Female	Total
1-10	8(0.70)*	8(0.70)	16 (1.40)
11-20	55(4.81)	183(16.01)	238(20.82)
21-30	59(5.16)	304(26.60)	363(31.76)
31-40	53(4.64)	222(19.42)	275(24.06)
41-50	21 (1.84)	101 (8.84)	122(10.68)
51-60	11 (0.96)	69 (6.04)	80 (7.00)
61-70	10(0.87)	30 (2.62)	40 (3.49)
>70	3 (0.26)	6(0.53)	9(0.79)
TOTAL	220(19.25)	923 (80.75)	1143(100.00)

* Number between brackets is percent.

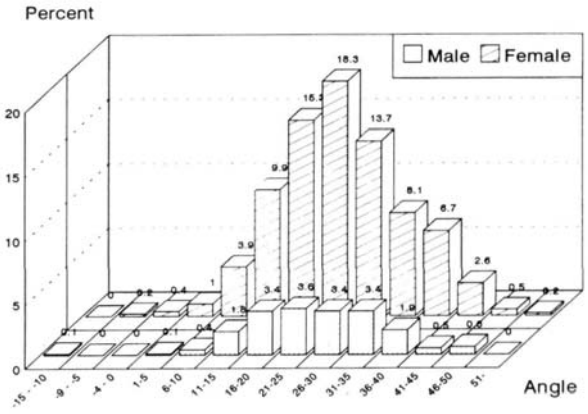

Figure 3. Variation of the right horizontal condylar angle in relation to sex.

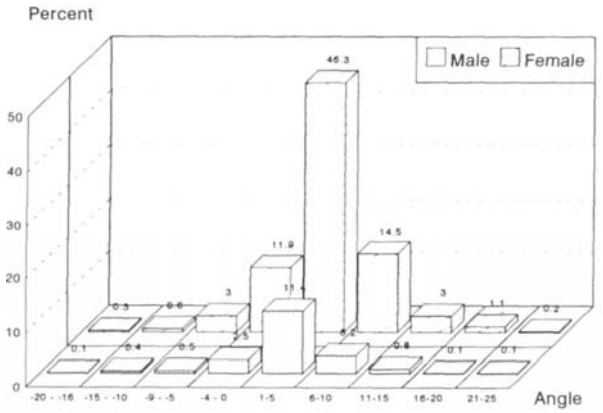

Figure 4. Variation of the right vertical condylar angle in relation

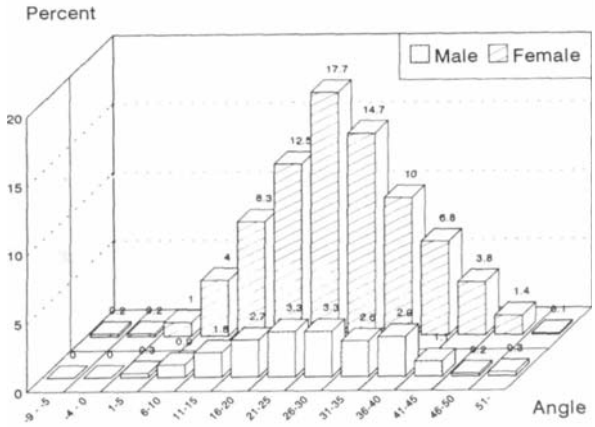

Figure 5. Variation of the left horizontal condylar angle in relation to sex.

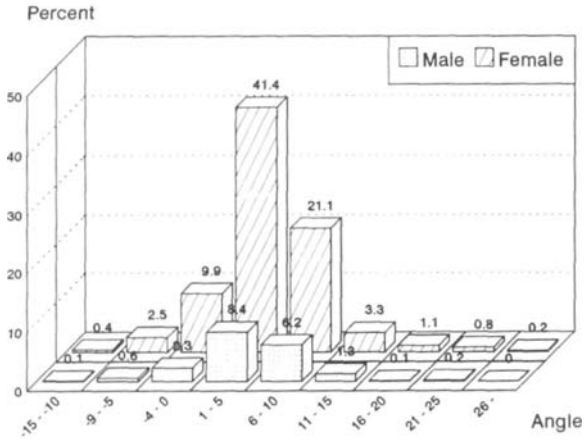

Figure 6. Variation of the left vertical condylar angle in relation to sex.

Table 2. Descriptive statistics and 95% confidence interval for the mean horizontal and vertical condylar angles.

Variable	Rt. Hor.	Rt. Vert.	Lt. Hor.	LtVert.
No. of cases	1143	1140*	1140*	1140*
Range	-15 to 52	-19 to 23	-7 to 53	-14 to 43
Mean	24.2	3.3	25.3	4.5
Standard error	0.28	0.14	0.29	0.15
95% Confidence	23.7-24.8	3.0-3.6	24.7-25.9	4.2-4.8

* Complete records were available for only 1,140 patients.

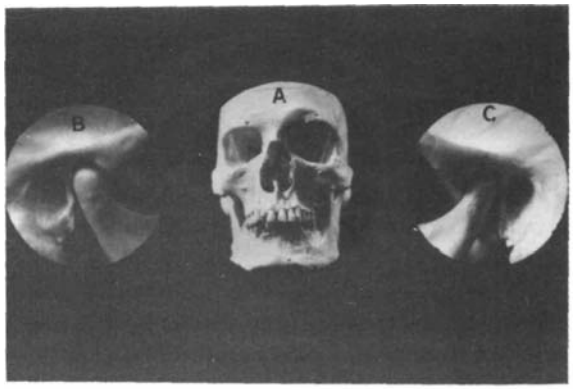

Figure 7. A photograph of the dry skull. *A*, frontal view; *B*, lateral view of right TMJ; *C*, lateral view of left TMJ.

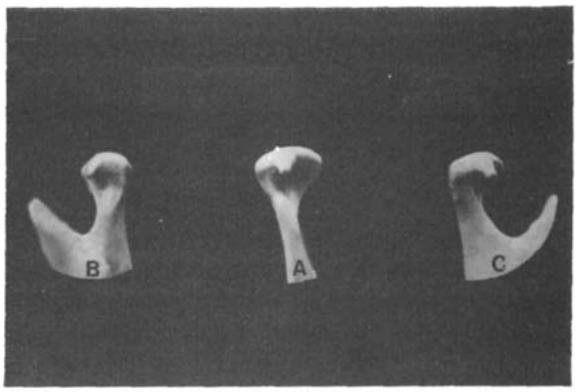

Figure 8. A photograph of the right condyle. *A*, frontal view; *B*, medial view; *C*, lateral view.

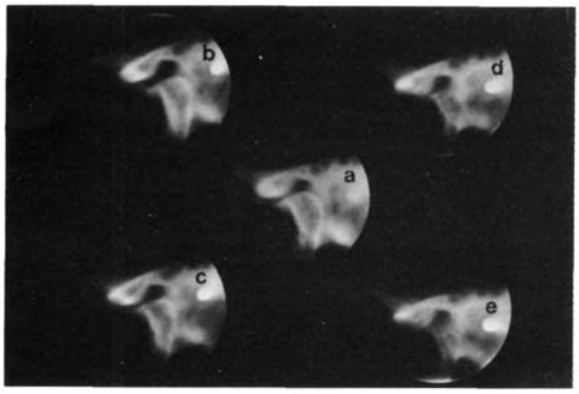

Figure 9. Tomographs of the right TMJ from specimens shown in Figure 7. Corrected measured horizontal and vertical angles *(a)*, corrected measured horizontal and vertical +2° *(b)*, corrected measured horizontal and vertical +4° *(c)*, corrected measured horizontal and vertical –2° *(d)*, and corrected measured horizontal and vertical –4° *(e)* angles.

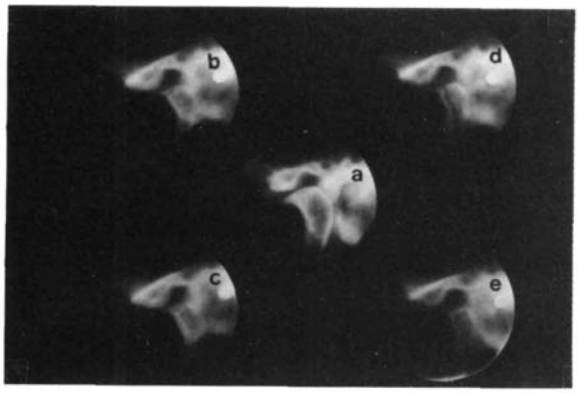

Figure 10. Tomographs of the right TMJ from specimens shown in Figure 7. Corrected measured horizontal and vertical angles *(a)*; corrected measured vertical and horizontal +2° *(b)*; corrected measured vertical and horizontal +4° *(c)*; corrected measured vertical and horizontal –2°o *(d)*; and corrected measured vertical and horizontal –4° *(e)*.

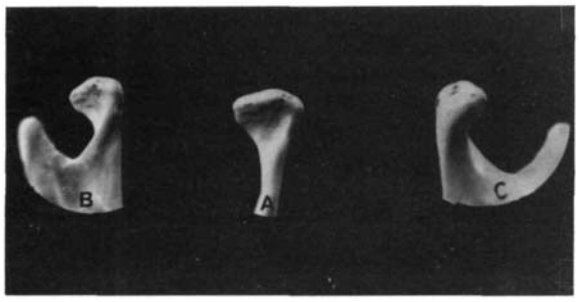

Figure 11. A photograph of the left condyle. *A*, frontal view; *B*, medial view; and *C*, lateral view.

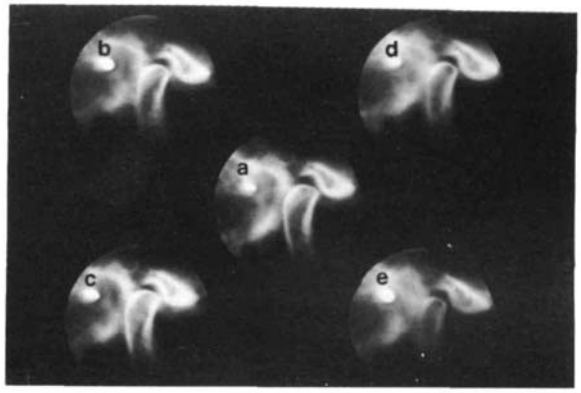

Figure 12. Tomographs of the left TMJ (specimen shown in Figure 7). Corrected measured horizontal and vertical angles *(a)*; corrected measured horizontal and vertical +2° *(b)*; corrected measured horizontal and vertical +4° *(c)*; corrected horizontal and vertical –2° *(d)*; and corrected horizontal and vertical –4° *(e)* angles.

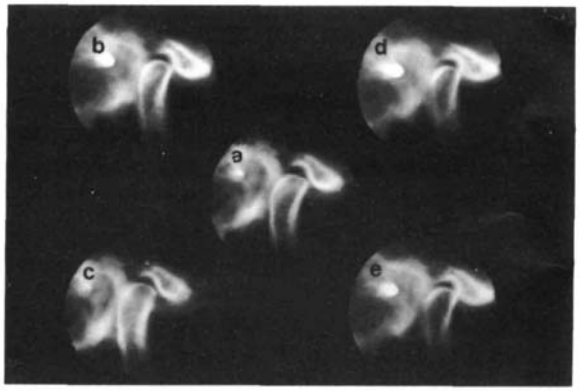

Figure 13. Tomographs of the left TMJ (specimen shown in Figure 7). Corrected measured vertical and horizontal angles *(a)*; corrected measured vertical and horizontal +2° *(b)*; corrected measured vertical and horizontal and vertical +4° *(c)*; corrected measured vertical and horizontal –2° *(d)*; and corrected measured vertical and vertical –4° *(e)*.

Discussion

Variation of the horizontal and vertical condylar angles was studied on 1,560 skulls of the Terry Collection by Yale and associates in 1966. These authors reported that the horizontal angle in most of the skulls studied (99% ranged between 0 to 33 degrees. The vertical condylar angle in their study ranged between -45 to +35 degrees with a mean vertical condylar angle of +5 degrees. They also reported that in 48.1% of the mandibles studied,

there was symmetry in the horizontal angle, while in 51.8% there was symmetry in the vertical angle. The symmetry in both horizontal and vertical condylar angles occurred in only 26% of the case.[18]

Our results, which showed a wide range in the horizontal and vertical condylar angles, are consistent with Yale and associates findings.[18] These results support the need to measure the horizontal and vertical angles individually for each joint prior to the tomographic examination of the TMJ. This measurement becomes of great importance in producing tomographic images which are free of distortion of the condylar image. The concept of a standard 20 degrees horizontal rotation of the head before tomographic examination of the TMJ was proposed and adapted by some investigators.[4,19] However, others, like Lundberg and Walander,[20] Eckerdal,[16] Eckerdal and Lunberg,[21] reported that a small difference of 5° in the horizontal condylar angle correction between two radiographs of the same joint can lead to marked changes in the image of the anatomic structures and might lead to a risk of erroneous interpretation of the joint relationships. On the other hand, Danforth and co-workers in 1991 reported that there was no difference between the standard 20° positioning and the actual condylar horizontal angle as measured on the patient's SMV radiograph.[22] Our results derived from the tomographic images of the dried skull clearly showed that a slight variation of +2 or -2 degrees in either the horizontal or vertical condylar angles resulted in alteration in the anatomic relationships as well as distortion of the image clarity.

Based on the findings in the present investigation, we can conclude that compensation for individually measured horizontal and vertical condylar angles is essential for the production of high quality diagnostic tomographic images of the TMJ.

Acknowledgement

The authors wish to express their grateful thanks to Ms.
Cora L. Alano for typing the manuscript and to Ms. Jane M. Sembrano for the computer graphics.

References

1. Lindblom G. Technique for roentgen-photographic registration of the different condyle positions in the temporomandibular joint. Dental Cosmos 1936;78:1227.
2. Gillis RR. X-rays reveal dysfunction. Dent Survey 1939;15:17.
3. McQueen WW. Radiography of the temporomandibular articulation. Min District Dent 1937;21:28.
4. Riesner SE. Roentgen technique for the mandibular joint. IntJOrthod 1937;23:740.
5. Higley LB. Practical application of a new and scientific method of producing temporomandibular roentgenograms. J Am Dent Assoc 1937;24:222.
6. Maves TW. Radiology of the temporomandibular articulation with correct registration of vertical dimension for reconstruction. J Am Dent Assoc 1938;25:585.
7. Mustermann HW. Principles and practice of X-ray technic and interpretation. New York:Dental Items of Interest PublCo, 1945:79-82.
8. Updegrave WJ. Improved roentgenographic technic for the temporomandi-bular articulation. J Am Dent Assoc 1950;40:391.
9. Updegrave WJ. An evaluation of temporomandibular joint roentgenography. J Am Dent Assoc 1953;46:408.
10. Grewcock RJG. A simple technique for temporomandibular joint radiography. Br. Dent J 1953;94:152.
11. Cole SV. Transcranial radiography: Correlation between actual and radiographic joint spaces. J Craniomandibular Pract 1984;2:153-58.
12. Rosenberg HM, Silha RE. TMJ radiography with emphajis on tomography. Dent Radiogr Photogr 1982;55:1-24.
13. Yale SH. Radiographic evaluation of the temporomandibular joint. J Am Dent Assoc 1969;79:102-07.
14. Bussard DA, Kerr G, Hutton C, Yune H. Technique and use of corrected axis tomograms of the mandibular condyles. Oral Surg Oral Med Oral Pathol 1980;49:394-97.
15. Yale SH, Rosenberg HM. Laminographic cephalometry in the analysis of the condyle morphology. Oral Surg 1961;14:798.
16. Eckerdal O. Tomography of the temporomandibular joint. Correlation between tomographic image and histologic sections in a three dimensional system. Acta Radiol Suppl Stockh 1973;329:1-107.
17. Rosenberg HM, Graczyk RJ. Temporomandibular articulation tomography: A corrected anteroposterior and lateral cephalometric technique. Oral Surg Oral Med Oral Pathol 1986;62:198-204.
18. Yale SH, Allison BD, Hauptfuehrer JD. An epidemiological assessment of mandibular condyle morphology. Oral Surg Oral Med Oral Pathol 1966;21: 169-77.
19. Stanson AW, Baker HL. Routine tomography of the temporomandibular joint. Radiol Clin North Am 1976;14:105-27.
20. Lundberg M, Walander U. The articular cavity in the temporomandibular joint: A comparison between oblique lateral and tomographic image. Medicamundi 1970;15:27-35.
21. Eckerdal O, Lundberg M. Periodic roentgenography of the temporo-mandibular joint. J Int Assoc Dento-Maxillofac Radiol 1975;4:4-11.
22. Danforth RA, Otis LL, Kipnis V, Ong SH, Voss R. Corrected TMJ tomography: Effectiveness of alternatives to SMV tracing. Am J Orthod Dentofac Orthop 1991:100:547-52.