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Original articles

Use of transcranial radiograph to detect morphological changes in mandibular condyles

Uso da radiografia transcraniana para detectar alterações morfológicas no côndilo mandibular

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ABSTRACT

Purpose: to evaluate the accuracy of conventional transcranial radiographs (TRANS) to identify morphological changes in mandibular condyles.

Methods: the sample consisted of 36 mandibular condyles, obtained from 18, randomly selected, dried human skulls, without the identification of age, gender, or ethnicity. Three experts in dental radiology examined the TRANS to identify possible changes in the condyles. The fourth examiner performed the macroscopic examination, which was considered the gold standard of the study. The condyles in both TRANS images and macroscopic examinations were classified as mandibular condyles with change (1) or no change (0). Statistical analyses were performed using the X^2 and the receiver operating characteristic (ROC) curve. Kappa intra- and interobserver tests were performed for examiners 1 to 3.

Results: the X^2 test showed a statistically significant association between changes in the condyle in the TRANS images and the presence of macroscopic changes in the condyle ($p < 0.05$). The area under the curve was 0.83, with 96% sensitivity and 70% specificity. The weighted kappa value for intraobserver agreement was 0.78, while the interobserver agreement was 0.71.

Conclusion: the use of TRANS proved to be an effective method to detect morphological changes in the mandibular condyle.

Keywords: Temporomandibular Joint; / radiography; Temporomandibular Joint Disorders; Diagnostic Imaging

RESUMO

Objetivo: o objetivo deste estudo foi avaliar a acurácia das radiografias transcranianas (TRANS) convencionais na identificação das alterações morfológicas nos côndilos mandibulares.

Métodos: a amostra consistiu em 36 côndilos mandibulares, obtidos a partir de 18 crânios secos humanos, aleatoriamente selecionados, sem identificação de idade, gênero ou etnia. Três especialistas em radiologia oral examinaram as TRANS para identificar possíveis alterações nos côndilos. Um quarto examinador realizou o exame macroscópico, que foi considerado o padrão ouro do estudo. As imagens das TRANS e os exames macroscópico foram classificados como (1) côndilos com alteração ou (0) côndilos sem alteração. A análise estatística foi realizada através do teste X^2 e da curva ROC (*receiver operator characteristic*). O teste Kappa intra e interexaminadores foi realizado para os examinadores 1 a 3.

Resultados: o teste X^2 mostrou uma associação estatisticamente significativa entre as alterações no côndilo vistas nas imagens TRANS e a presença de alterações macroscópicas ($p < 0,05$). A área sob a curva ROC foi de 0,83, com 96% de sensibilidade e 70% de especificidade. O valor Kappa para a concordância intraobservador foi de 0,78, enquanto que a concordância interexaminador foi de 0,71.

Conclusão: o uso de radiografias transcranianas apresentou-se como método eficaz para a detecção de alterações morfológicas no côndilo mandibular.

Descritores: Articulação Temporomandibular; / radiografia; Transtornos da Articulação Temporomandibular; Diagnóstico por Imagem

INTRODUCTION

Temporomandibular disorders (TMDs) are classified as musculoskeletal degenerative disorders associated with morphological and functional deformities[1-3].

These present a multifactorial etiology[1,2,4-7] and constitute a common complaint in many public and private dental services. TMDs are associated with one's quality of life, presenting a positive correlation between the severity of the temporomandibular dysfunction and the negative impact upon one's quality of life[4-8].

Prior epidemiological studies, using diverse populations, have examined the prevalence of TMDs[9]. Some studies indicate a prevalence of 5-12%[2,10,11], while others have shown that nearly 40-60% of the general population can present the symptoms and signs of TMD[9], but only a small percentage of these affected individuals actually seek treatment[1,12], This diversity of results concerning prevalence stems from the wide range of methodologies used in studies, especially as regards the sample selection criteria and the lack of standardization related to TMD diagnoses[12,13]. As regards gender, it is estimated that TMD is more prevalent in women than in men[1,7,10].

Patients with TMD may also present other symptoms in addition to pain, such as clicking and crackling, changes or limitations in mandibular movements, and headaches and/or muscular pain[1,14]. TMDs can also affect the ears, eyes, and throat. Patients commonly report headaches that involve part or all of the head (frontal, temporal, parietal, occipital) and neck[1,2,5-7,15].

TMD diagnosis is based on the patient's medical history, in the clinical exam, and in the evaluation of the imaging exam[1-3,14,16]. The clinical diagnosis evaluates the mandibular movements and the pain associated with these movements, joint noises, and symptoms found upon palpation of the region of the joints and muscles associated with temporomandibular joint (TMJ)[17]. As regards the imaging exam, various radiographic techniques have been proposed to evaluate TMJ, such as the transcranial radiograph (TRANS), computed tomography (CT), cone beam computed tomography (CBCT), arthrography, and magnetic resonance (MR)[4,14,17-19].

Transcranial radiographs have been used worldwide as a preferential complementary exam in comparative studies aimed at verifying the form, shape, and position of condyles during the opening and closing of the mandible. This radiograph guides the request for complementary exams in many countries, as it can be a way to reach a diagnosis speedily, easily, inexpensively, and with a low dose of radiation[1,18,20-23].

Considering the importance of the evaluation of the morphological changes of mandibular condyles in the radiographic exams of TMJs in patients with TMD, this work seeks to evaluate the accuracy of transcranial radiographs in identifying osteophytes, worn or flattened surfaces, erosion, among other changes in mandibular condyles.

METHODS

Subjects

Research for this study began after having received approval from the local ethics committee (CAAE: 51173515.2.0000.5137 seems 1421150). The sample consisted of 36 mandibular condyles from 18 mandibles from dried human skulls selected from the collection of anatomical specimens at the Department of Dentistry of the University. The condyles were numbered from 1 to 36 for this study. The selection criterion to select the skulls was random, with no identification of age, gender, or ethnicity.

Transcranial radiographs

To obtain the TRANS scans, a utility wax sheet was fixed to the articular fossa of the skulls (Wilson, Polidental, Cotia, SP, Brazil) to create space between the mandibular condyle and the mandibular fossa. Next, the mandible was fixed to the maxilla using hot melt adhesive (CIS, Sertic, São Paulo, SP, Brazil) with teeth in occlusion. The skulls were positioned using the Accurad-200 head holder (Whip Mix Corporation, Fort Collins, CO, USA). The Frankfort horizontal plane was used as a reference to position the dried human skull, while the midsagittal plane was aligned using vertical supporting bars, simulating the position of a patient. The head holder directs the central x-ray beam to the long axis of the condyles, causing the condyle to be radiographed so as to align itself perpendicularly to the film and parallel to the x-ray path. The imagens were taken on a traditional Oralix Gendex X-ray machine (Gendex Dental Systems, Hatfield, PA, USA), which operated at 70 KVP and 10 mA, with an exposure time regulated according to the bone thickness, at 0.05 for the TMJ region in a dried human skull. Kodak film (Eastman Kodak Company, Rochester, NY, USA) was used and automatic processing was performed by means of the A/T2000 XR Automatic Dental Film Processor (AIR Techniques, Melville, NY, USA) (Fig. 1).

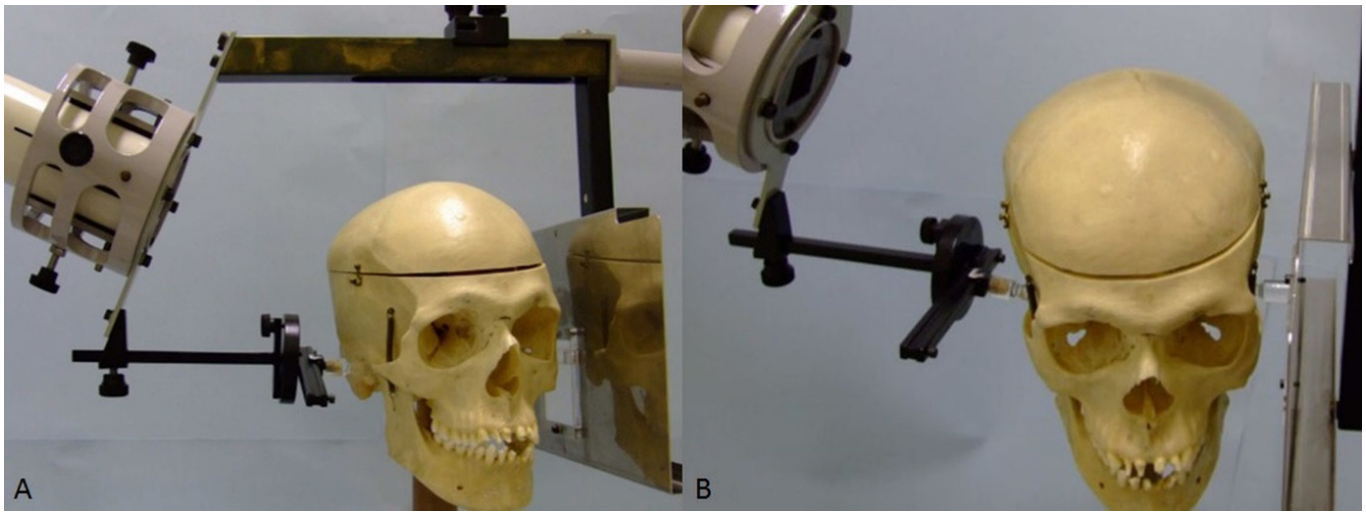

Figure 1. Transcranial radiograph. (A, B) Stabilization of the dried human skull using the Accurad-200 head holder

Image analysis

All structural changes in the condyles shown both in the radiographs and in the anatomical specimens, including osteophytes, worn and flattened surfaces, and erosion, were grouped as being visible changes and received the code (1), i.e., "with change." The condyles that did not present changes received code (0), i.e., "no change" (Fig. 2).

Figure 2. Condylar bone changes observed macroscopically. (A) Erosion with exposure to bone marrow. (B) Osteophyte. (C) Flattening of the condyle with the preservation of the cortical bone

The TRANS images were evaluated by three oral radiologists (examiners 1 to 3), two with ten years of experience and another with eight years of experience. The three examiners had prior knowledge that the images had come from dried human skulls. All three radiologists drafted reports about the images, considering the value (1) for the images in which the condyle presented change, and (0) when the condyle presented no change (Fig. 3).

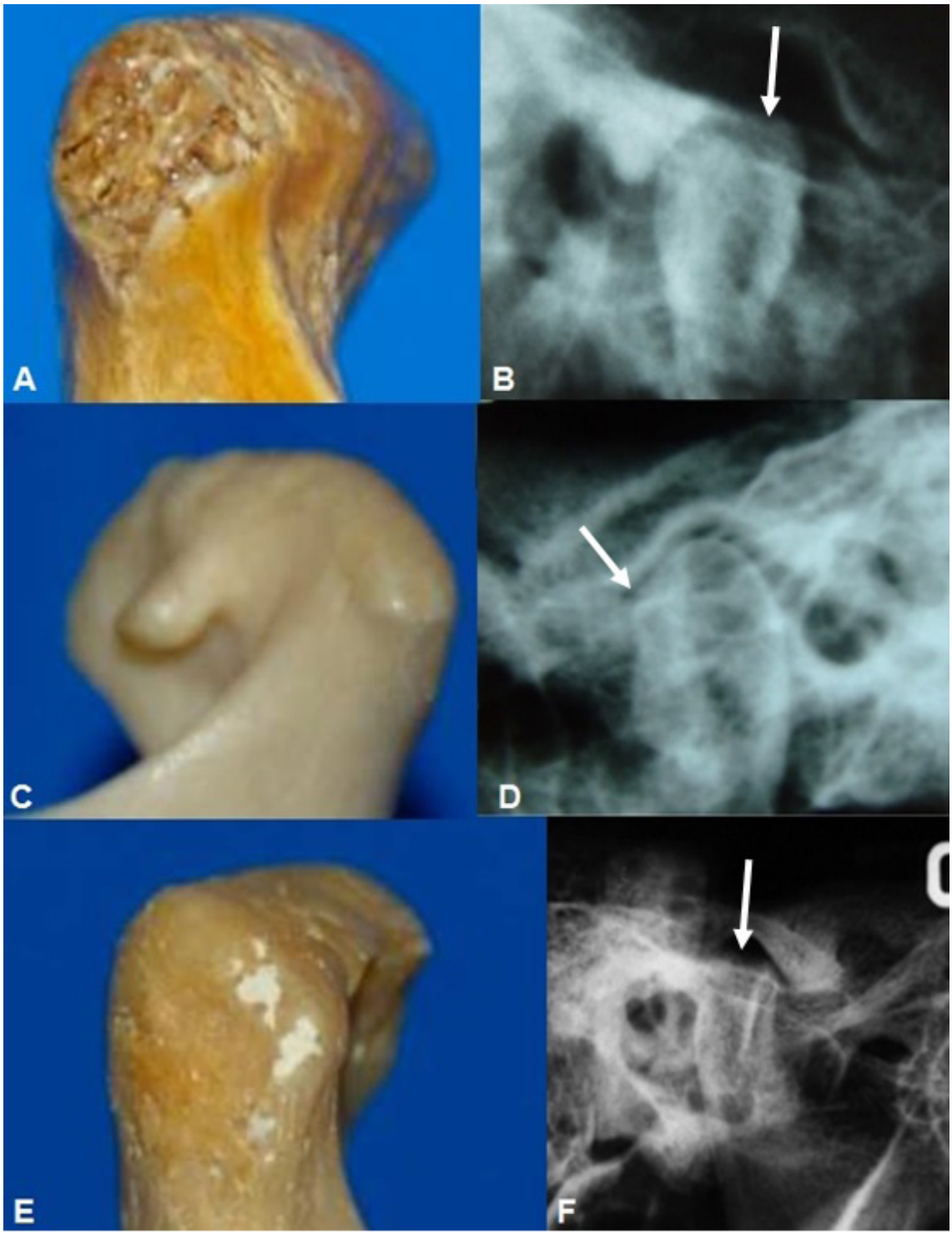

Figure 3. Transcranial images. A. Condyle with erosion. B. Transcranial radiograph shows the erosion. C. Condyle with osteophytes. D. Transcranial radiograph shows the osteophytes. E. Condyle with flattening of the articular surface. F. Transcranial radiograph shows the flattening

A fourth oral radiologist (examiner 4) examined the dried human skulls macroscopically and drafted a report about the images, considering the same TRANS criteria, that is, value (1) for the images in which the condyle presented change, and (0) when the condyle presented no change. This result was considered the gold standard of the study.

Statistical analyses

The X^2 test was used to determine the association between the diagnosis of the change in the condyle in the TRANS and the morphological changes in the mandibular condyle observed in the anatomical specimen. The significance level was $p<0.05$. The receiver operating characteristic (ROC) curve was used to measure the accuracy. The area under the ROC curve (AUC) was calculated using BioEstat Software, v. 5.0 (Instituto de Desenvolvimento Sustentável Mamirauá, Belém, Brazil). True negatives, true positives, false positives, and false negatives were calculated.

The intra and interobserver KAPPA test was performed for examiners 1 to 3. To interpret the KAPPA statistics, values of 0.81–1.00 indicated very good agreement, 0.61–0.80 indicated good agreement, 0.41–0.60 indicated moderate agreement, 0.21–0.40 indicated fair agreement, and 0.20 or less indicated poor agreement[24].

RESULTS

According to macroscopic examination, of the 36 mandibular condyles, 26 presented morphological changes, whereas 10 presented no morphological changes (Table 1).

Table 1. Frequencies of test results for 26 mandibular condyles with morphological changes and 10 mandibular condyles without morphological changes

Diagnostic test result	Morphological changes in the mandibular condyle	
	POSITIVE (1)	NEGATIVE (0)
POSITIVE (1)	25	3
NEGATIVE (0)	1	7
TOTAL	26	10

Considering the evaluation of the TRANS images by examiners 1-3, the weighted KAPPA value for intraobserver agreement was more than 0.78. The weighted KAPPA value for interobserver agreement was 0.71. These results showed good intra and interobserver agreement[24].

The X^2 test showed a statistically significant association between the change in the condyle in the TRANS and the presence of macroscopic change in the condyle ($p < 0.05$). The area under the curve was 0.83, with 96% sensitivity and 70% specificity (Fig. 4). The positive and the negative predictive values were determined to be 89% and 87%, respectively.

Table 2. Sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of transcranial radiographs

Sensitivity	0.96
Specificity	0.7
Negative predictive value	0.87
Positive predictive value	0.89
Accuracy	0.88

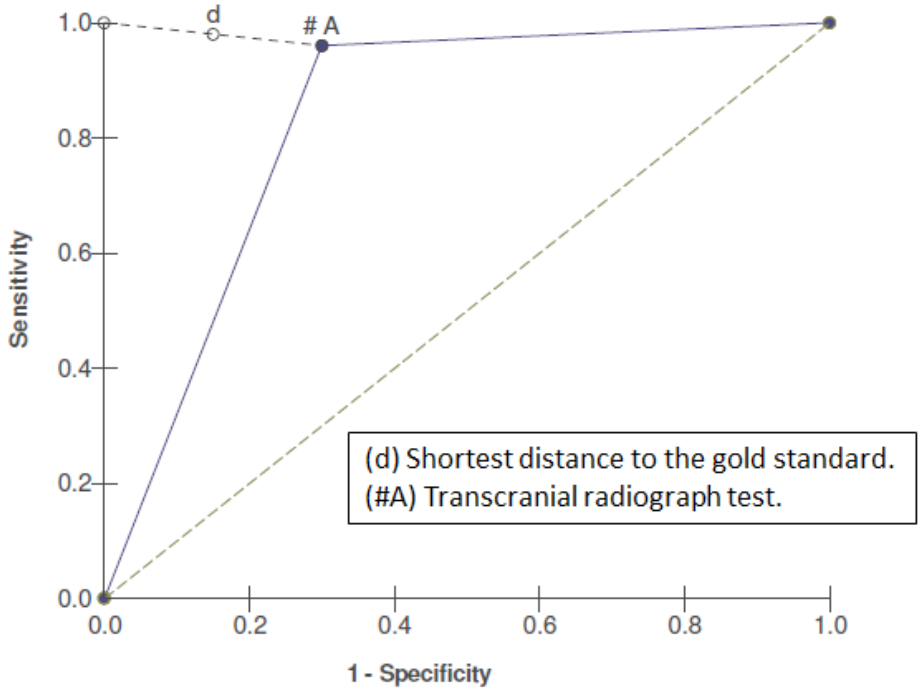

Figure 4. ROC curve. Area under ROC curve = 0.83

DISCUSSION

In this study, the accuracy of TRANS was assessed in its capacity to detect the morphological changes present in mandibular condyles through transcranial radiographs, using the macroscopic examination of anatomical specimens as the gold standard.

Some criteria are used to classify and guide the clinical approach of the TMDs[2,14,16,25], associating the history of the patient with the data that can be found in the patient's clinical exam and radiograph[2,3,14]. However, in the absence of an imaging exam, the sensitivity should be of 55% and the specificity of 61% for degenerative joint diseases of TMJ[2]. Thus, for better accuracy in TMD diagnoses, imaging exams are essential.

Condylar bony morphological changes, such as bony surface erosion, concavity, spurring, and flattening are bone alterations related to TMD[12] and that provide radiological signs. The imaging techniques used to evaluate such TMJs include: radiographic techniques (panoramic, lateral transcranial, transpharyngeal, and transmaxillary view), arthrography, as well as CT and MR exams. The structural changes (osteophytes, flattening, erosion, and sclerosis) and arthritic changes can be detected through TRANS[12,26,27].

Studies that have compared the CT exam, arthrography, and surgery with TRANS, have shown contradictory results. For some, there is a good correlation between these exams[28]. For others, when a condyle is not symmetrically positioned due to torsion within the joint cavity, the evaluation in the conventional radiograph is only partially relevant[29]. MR imaging uses no radiation, has a high diagnostic accuracy, and is capable of assessing the disk position, disk shape, and bony changes; however, its cost is rather high[4,9,17,30].

The correct three-dimensional positioning of the head is necessary to properly conduct a TRANS, given that the long axis of the condyle must be radiographed perpendicularly to the film on the axial and coronal planes. Due to the angle of 75° of the X-ray beams, the lateral third of the glenoid fossa and condyle are projected upon the film. As a result, the central and medial portions of the condyle are projected below the radiographic image of the condyle and cannot be observed in the TRANS[31]. Thus, the TRANS radiograph possesses a limitation, as it is essentially a profile or cross-sectional view of the lateral third of the glenoid fossa and condyle[31]. By contrast, bony changes occur on the articular surface[32], and although the joint space is not constant in various sagittal and transversal locations, the relative anterior and posterior joint spaces remain proportional in such a way that the classification of the condyle position in the fossa (i.e., retruded, concentric or protruded) remains the

same[31]. Hence, the TRANS radiograph can be used as a reference of condylar position within the fossa and as an aid in the diagnosis and treatment of pain caused by TMJ dysfunction[27,31].

In the literature, there are few works that assess the accuracy of TRANS in the evaluation of the degenerative processes of TMJ. The work of Scarfe et al.[21] show a sensitivity of 42.9%, a specificity of 75.3%, and an accuracy of 69.2% in the detection of osteophytes, with a digital sensor and a sensitivity of 52.4%, a specificity of 68.7%, and an accuracy of 65.6% with conventional film. As regards the CT exam, Scarfe et al.[21] show a sensitivity of 61.9%, a specificity of 84.1%, and an accuracy of 79.9% in the detection of osteophytes. In a position of maximum mouth opening, Menezes et al.[4] found a sensitivity of 84%, a specificity of 92%, and an accuracy of 91% for TRANS; however, the purpose of these authors was not to assess the accuracy of TRANS in the detection of the degenerative processes of the condyle, but rather in the positioning of the condyle within the TMJ. The present study obtained a sensitivity of 96%, a specificity of 70%, and an accuracy of 88% in the detection of degenerative processes and structural changes, with the use of conventional films, values which proved to be quite similar to those obtained by MR. According to Kumar et al.[12], MR has a sensitivity of 82.6% and a specificity of 66.7% in symptomatic patients.

MR is considered the gold standard to assess the position of the condyle and the mandibular joint disc in the glenoid fossa; however, its cost is quite high[4,12]. The tomographic digital images are also of high quality and precision[1,2,4], however, they also have a high cost[33,34]. By contrast, TRANS has been exclusively used to assess the position of the condyle within the fossa as well as to evaluate bone changes, all at a low cost. Nevertheless, to date, no study has assessed the accuracy of TRANS specifically regarding the detection of the morphological changes of the condyles. This study demonstrated that TRANS presents an appropriate accuracy for the evaluation of the morphological changes of the condyles.

TMD treatment does have an economic impact. The annual cost related to TMD treatment in the USA, not including imaging exams, has doubled over the past decade, reaching nearly US$4 billion[2,35]. Thus, due to the cost and high prevalence of TMD, it is crucial that these problems be assessed in specific primary healthcare units, using a standardized clinical exam and a diagnostic protocol[1,2,5,7,8]. For this to occur, complementary exams must have an accessible cost without a loss in the quality of data, so that they can be considered in the complex system of public funding. The present study showed that TRANS is an efficient and inexpensive exam that is capable of aiding in TMD diagnoses in cases in which the condyle presents morphological changes.

This study has some limitations. First, the imaging on dried skulls are more accurate than a live individual because the skulls can be accurately oriented for the radiographic examination, whereas, the live person may be more difficult to get the correct alignment of the radiograph beam with the long axis of the condyle. Second, the soft tissues in a live individual could possibly blunt some of the definition of bony changes seen on dried skulls. Third, TRANS evaluates only the lateral one third of the condyle, so pathology that may exist in the middle or medial aspect of the joint may not be identified. Fourth, drying skulls could possible cause some desiccation of the condylar surface resulting in greater arthritic bone changes than when the patient was alive. Finally, radiographic assessment was done by three dental radiology experts who have a far better expertise to identifying minor osseous changes as compared to the average clinician that may use this radiographic approach.

CONCLUSION

In conclusion, it was possible to compare the reports of the images obtained by transcranial radiographs on dried skulls with the macroscopic viewing of radiographed anatomical specimens. This present study performed on dried skulls proved that TRANS is an efficient and inexpensive exam that can be used to detect morphological changes in condyles.

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