Comparison of Image Negatives and Brightness Enhancement for Temporomandibular Joint Visualisation in Lateral Cephalometric Digital Radiography

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Abstract

A purpose of the current study was to compare the negative and brightness adjusted images in the visualization of the temporomandibular joint in the cephalometric radiographs.

The visualization the condylar head and the surrounding structures was evaluated with a two-alternative forced-choice trial. Thirty observers individually evaluated 20 sets of lateral cephalometric images. Each set included an original image, a negative image, and a brightness-adjusted image. The observer's gender, age, and clinical experience duration were described with Levene's test ($P > 0.05$). The preference of processed images selected by the observers with each parameter was assessed with Pearson's chi-square test ($P < 0.05$).

Observers in the aggregate had no significant preference between these two enhancement techniques. However, female observers significantly preferred image negatives, while male observers preferred images with brightness adjustment ($P = 0.001$). The observers with 3 to 10 years of experience significantly preferred the images with brightness adjustment, while those with 11 or more years of experience preferred the image negatives ($P = 0.002$).

There is no statistical significant in visualization negative images and brightness adjustment images for temporomandibular joint assessment in lateral cephalometric image. However, the observers' gender and their length of clinical experience influenced their selection of image enhancement techniques for temporomandibular joint lateral cephalograms ($P < 0.05$).

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Introduction

The temporomandibular joint (TMJ), a bilateral articulation between the skull's temporal bone and mandible, is heavily loaded by the action of the incisors. The TMJs must constantly cooperate to a greater extent than other paired joints of the human body.[1] The TMJ shape is determined by the chewing surfaces of the teeth[2] and changes with age.[3] A condylar neck supports an articular surface and fits into the mandibular fossa of the temporal bone. Its head possesses no fixed turning point, causing a sliding movement in the sagittal direction.[1]

The mandibular condyle needs a thorough inspection before the commencement of orthodontic treatment, as condylar abnormalities sometimes result in orofacial pain or tenderness.[4-6] The morphology of the TMJ can be roughly seen in lateral cephalograms, routinely prescribed by orthodontists and used diagnostically by oral radiologists and/or orthodontists.

The lateral cephalometric radiograph is the most commonly used for orthodontic diagnosis and treatment planning. Applications of lateral cephalometry include the radiographic assessment of condyle position as well as pre- and post-operative assessment for temporomandibular disorder (TMD). The lateral cephalometric radiograph illustrates the condylar head and glenoid fossa outlines. The superimposition of surrounding structures causes

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anatomical or background noise leading to difficulty in the condylar assessment.[7-9]

Several efforts can be taken to overcome TMJ visualization problems in lateral cephalometric images including substantial viewing with three-dimensional imaging[10-11] adjusting exposure factors, positioning the patient properly, and having the patient remove metal objects (e.g., jewelry or clothing that restricts imaging). Whilst three-dimensional imaging can significantly maximize the condylar structure, it is exorbitantly expensive and not always available.[12] For this reason, a variety of image-processing techniques have been utilized for image enhancement. The principle of image enhancement aims to improve the original image for specific tasks. Two broad categories of image enhancement methods are spatial domain methods and frequency domain methods.

Spatial domain techniques directly deal with the image pixels. The pixel values corresponding to x-ray intensity at each specific location are manipulated to obtain the desired visualization.[13] Frequency domain methods initially transfer the image into the frequency domain and then manipulate it in the Fourier transform. The result images are obtained from Inverse Fourier transformation afterward. Common enhancement techniques in dentistry such as negative image conversion and brightness optimization are performed in the spatial domain. The pixel intensities in the resultant image will be modified according to the transformation function applied to the input image pixels.[14-15]

An image negative is produced by subtracting each pixel from the maximum intensity value in an image. For greyscale images, bright area appears dark and vice versa. It is suitable for enhancing white detail in dark regions and has many applications in medical imaging.[15] Brightness adjustment defines as a method that moving all pixel values towards white or black direction. The difference between the original and the resultant pixel values remains the same.[16] Enhancing an image by converting it to negative or adjusting image brightness may be necessary to visually achieve acceptable image content. Many commercial dental software programs possess of these basic adjustment properties for image processing.[17] However, there are few studies investigating the influence of image negative and brightness adjustment on lateral cephalometric images for the TMJ visualization.

Of above reasons, the present study aimed to evaluate the visualization of negative images and brightness adjustment images in lateral cephalometric radiography by using a observer's preferences related to subjective image visualization for these images.

Materials and methods

This study was approved by the university ethical committee (IRB Number 1139/60). Before starting the experimental procedures, the effect size was calculated based on the previous study.[17] The study was designed to have 80 percent power of test, assuming calculated using G*Power version 3.1.9.2 (Franz Faul, University kiel, Germany). Total number of observer was twenty.

Due to limitation of staffs, thirty observers with good or corrected vision were recruited from the postgraduate students and academic staffs in the faculty. None of these was formal training in image processing.

The selected image was from Angle's Class I malocclusion patients without temporo-mandibular disorder sign and symptom, age ranged from 20-30 year old. Twenty data sets of lateral cephalograms corresponding 20 patient' digital radiographic files obtaining between January 2018 and June 2019 were recruited for this experiment. The unclear lateral cephalometric images were excluded from this study.

The visibility of the bony contours of the mandible's condylar head and the surrounding structures in 8 bit resolution cephalogram (Figure 1A) were enhanced by converting the image to a negative (Figure 1B) or adjusting the brightness of the image (Figure 1C) in Adobe Photoshop 6.0 Graphics and Image Processing Software (Adobe Inc., San Jose, CA). Thereafter, each original radiograph had inverted and +50% brightness adjustment resulting from invert and brightness sub-menu according to a previous study.[18]

A program was written using commercially available software (MATLAB; MathWorks Inc., MA) to present the 20 sets of three images (the original image, negative image and adjusted brightness image) to each observer, one set at a time. Each observer was initially informed the study purpose, the cortical border visualization of the condylar head and the integrity of glenoid fossa. Thereafter, the observer compared optimal brightness and negative images blindly and randomly.

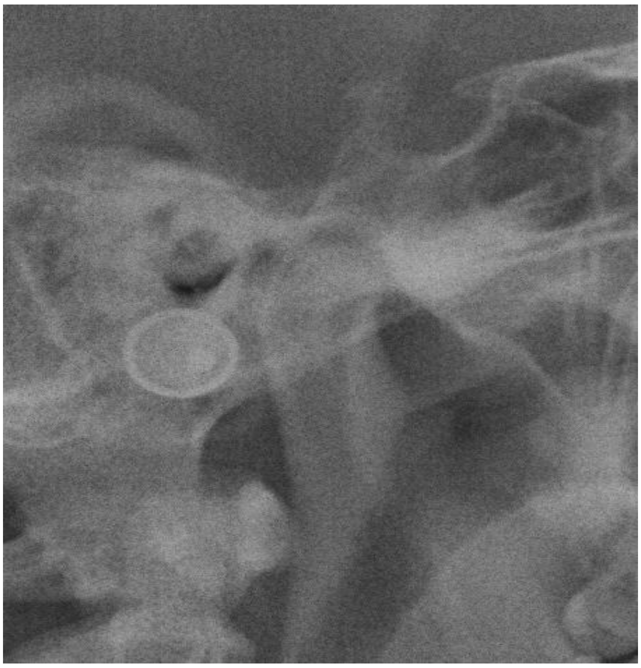
Figure 1A.

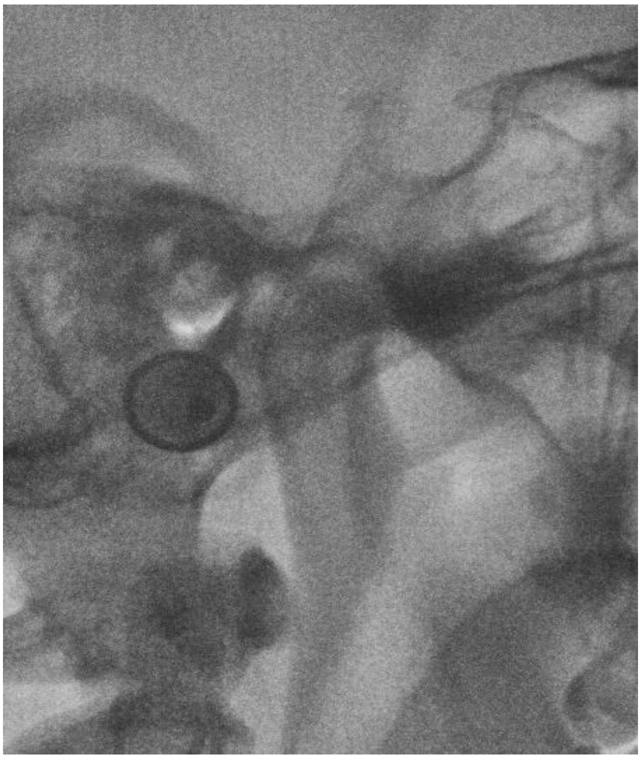
Figure 1B

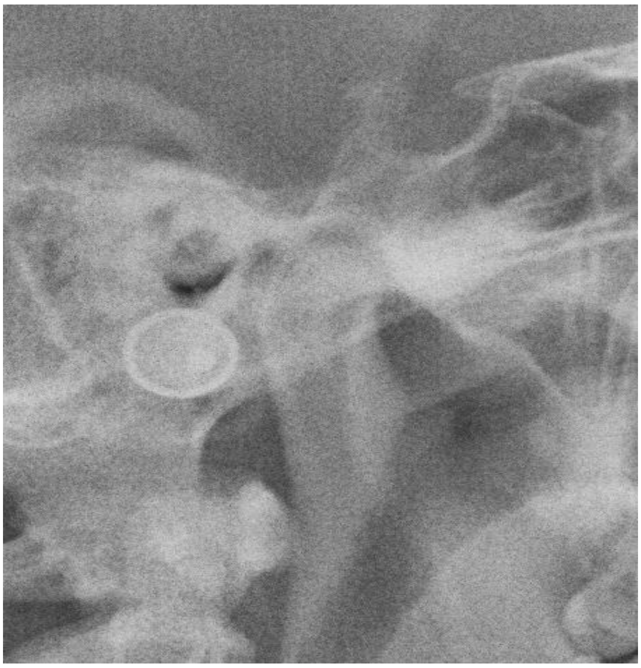
Figure 1C

Figure 1. Original image (A), together with the original images undergone inverse filtering (B) and a brightness adjustment (C), of a mandible's condylar head applied in a lateral cephalogram digital radiography.

The program presented the question, "Which image is better?" followed by the statement, "To make your decision, you need to consider how clearly the anatomical details of the condylar head and glenoid fossa have been revealed", after which it let the observer choose between two processed images in response.

On initiation of the program, two example images from two additional cephalograms were presented to the observer to acquaint them with the TMJ images. Subsequently, the 20 sets of images were presented one set at a time in random order, with the spatial arrangement of the Group 1 and Group 2 images randomised in each set. The experimental procedures were conducted under the same lighting and viewing conditions for all observers. A 30-inch liquid crystal display screen with a maximum resolution of 1,920×1,200 pixels was used under regular ambient office lighting to display the images at a scale of 1 pixel to 1 pixel. Each observer completed the task in isolation and was blinded to the other observers' results. A re-test was performed two weeks later.

The obtained data were analysed using SPSS for Windows (Version 23.0, SPSS, NY).

Descriptive statistics (means ± standard deviations) were calculated for observers' age and clinical experience duration (in years), and Levene's test was performed (Table 1).

Gender (*n*)	Mean age, years (standard deviation)	Mean duration of clinical experiences, years (standard deviation)
Male (13)	34.08 (7.15)[a]	10.00 (6.90)[b]
Female	37.35 (4.91)[a]	13.12 (5.12)[b]
P	0.148	0.166

Table 1 Observer descriptions.
Same uppercase letters indicate non-significant differences intra-column by Levene's test (P > 0.05).

Parameter (N)		Processed images selected by observers (n, %)		Total	*P*[a]
		Image negative	Brightness adjustment		
Observers' gender	Male (13)	93 (14.1)	147 (22.3)	240 (36.4)	0.001
	Female (17)	217 (32.9)	203 (30.7)	420 (63.6)	
Observers' exposures to the images	Non-daily (18)	182 (27.6)	218 (33.0)	400 (60.6)	0.348
	Daily (12)	128 (19.4)	132 (20.0)	260 (39.4)	
Observers' dental specialty	Orthodontist (8)	75 (11.4)	105 (15.9)	180 (27.3)	0.095
	Non-orthodontist (22)	235 (35.6)	245 (37.1)	480 (72.7)	
Observers' clinical Experience duration	3-10 years (15)	103 (15.6)	157 (23.8)	260 (39.4)	0.002
	11 years or over (15)	207 (31.4)	193 (29.2)	400 (60.6)	

Table 2. Number of the processed images selected by observers in this study in relation to each parameter.
[a]Pearson chi-square test for independence significant at P < 0.05.

Pearson's chi-square test was performed to test for independence ($P < 0.05$) between the images (processed by negative images and by brightness adjustment) and the following selected parameters (Table 2):

1. The observers' gender (male or female).
2. The observers' exposures to radiographic images (non-daily or daily).
3. The observers' dental speciality (general practitioner or specialist).
4. The observers' duration of clinical experience (3-10 years or 11+ years).

Results

In the end of the experiment, the frequency of preferences in both processed images was count. Pearson chi-square test was performed to determine the relationship between observers' parameters and their responses to the processed images. The result revealed that the negative images and the brightness adjustment images had the similar image preference. Table 1 shows descriptions of the observers. Neither age ($P = 0.148$) nor duration of clinical experience ($P = 0.166$) was significantly different between male and female observers. With respect to the processed images selected by the observers, no significant association was detected with the observers' exposures to the images ($P = 0.348$) or with their dental specialties ($P = 0.095$). However, there were significant associations between the selected images and the observers' gender ($P = 0.001$) as well as their duration of clinical experience ($P = 0.002$).

Discussion

Our two-alternative forced-choice visual trials revealed that brightness-adjusted lateral cephalograms of the TMJ were selected more frequently than negatives with no statistical significance, implying that the former option is more effective in preserving or restoring the images of the underlying structures. This result corresponds to the findings of previous studies. Preferences regarding brightness adjustment have been found to differ among observers.[14,20-24] Hence, an optimal brightness applicable to improve the accuracy of image interpretation is needed.

Gender differences in visual perception are controversial.[25] In primates, inputs from rod photoreceptors, which enable good vision in low light, are received by the magnocellular layer of the lateral geniculate nucleus.[26-27] In a clinical measurement of contrast thresholds, magnocellular-biased stimuli were processed similarly by both genders.[28] In another investigation, females showed significantly higher sensitivity than males at low contrast levels in response to stimuli of uniform grating patterns in vertical and oblique directions.[29] However, a study utilising standard tests of acuity, colour vision, and stereopsis revealed significantly higher contrast sensitivity in males than in females at all spatial frequencies.[30] These findings stand in contrast to ours regarding the association between gender and preferred image enhancement techniques. The images processed with contrast enhancement were significantly preferred by females, whereas the images that had undergone brightness adjustment by males ($P = 0.001$). Additional studies are needed to clarify whether contrast enhancement and brightness adjustment of TMJ lateral cephalometric digital radiographs improve visibility specifically for female and male dentists, respectively.

Since experience in clinical practice has been reported to affect the interpretation of medical radiographs in some instances,[31-32] a deficiency of experience could contribute to errors in disease diagnoses. In the present study, no significant correlation was detected between the observers' frequency of exposures to radiographs or their dental specialities and their preferred image processing technique (P = 0.348 and 0.095, respectively). However, the observers' duration of clinical experience was significantly correlated (P = 0.002). Evidence implies that radiologic image interpretation depends on learned, task-specific skill, as there is no significant difference among radiologists in search pattern behaviour or in skill with non-medical images.[33-34] Therefore, focused training is an effective way to build skills important to radiographic interpretations for all dental specialities.[35]

The visual trials in this study were subjective evaluations highly dependent on perception. Both visual perception and cognition are essential in diagnostic performance.[36] Some significant variations in medical image interpretation have been reported within and between observers.[37] This variability, together with the normal case-to-case variation within individuals, highlights the importance of calibration to improve performance and reduce the variability of interpretation. In addition, experience in medical image interpretation and knowledge of anatomical structures would promote good diagnostic performance, which would significantly impact the care of patients with TMD.

Radiographic images, being created by the shadows of attenuated X-rays passing through the target organ, are different from other image types, for example, paintings and photographs.[36] Additionally, overlapping anatomical structures increase the difficulty of image visualisation. A relationship between colour image display and medical image visualisation has been reported.[31] Nevertheless, the alteration of colours to grey values within specific criteria[39], with the aim of enhancing both visualisation and interpretation of achromatic images in pseudo-colour, should be investigated. Further knowledge in this area is expected to benefit radiologists' visual perception.

Conclusion

Both negative images and brightness adjustment images showed a similar preference for TMJ assessment in lateral cephalometric image. Within the limitations of this *in vivo* study, the observers' gender and their duration of clinical practice were significantly associated ($P < 0.05$) with different preferred image enhancements—negatives versus brightness adjustment—for lateral cephalograms of the TMJ.

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Declaration of Interest

The authors report no conflict of interest.

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