Reliability in Mandibular Movement Evaluation Using Photogrammetry in Patients With Temporomandibular Disorders

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Abstract

Objective: The purpose of this study was to propose a quantitative evaluation for mandibular opening–closing movement asymmetries and to verify the intraexaminer and interexaminer reliability using photogrammetry in individuals with and without myogenic temporomandibular disorders.

Methods: Forty-nine female participants between ages 18 and 40 were enrolled in this study. They were assigned to 2 different groups: a temporomandibular disorder group, (n = 25; 28.1 ± 3.6 years) and an asymptomatic group (n = 24; 25.6 ± 5.1 years). Data were collected through photogrammetry using Corel Draw X3 software (Corel Corp, Ottawa, Ontario, Canada) for angle measurements. Reliability analysis was done on the total sample, and the photographs were obtained by a singular examiner on 2 occasions (intraexaminer) 1 month apart and from measurement made by another examiner (interexaminer) on different days. The intraclass correlation coefficient (ICC) was applied with a significance level of 5%.

Results: The photogrammetry had excellent intrarater and inter-rater reliability for the evaluation of opening and closing movements of the jaw (intrarater: opening ICC = 0.99; closing ICC = 0.98; inter-rater: opening ICC = 0.89 and closing ICC = 0.82). Photogrammetry also demonstrated excellent intra- and inter-rater reliability in the evaluation of head posture (intra-rater: head deviation ICC = 0.96; head position ICC = 0.75; inter-rater: head deviation ICC = 0.98; head position ICC = 0.98).

Conclusion: Under these experimental conditions, most angular values presented excellent intra- and interexaminer reliability. (J Manipulative Physiol Ther 2019;xx:1-xxx)

Key Indexing Terms: *Temporomandibular Joint Disorders; Posture; Photogrammetry; Chronic Pain; Reproducibility of Results*

Introduction

Mandibular movement measurements are important for evaluating and monitoring temporomandibular disorders (TMDs).[1] Epidemiological studies estimate that 40% to 75% of the population shows at least 1 sign of temporomandibular disorder (TMD), and 33% show at least 1 symptom, such as facial pain or temporomandibular joint pain. Of this percentage, the greatest prevalence is between 20 and 45 years of age, with women more affected than men at a 5:1 ratio.[2]

Despite all these risk factors, the clinical status is usually characterized by TMD pain in the periauricular area, in the masticatory muscles, in the face, and in the head. The presence of articular sounds, such as cracking and popping, in association with deviations or limitation of the mandibular movement is also observed.[2,3] However, it is still unclear how these etiological elements induce the development of TMD.[4,5]

Of all signs and symptoms observed in the clinical history of TMD, current literature clearly focuses on the

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importance of investigating mandibular movement. Hypermobility (very large range of movement) or hypomobility (limited range of movement) are signs of dysfunction. Thus, a simple and objective recording method is needed to facilitate TMD diagnosis and follow-up.[1]

The precise assessment of the mandibular movement was for many years a difficult task because the mandibular movement consists of a complex combination of translation and rotation movements. Initially, direct measurements were conducted with a plastic ruler. In time, several techniques were developed to record and analyze mandibular movements.[6-9] One of them is the kinematic evaluation of the mandibular movement, which for decades was conducted in 2 dimensions, that is, at a single point of the mandibular, usually below the incision point.[10-12]

More recently, analysis systems have evolved and movement recording systems have been developed to track 6 degrees of freedom for the mandibular movement, that is, analyses in 3 dimensions. These analyses allowed the reconstruction of mandibular movements from any point in the lower mandibular in reference to the upper mandibular.[11,13-16] In addition to the 3-dimensional kinematics,[16,17] electromagnetic devices,[10,15] magnetic resonance,[18] and photostereometric systems[19,20] have also been developed.

The great difficulties professionals face is the analysis of mandibular movement, which is currently done solely on the basis of qualitative information—that is, visual observation only. The advantage of the method proposed in this study is its objective and quantitative evaluation of the mandibular movement angle, which can be related to other clinical alterations in the patient, especially the pain symptoms and posture. The specificity of this information and its associated applicability, reproducibility, and validity[21,22] may offer advantages for better monitoring and clinical understanding of the patient. This photogrammetry method could lead to better diagnoses, benefiting the patients and health professionals involved.

Photogrammetry is based on the application of the photogrammetric principle to photographic images obtained through body movements, in which images are recorded for photointerpretation of the movement.[21,22] This enables a static and dynamic evaluation of body segments.

With this resource the health professional is able to record and measure changes and subtle postural deviations and follow them over time, hence the importance of developing very well-defined methodological studies that ensure repeatability of the procedure and future comparisons. Moreover, the use of low-cost and readily available methods for the clinical context becomes a priority.[23]

Thus, the aims of this study were to verify the intra- and interexaminer reliability of the measurement of mandibular opening–closing movement asymmetries in individuals with and without myogenous TMD. Our hypothesis is that photogrammetry is able to evaluate mandibular opening–closing movement, showing acceptable values of intraexaminer and interexaminer reliability, and that more irregular mandibular opening–closing movement will be found using photogrammetry in the group with myogenous TMD than in the asymptomatic group.

Materials And Methods

Participants

Participants diagnosed with TMD were enrolled from a waiting list and their diagnoses were previously confirmed by senior dentists of the Surgery, Prosthetics, and Maxillofacial Trauma Department of the School of Dental Medicine of the University of Sao Paulo, Brazil. Participants were selected based on the following criteria: chronic pain (for more than 3 months); myogenous TMD based on the Helkimo index score[24]; and presence of parafunctional habits, such as bruxism, teeth grinding, mouth breathing, and lip biting. Exclusion criteria included surgery or trauma in the orofacial region; systemic or degenerative odontologic diseases and in the spine and upper limbs; and participants undergoing psychological, odontologic, or physical therapy treatments and who had more than 3 dental flaws or absence of 2 teeth antagonists.[24]

All participants in the waiting list for treatment in the Surgery, Prosthetics, and Maxillofacial Trauma Department of School of Odontology, University of São Paulo were part of the first stage of enrollment of TMD participants. Of this list, 84 participants were assessed, and 59 of those were excluded for not meeting the inclusion criteria. Twenty-five selected participants (28.1 ± 3.6 years) had a diagnosis of temporomandibular disorder and met the inclusion criteria; they were assigned to the TMD group.

Participants in the asymptomatic (A) group were selected among students and employees of the Physiotherapy, Speech Therapy, and Occupational Therapy Department of School of Medicine, University of São Paulo. Thirty-eight participants were initially enrolled, but 14 of them did not meet the inclusion criteria; therefore, the A group consisted of 24 participants (25.6 ± 5.1 years). Their characteristics included lack of pain complaints in the temporomandibular joint area, face, head, neck, and scapular waist.

For the calculation of the minimum sample size, a confidence interval of 95%, a precision value (α) of 5%, and an 80% power were used. A moderately important difference between groups of 30% on the pain intensity outcome measured by the visual analog scale (0-100 mm) and standard deviation of 15.8 mm were assumed. A result of 46 was found, with 23 participants in each group. All participants were instructed regarding their participation in the study and were given an informed consent form to sign. The study was approved by the Independent Ethics Committee of the School of Medicine of the University of Sao Paulo according to research protocol number 005/11.

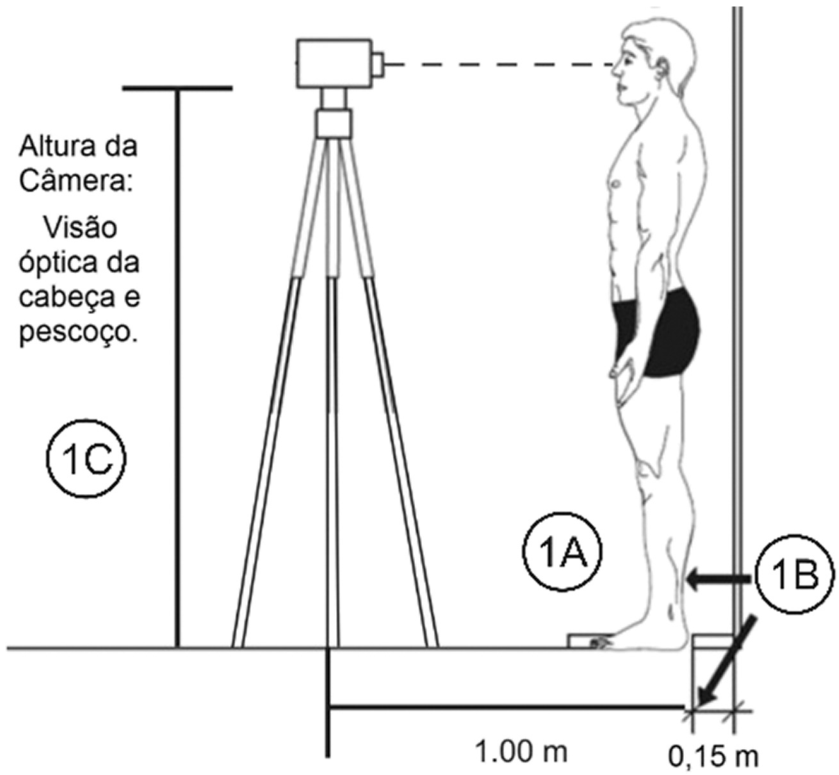

Fig 1. *Standard for evaluation of the jaw opening–closing movement (frontal plane): (1A) Distance between the participant and the camera, (1B) distance between the wall and the participant, and (1C) camera height.*[53]

Procedures

Clinical Evaluation. All participants (asymptomatic participants and those with TMD) underwent a clinical exam by a physiotherapist (principal investigator) with special interest in TMD treatment to establish their eligibility for this study and group assignment (myogenous TMD or asymptomatic). When the physiotherapist felt the participant failed to comply with the inclusion criteria, the participant was discontinued from the study.

Instruments and Procedures. Demographic data, such as age, weight, and height, were collected from all participants who met the inclusion criteria. In addition, all participants were asked to report specific characteristics of their TMD problem, such as onset, duration of symptoms, and treatment.

Mandibular Movement. A Sony digital camera was used to record films of the mandibular opening–closing movement in the anterior frontal plane. Participants were positioned 1.00 m away from the tripod (Fig 1A), and their heels were 0.15 m away from the wall (Fig 1B); to keep this distance, an ethyl vinyl acetate marker 0.15 m wide, 0.60 m long, and 0.05 m thick was placed between the wall and the participant.[21] The camera was positioned on a tripod to get an optic view of the head and neck of each participant (centered in the nose) (Fig 1C).

At first the identification and marking of the anatomical points were performed. The glabella and mentum apex points were used.[25] During recording, each participant maintained a static position, in a comfortable orthostatic posture, with their arms alongside their body as stable as possible and with their feet parallel. Points analyzed included glabella, mentum apex, and a straight line perpendicular to the ground to form the angles.

Five attempts to open and close the mandibular in a natural way were made per film. All films last 15 seconds. To analyze the data, the first and last attempts were disregarded and the other 3 were used and evaluated. The videos were recorded in a VAIO laptop computer (SONY, São Paulo, Brazil), with Windows 7 (Microsoft, Redmond, Washington), using the Free Video JPG Converter program (Digital Wave Ltd, Huntingdon Valley, Pennsylvania), where the film was separated in 30 images per second and analyzed frame by frame.[22] Twelve images were evaluated for each participant, with 6 mandibular opening images and 6 mandibular closing images.

For each attempt of movement (opening–closing), 4 images were separated: initial position for mandibular opening, maximum irregular movement of the mandibular when opening, maximum opening of the mandibular, and maximum irregular movement of the mandibular when closing (Fig 2). These images were imported into the Corel Draw X3[21,22] software (Corel Corp, Ottawa, Ontario, Canada), where they were measured to obtain irregular movement values (degrees) for the mandibular opening–closing movement.

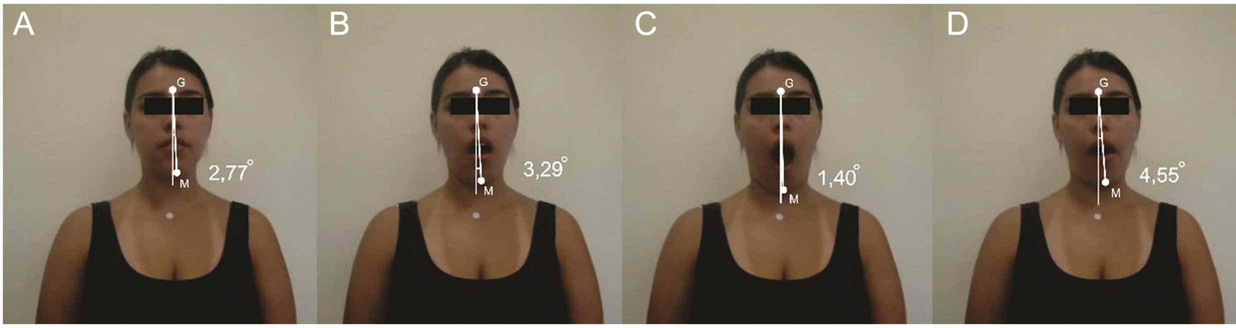

Fig 2. *Measurement of the opening and closing movement deviation. (A) Initial position for jaw opening, (B) maximum deviation of the jaw when opening, (C) maximum jaw opening, and (D) maximum deviation of the jaw when closing. Values assessed in degrees (°).* G, *glabella;* M, *mentum (vertical).*

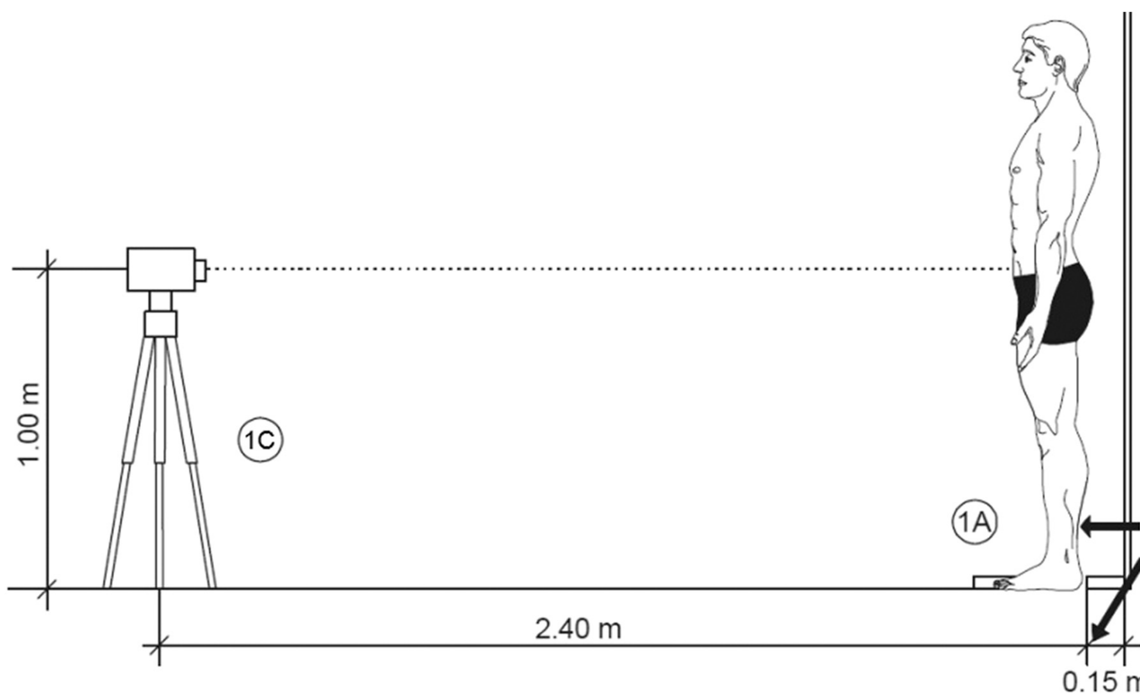

Fig 3. *Standard for head posture evaluation (sagittal and frontal plane): (1A) Distance between the participant and the camera, (1B) distance between the wall and the participant, and (1C) camera height.*[53]

The mandibular irregular movement value (opening and closing) is represented by the maximum irregular movement value of the mandibular minus the initial position value. With the value of the 3 attempts in hand, a mean value of the mandibular opening and closing irregular movement was calculated.

Head Posture Evaluation. To assess the participants' head position (positioning in the sagittal plane and alignment in the frontal plane), a Sony digital camera was used. Participants were positioned at 2.40 m from the tripod (Fig 1A); the lateral portion of the left foot (right lateral view) and the heels (anterior view) of the participants were 0.15 m away from the wall (Figs 1B and 3). To keep this distance, an ethyl vinyl acetate marker 0.15 m wide, 0.60 m long, and 0.05 m thick was placed between the wall and the participant.[21] The camera was positioned on a tripod to get an optic view of the hip of each participant (centered in the umbilical scar) (Figs 1C and 3).

Photographic images of the full body of the participants were recorded in the right lateral and anterior views in orthostatism. Participants were wearing a sports top or the top of a 2-piece bathing suit.

Before the photographic image recording, surface markers were used to identify and mark the anatomical points. Mandibular condyle points and the spinous process of the seventh cervical vertebrae (C7) were used (Fig 4). For the C7 spinous process point, 2 surface markers were used

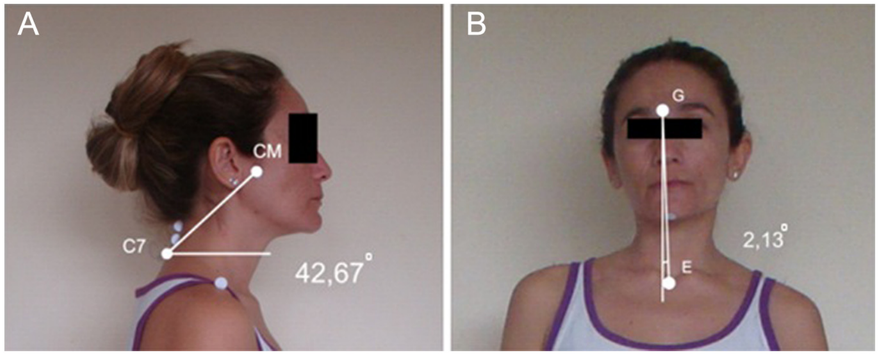

Fig 4. *(A) Evaluation of the head positioning (sagittal plane): angle formed from the intersection of the straight line that binds the points: CM-C7-horizontal. (B) Evaluation of the head alignment (frontal plane): angle formed from the intersection of the straight line that binds the points G-E (vertical). Values assessed in degrees (°).* CM*, mandibular condyle;* C7*, spinous process of the seventh cervical vertebrae;* E*, manubrium of the sternum;* G*, glabella.*

Table 1. *Table Showing Mean, SD, and* P *Value of the Comparison of Anthropometric Data Between the TMD Group and the A Group.*

Anthropometry	TMD Mean (SD)	A Mean (SD)	*P* Value [a]
Age (y)	28.1 (3.6)	25.6 (5.1)	.053
Weight (kg)	60.0 (12.5)	61.6 (8.6)	.621
Height (m)	1.6 (0.1)	1.6 (0.1)	.150
BMI (kg/cm^3)	23.2 (3.9)	23.1 (2.9)	.896

A, asymptomatic; *BMI*, body mass index; *SD*, standard deviation; *TMD*, temporomandibular disorder.

[a] Independent Student *t* parametric test. $P < .05$ significant difference.

and placed in a triangular way so that they could be viewed from the side to evaluate the position of the head in profile. To evaluate the alignment of the head in the anterior view, surface markers were employed using the glabella and the manubrium of the sternum points (Fig 4).

The placement of the surface markers and the photographic records were conducted by the same investigator.[21] Participants were positioned in a comfortable fashion, over a white laminated wood plate, with their feet parallel, and with a pen the contour of their feet was drawn over the plate so that the participants could keep the same position in both views.

Digital images obtained with a 1600 × 1200 pixel resolution were transferred into the notebook, Windows 7, using the Corel Draw X3[21,26,27] software, assessing the position (sagittal) and alignment of the head (frontal plane) in degrees.

The following guidelines were used to mark the anatomic points in the photographs and to establish the angles (Fig 4):

A) Position of the head (sagittal plane): CM-C7-horizontal—The angle was determined from the straight line intersection that bound the mandibular condyle and C7 points and a horizontal line (parallel to the ground).[21,28]

B) Alignment of the head (frontal plane) in the anterior view: G-E-vertical—The angle was formed from the intersection of the straight line that bound the glabella (G) and the manubrium of the sternum (E) points and a vertical line (perpendicular to the ground).[21]

Statistical Analysis

For mathematical treatment and statistical analysis of the data, the following software was used: Excel 2003 (Microsoft, Redmond, Washington), Minitab version 13 (Minitab, State College, Pennsylvania), and Statistica version 7 (Tibco Software, Palo Alto, California). Because they were quantitative variables in ratio scale (head posture, mandibular irregular movement, and pain), the normality of each variable was tested a priori using the Shapiro-Wilk test. After checking their normality, a homogeneity and homoscedasticity test of the variables was conducted, showing that they were all homogeneous. Once the hypotheses above were confirmed, parametric tests were conducted. In addition, comparisons of

Table 2. *Intrarater Reliability by ICCs for the TMJ Opening and Closing Index.*

	Intrarater					
TMJ	Groups	Assessment 1 (Mean ± [SD])	Assessment 2 (Mean ± [SD])	CIs	ICC	*P* Value [a]
Opening of the jaw	TMD	0.74 ± 0.46	0.74 ± 0.47	0.99-1.00	0.99	.962
Closing of the jaw	TMD	0.86 ± 0.60	0.83 ± 0.54	0.98-0.99	0.98	.931

CI, confidence interval; *ICC*, intraclass correlation; *SD*, standard deviation; *TMD*, temporomandibular disorder; *TMJ*, temporomandibular joint.
[a] *P* value: significant correlation.

Table 3. *Intrarater Reliability by Means of ICCs for the TMJ Opening and Closing Index.*

	Inter-rater					
TMJ	Groups	Examiner 1 (Mean ± [SD])	Examiner 2 (Mean ± [SD])	CIs	ICC	*P* Value [a]
Opening of the jaw	TMD	0.74 ± 0.47	0.75 ± 0.46	0.70-0.98	0.89	.975
Closing of the jaw	TMD	0.83 ± 0.54	0.88 ± 0.54	0.65-0.93	0.82	.821

CI, confidence interval; *ICC*, intraclass correlation; *SD*, standard deviation; *TMD*, temporomandibular disorder; *TMJ*, temporomandibular joint.
[a] *P* value: significant correlation.

Table 4. *Intrarater Reliability by Means of ICCs for the Head Posture Over the TMJ.*

	Intrarater					
Posture	Groups	Assessment 1 (Mean ± [SD])	Assessment 2 (Mean ± [SD])	CIs	ICC	*P* Value [a]
Head deviation	TMD	2.12 ± 1.90	2.19 ± 1.87	0.92-1.0	0.96	0.873
Head position	TMD	46.91 ± 2.61	43.73 ± 2.54	0.68-1.0	0.75	0.617

CI, confidence interval; *ICC*, intraclass correlation; *SD*, standard deviation; *TMD*, temporomandibular disorder; *TMJ*, temporomandibular joint.
[a] *P* value: significant correlation.

Table 5. *Inter-Rater Reliability by Means of ICCs for the Head Posture Over the TMJ.*

	Inter-rater					
Posture	Groups	Examiner 1 (Mean ± [SD])	Examiner 2 (Mean ± [SD])	CIs	ICC	*P* Value [a]
Head deviation	TMD	2.19 ± 1.87	2.18 ± 1.87	0.98-1.0	0.98	0.939
Head position	TMD	46.73 ± 2.54	46.61 ± 2.66	0.97-0.99	0.98	0.924

CI, confidence interval; *ICC*, intraclass correlation; *SD*, standard deviation; *TMD*, temporomandibular disorder; *TMJ*, temporomandibular joint.
[a] *P* value: significant correlation.

dependent variables (head posture and mandibular movement deviation) were performed between the groups (TMD and A) using the independent Student *t* test.

The ICC form was based on the study by Koo and Li.[29] The intrarater reliability was analyzed with a 2-way mixed-effects model, appropriate for the same rater—that is, a single rater type with a definition of absolute agreement. The inter-rater reliability was analyzed with a 2-way random-effects model, absolute agreement, and multiple raters/measurements (ICC 2, k).

An $\alpha = 0.05$ (significance level) was adopted, with differences with a description level (*P*) lower than .05 deemed significant.

Results

Anthropometric data of the studied sample were characterized as shown in Table 1. No significant differences were observed between the groups ($P > .05$).

In Tables 2 and 3, the reliability of photogrammetry for evaluation of opening and closing movement of the jaw can be observed: intrarater (opening ICC = 0.99; closing ICC = 0.98) and inter-rater (opening ICC = 0.89 and closing ICC = 0.82).

Tables 3 and 4 also demonstrate intra- and inter-rater reliability for evaluation of head posture (intrarater: head deviation ICC = 0.96; head position ICC = 0.75) and (inter-rater: head deviation ICC = 0.98; head position ICC = 0.98). (See Table 5.)

Discussion

The results of this study show that the proposed method for quantification of mandibular opening–closing movement by photogrammetry presented excellent intra- and interexaminer reliability for angular measures studied when evaluated by the same examiner at different times (intrarater reliability) and when evaluated by different examiners in the same photographic record (inter-rater reliability). The main results of this study provide evidence that support the initial research hypothesis, which is that photogrammetry is able to evaluate mandibular opening–closing movements and head posture, showing acceptable values of intra- and interexaminer reliability.

It is difficult to compare the results obtained in this study with those in the literature because several existing studies about evaluation of mandibular movement in TMDs use different methodologies.[6,11,13,17,30,31] Among these methodologies, we note electromagnetic devices, magnetic resonance, arthrography, ultrasound, and 3-dimensional analysis. These methodologies allow reconstruction of the mandibular movement trajectory from any point of the lower jaw relative to the upper jaw.[14] However, although these resources do offer valuable quantitative data, they represent higher cost and low accessibility in clinical practice, physical therapy, speech therapy, and occupational therapy.

In this sense, the optoelectronic technique is an example of a more complex methodology. This form of evaluation is commonly used because it is less invasive, and is reliable for recordings of jaw movement.[32,33] This method uses video cameras (at least 2) and markers attached to the participant, thus digitizing the movement of the jaw in the 3-dimensional space.[34]

But some studies demonstrate that the main displacement components are produced on a 2-dimensional plane.[32,33,35] Thus, Pinheiro et al[32] propose the development of a new tool, that is, a low-cost video camera, and a computer program capable of quantifying the movements of opening/closing, protrusion, and laterotrusion of the mandible (with a reflective marker fixed on the jaw). When tested, the average error of the system was less than 1.0%, demonstrating that this method is precise and reliable.

Recording and analysis of mandibular movement are important indicators of temporomandibular joint function, and consequently TMD.[32,36] Individual recording of mandibular movement is possible with the help of photogrammetry because this methodology allows quantitative evaluation.

Our study demonstrates that photogrammetry is reliable for angular measures studied, justifying its use in clinical practice for analysis and diagnosis. Furthermore, this form of evaluation is preferable because it has a low cost and objective record in clinical and scientific contexts. On the basis of the results of this study, we claim that photogrammetry can also be an appropriate method for evaluating head posture and the opening and closing movements of the jaw.

Limitations

Photogrammetry evaluates the posture at a single moment and in a single plane; therefore, it may compromise tridimensional irregular movement analyses, such as rotation of the head. We only studied female participants in 1 region, therefore the findings of this study may be limited.

Further investigation should focus on the influence of changes to the alignment and positioning of the head in the development of TMDs. Longitudinal studies with a variety of participants and who have various craniocervical postures should be conducted to investigate the development of TMDs. Also, several elements other than head posture can influence mandibular dysfunction.

Conclusion

Under these experimental conditions, our conclusion was that photogrammetry was able to evaluate mandibular opening–closing movement and posture of the head, shown through angular values that have intra- and interexaminer reliability and repeatability.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): R.M.A., S.M.A.J.
Design (planned the methods to generate the results): R.M.A., S.M.A.J.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): R.M.A., L.R.G., A.P.R., B.K.G.d.C., S.M.A.J.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): R.M.A., L.R.G.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): A.P.R.

Literature search (performed the literature search): R.M.A., B.K.G.d.C.
Writing (responsible for writing a substantive part of the manuscript): R.M.A., A.P.R., B.K.G.d.C., S.M.A.J.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): R.M.A., A.P.R., A.P.M., O.C., B.K.G.d.C., S.M.A.J.

Practical Applications

- Deviations in degrees of movement during mandibular opening–closing may have clinical implications and may be important in patient assessment.
- The results of this study will be useful for the importance of the use of photogrammetry to evaluate irregular movement in the mandibular opening–closing movements. Based on our results, they can generate significant data for the evaluation of TMDs because this tool evaluates on a quantitative basis, is low-cost, can be used in the clinical setting, and has good reproducibility. Further, they help us with the understanding of TMDs and their relationships with head posture.

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