Reliability of three-dimensional motion analysis in assessment of Bell's palsy

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Abstract: Objective analysis of facial movements forms an important consideration in the assessment and outcomes of several medical disciplines. This study was conducted to investigate the reliability of the three- dimensional (3-D) motion analysis system as a method for assessment of Bell's palsy quantitatively. Sixty female patients suffered from Bell's palsy; their ages ranged from 25-40 years, participated in this study. Three-dimensional motion analysis by Qualisys motion capture system was used to analyze facial movements by measuring specific facial angles. Measurements were taken for both the affected and non-affected sides to measure the facial asymmetry (from both contracted and relaxed positions). The intra-examiner and inter-examiner reliability of the measurement were examined. The measured angles were correlated with the manual muscle testing (MMT) of the corresponding muscles. Facial Disability Index was also used to assess facial function. Statistical analyses revealed that there was a statistical non-significant difference in the angles recorded between both examiners. The intra examiner and inter-examiner reliability of the measured angles were highly accurate with Intra-class Correlation Coefficient (ICC) between 0.88 and 0.97. Qualisys motion capture system proved to be strongly correlated with the grades of MMT of the corresponding muscles (Pearson's product moment correlation coefficient [*r*] ranged from 0.61 to 0.81). It was concluded that 3-D motion analyses by Qualisys motion capture system can be considered as a reliable method for assessment of Bell's palsy and can detect and characterize a wide range of clinically significant facial functional deficits.

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1. Introduction

Bell's palsy is a devastating disorder; it is caused when the facial nerve, which sends nerve impulses to the muscles of the face, loses function [1, 2]. Bell's palsy results in significant psychological and functional disabilities from the impairment of facial expression, communication, eye protection and oral competence [3]. Systemic evaluation of facial nerve paralysis allows the clinician to determine objectively the severity of disability, record and communicate this information to colleagues and evaluate response to therapy [2].

The usual method of facial paralysis diagnosis is a subjective judgment of the functionality of face muscles by physicians using their clinical experience [2]. To provide physicians with an objective and quantitative measurement of the degree of facial paralysis, several computer-based methods have been proposed [4, 5]. Gebhard *et al* [6] used eye and mouth corners as key points of averaging masks. The signatures extracted at the key points contain local orientation information about the surroundings of the eye and mouth corners. The information is used to measure the asymmetry of the two halves of the face [7, 8]. Wang *et al* [9] used two factors, density differences and expression variations, to analyze the asymmetry during patient's attempt to mimic exercises. By combining the two factors, they proposed a new method for the diagnostic support of patients with single-sided facial paralysis. Helling and Neely [10] calculated the facial differences in grey-scale intensities between adjacent frames of a video sequence and then used the House-Brackman rating scale [11] as a reference to combine the differences to be scored. Their method lacks stability because it does not consider individual facial differences.

Three-dimensional (3-D) methods have been used to study asymmetry of soft tissues of face but very few studies have quantified the 3-D motion of face [12]. 3-D methods that have been used to study facial asymmetry include stereophotogrammetry [13], video [14] and laser scanning [15, 16]. Some researchers work was based on the analysis of two-dimensional images [17, 18] but, movements associated with facial paralysis, especially around eye and the mouth, were able to be evaluated in details by 3-D analysis system, whereas were difficult for evaluation two-dimensionally [19-21].

A Shift from subjective scales to objective measures of facial paralysis requires physical models against which to validate and calibrate the new objective techniques [10]. Manual muscle testing (MMT) is the most commonly used method for documenting impairments in muscle strength. It is employed by physical therapists and occupational therapists to determine the grades of strength in patients with pathological problems and neurological or physical injuries [22, 23]. The results of MMT also are used to make clinical judgments concerning the patient's progress or deterioration, as well as to assess the effectiveness of a particular treatment [24, 25]. Manual muscle testing as a method of diagnosis for facial dysfunction has been well utilized [26].

Facial disability index (FDI) is a brief, self-report questionnaire of physical disability and psychosocial factors related to facial neuromuscular function. It produces a reliable measurement, with construct validity for measuring disability of individuals with disorders of facial motor system. As a disease-specific disability status measure, the range of disability assessed by the FDI was narrowed to the domains of physical function and social/well-being function (including psychological and social/role function) [27, 28].

This study was conducted to investigate the reliability of the 3-D motion analysis system as a method for assessment of Bell's palsy quantitatively and to compare the results obtained from the 3-D motion analysis system with the scores obtained in MMT and FDI for assessing facial disorders.

2. Patients and Methods

Sixty female patients suffered from Bell's palsy participated in this study; age ranged from 25-40 years with a mean age of 32.73±4.56 years. They were recruited from the Neurological Physical Therapy outpatient clinic of the Faculty of Physical Therapy, Cairo University. Patients enrolled in this study fulfilled the following criteria: (1) had a history of a disorder of the facial neuromotor system and some residual facial neuromuscular dysfunction, (2) duration of illness ranged between three to six months, (3) demonstrated or reported some difficulty on one or more basic activities of daily living or social activities included in FDI. The exclusion criteria were: (1) surgical operation for correction of any deformities in the face, (2) facial ulceration (3) apparent disorientation to time and place, (4) inability to read and speak, (5) hearing disabilities, and (6) presence of orthodontic appliances and/or facial hair that would interfere with marker placement. Approval for the study was obtained from the ethical committee of the Faculty of Physical Therapy, Cairo University. After explaining the experimental protocol to the participants, their informed consents were obtained.

Instrumentation and Measurements

This study was conducted in the motion analysis laboratory, Basic Sciences department, Faculty of Physical Therapy, Cairo University with Qualisys Motion Capture System, Goteborgsvgen 74, SE - 43363 Savedalen, SWEDEN. The examiners involved in this study were trained and instructed in the use of the system prior to commencing testing. They undertook a period of training and familiarization in the use of the Qualisys Motion Capture System and in the placement of facial skin markers, to ensure competency and efficiency. In addition, a pilot study was carried out on five patients prior to commencement of testing. Throughout the testing period, each examiner was blinded to the results obtained by the other examiner.

Qualisys Motion Capture System is consisting of three ProReflex infrared high speed cameras to perform multi-camera measurements and have a capture capability of 120 frame/sec. The basic principle of the ProReflex Motion Capture Unit (MCU) is to expose reflective markers to infrared light and to detect the light reflected by the markers [29, 30]. Twenty two small sized passive reflective skin markers with a diameter of 4mm were applied at specific facial sites.

The camera system was calibrated at the beginning of each 3-D capturing session to enable the cameras to pick up the positions of the markers in the trajectory field. The positions of the cameras and their spatial orientation remain unchanged during capturing by a fixed marker placement on the ground to prevent shifting of the camera during retest capture. Any relocation of the cameras required re-calibration. The cameras were arranged to cover the entire measurement volume which was marked out with the skin markers. The monitor window of the software was used to make sure that all markers are seen by all three cameras. To assure that all markers are registered in three dimensions, the lateral cameras were rotated about 30 degrees converging on the central camera, while the central camera was 20 cm higher than the lateral cameras and rotated about 15 degrees downwards [19].

Data gathering

The capture process is very simple. Firstly, the reflective markers have to be placed at several facial landmarks depending on the configuration chosen. For accurate placement of marker, they were applied on both sides of the face for each patient over a set of twenty-two well defined anatomical landmarks with double faced adhesive tape to ensure proper fitting on the face (Fig. 1). Facial markers did not impede movement of the face. The examiners previously defined these configurations. The inferior facial landmarks were configured following the experience of Laura and Ralph [20]. On the other hand, landmarks at the upper face that would most appropriately provide us with the angle of two crucial movements in a patient with a facial palsy :eyelid closure and eyebrow elevation, following the experience of Hontanilla and Auba [19]. The markers used for reference (markers that do not move) are :7, 10, 11, 16. Once the reflective markers have been placed, the patient just has to sit in front of three cameras to ensure the capture of movement in 3-D.

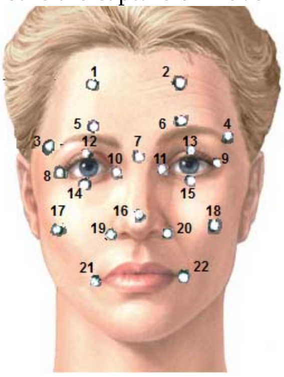

Fig. 1 The facial landmarks of the upper face **:**1, right frontal; 2, left frontal; 3, right external eyebrow; 4, left external eyebrow; 5, right middle eyebrow; 6, left middle eyebrow; 7, nasium point; 8, right external canthus; 9, left external canthus; 10, right internal canthus; 11, left internal canthus; 12, right upper eyelid; 13, left upper eyelid; 14, right lower eyelid; 15, left lower eyelid**.** The facial landmarks of the lower face**:** 16, middle nasal point; 17, right zygomaticus; 18, left zygomaticus; 19, right nasogenian; 20, left nasogenian; 21, right commissure; 22, left commissure.

Because all facial points provide a reference from which the cameras are aligned, no device was used to fix the patient's head in place .The patients were instructed to sit comfortably and remain as still as possible while fully performing the facial expression, and then to relax after each expression was performed. Before each trial, a cue picture of a particular motion to be made was shown to the patient. The patient began motion after a verbal signal from the examiner (go) until the end of the session. To record the upper face expression, patients were instructed to close and open the eyes (not blinking) and to lift the eyebrows and relax. To record the lower face, subjects were instructed to smile with the mouth closed, with their lips together, and then allowing the lips to return to a resting state . And finally they were then asked to draw the angle of the mouth straight upward and relax. Three sets of movement are required from the patients. The capture process may last from a few seconds to up to one minute. The parameters studied on both sides of the face were the amplitude of the selected facial angles including: frontal, palpebral, nasolabial and smile angles at rest and after contraction (Fig. 2). The data captured by 3-D motion analysis system were saved in a file named by the ID number of the subject and this file saved in a folder named by the examiner's name on the computer.

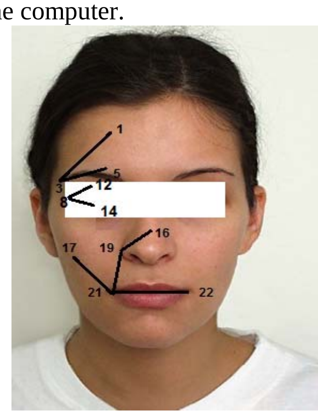

Fig. 2 Main facial plots used for determination of facial angles among landmarks. Frontal angle among 1, 3, 5; palpebral angle among 12, 8, 14; nasolabial angle among 16, 19, 21 and smile angle among 17, 21, 22.

Manual muscle testing for facial muscles took approximately 10 minutes to complete. It was performed from sitting position. Gravity is not considered a factor for muscle assessment of the face. The grades were therefore altered from the standard format according to Palmer and Epler [26] as follows:

Zero (0): No contraction.
Trace (1): Minimal contraction.
Fair (2): Movement with difficulty.
Normal (3): Completion of movement with ease.

Muscles tested were frontalis, orbicularis oculi, levator anguli oris and zygomaticus major. Each patient was then asked to complete FDI self-reported questionnaire including both physical function and social/well-being subscales to provide an account of the patient's daily experience of living with a facial nerve disorder [27, 28].

Measurement sequences for both examiners were obtained to assess the amplitude of selected facial angles (by 3-D motion analysis), MMT and FDI subscale item scores for each patient. The whole procedure was carried out on two occasions, three days apart (trial A and trial B) for investigation of inter-examiner reliability [30].

Statistical analysis

All analyses were conducted using the SPSS statistical package, version 10.0. Descriptive statistics were used for the means and standard deviations. The mean of the three trials is an estimate of the true value. The standard deviation is an indication of the progression of the single measurement. Intra-class correlation coefficients (ICCs) were estimated from analysis of variance. ICC was selected to measure the reproducibility of the measurements from a given examiner, and the reliability between the two examiners. The level of significance was accepted as $p < 0.05$. ICC values were interpreted according to the evaluation criteria listed in the study done by Graham [31] which showed that: 0.9 - 0.99 indicate high reliability, 0.80 - 0.89 indicating good reliability, 0,70 - 0.79 indicating fair reliability, 0.60 - 0.69 and below indicating poor reliability. Pearson product moment correlation coefficient (r) was used to study the correlation between the measured facial angles and the grades of MMT of the corresponding muscles.

3. Results

Sixty female patients suffered from Bell's palsy participated in this study. Their ages ranged from 25-40 years with a mean age of 32.73±4.56 years. Table 1 shows the measurements of the facial angles (mean ± standard deviation) including; frontal, palpebral, nasolabial and smile angles for examiner 1 for all patients. Each angle was measured from two positions; contracted and relaxed positions. Examiner 1 measured each angle for two trials; trial A and trial B for affected and non- affected sides. Table 2 shows the same data for examiner 2. The results showed statistical significant difference (p<0.001) in the measured facial angles recorded between the affected and non-affected sides (t=-3.39, -12.69, 43.40, 4.93 for frontal, nasolabial, palpebral and smile angels respectively). On the other hand, there was no statistical significant differences (p>0.05) in the facial angles of the affected side recorded between both examiners (t=1.93, 2.02 for frontal angle, -1.97, -0.66 for nasolabial angle, -1.79, -0.06 for palpebral angle, and 3.11, -1.04 for smile angle from contracted and relaxed positions respectively). Moreover, there was no statistical significant difference (p>0.05) in the facial angles of the non-affected side recorded between both examiners (t=1.85, 1.97 for frontal angle, -1.09, -1.18 for nasolabial angle, 1.94, 0.03 for palpebral angle, and 1.78, -1.89 for smile angle from contracted and relaxed positions, respectively)

The intrarater reliability (re-test reliability) of the measurement of the facial angles for the Qualisys Motion Capture System in both the affected and nonaffected sides was highly accurate, with ICC greater than 0.88 as shown in Table 3, for examiner 1. Table 4 shows the same data for examiner 2, with ICC greater than 0.89.

The interrater reliability (agreement between raters) of the measurement of the facial angles for the Qualisys Motion Capture System was highly accurate, with ICC greater than 0.90 for facial angles measured from relaxed and contracted positions in both the affected and non affected sides of the face as shown in Table 5.

There was a positive strong correlation between the frontal angle and the grades of MMT of frontalis muscle (r=0.78 & 0.61), between the palbebral angle and orbicularis oculi (r=0.7 & 0.64), between the nasolabial angle and levator anguli oris (r=0.7 & 0.71) and between the smile angle and zygomaticus major (r=0.81 & 0.71) of the affected side for rater 1 and rater 2, respectively.

Furthermore, the reliability values attained for the FDI subscales are close to the reliability values for the facial angles measured by the Qualisys Motion Capture System. The intrarater reliability of the FDI physical function subscale was 0.92 and it was 0.93 for the FDI social function subscale as shown in Table 6.

Table 1: Facial angle as obtained from 3-D motion analysis system by examiner 1

Facial angles	Trial A				Trial B			
	Affected side		Non-affected side		Affected side		Non-affected side	
	Contract	Relax	Contract	Relax	Contract	Relax	Contract	Relax
Frontal (1, 3, 5)	48.68±3.97	46.21±4.19	52.13±3.89	46.96±4.25	48.26±4.17	44.48±4.60	50.88±4.42	45.08±4.91
Palpebral (12, 8,14)	33.03±2.02	47.13±2.23	8.66±2.31	47.25±2.33	31.98±1.79	44.96±2.20	7.21±2.78	45.03±2.12
Nasolabial (16,19, 21)	112.83±3.65	97.80±2.26	126.26±4.49	108.63±4.95	115.06±3.07	99.93±2.13	127.9±3.27	111.20±4.91
Smile (17,21,22)	139.23±2.66	126.3±1.31	134.85±4.07	127.68±1.15	138.56±2.22	126.38±1.5	133.75±2.94	128.20±0.99

Numbers below the name of the angles indicate the number of markers to form the angles (Figs. 1 and 2).

Table 2: Facial angles as obtained from 3-D motion analysis system by examiner 2

Facial angles	Trial A				Trial B			
	Affected side		Non-affected side		Affected side		Non-affected side	
	Contract	Relax	Contract	Relax	Contract	Relax	Contract	Relax
Frontal (1, 3, 5)	46.83±3.39	44.11±3.83	49.75±4.30	44.81±4.15	49.81±3.33	47.08±3.39	52.21±3.20	47.55±3.30
Palpebral (12, 8,14)	34.03±2.28	47.16±2.26	7.55±2.13	47.23±2.23	32.03±2.60	44.73±2.21	6.40±2.09	44.86±2.22
Nasolabial (16,19, 21)	114.70±3.20	98.23±2.25	127.36±3.17	109.96±3.66	112.90±2.69	96.41±2.53	129.05±1.91	112.13±3.58
Smile (17,21,22)	137.55±1.07	126.63±1.18	133.16±1.44	128.26±1.22	136.9±1.15	125.76±1.25	132.53±1.65	127.45±1.36

Numbers below the name of the angles indicate the number of markers to form the angles (Figs. 1 and 2).

Table 3: Intraclass correlation coefficients (ICC) for testing intrarater reliability for examiner 1

	Contract		Relax	
	ICC	p-value	ICC	p-value
Frontal (14,10,16)				
Affected side	0.90	0.008	0.91	0.01
Nonaffected side	0.95	0.0001	0.89	0.0001
Palpebral (14,10,16)				
Affected side	0.88	0.0001	0.92	0.0001
Nonaffected side	0.91	0.002	0.92	0.002
Nasolabial (14,10,16)				
Affected side	0.93	0.0001	0.91	0.003
Nonaffected side	0.90	0.009	0.92	0.0001
Smile (14,10,16)				
Affected side	0.89	0.0001	0.91	0.003
Nonaffected side	0.92	0.0001	0.96	0.0001

ICC: Intraclass correlation coefficient. * Significant at $p < 0.05$.

Table 4: Intraclass correlation coefficients (ICC) for testing intrarater reliability for examiner 2

	Contract		Relax	
	ICC	p-value	ICC	p-value
Frontal (1, 3, 5)				
Affected side	0.94	0.0001	0.93	0.0001
Nonaffected side	0.89	0.0001	0.91	0.02
Palpebral (12, 8,14)				
Affected side	0.93	0.0001	0.91	0.005
Nonaffected side	0.92	0.0001	0.91	0.003
Nasolabial (16, 19, 21)				
Affected side	0.92	0.0001	0.89	0.0001
Nonaffected side	0.93	0.0001	0.91	0.003
Smile (17, 21, 22)				
Affected side	0.94	0.0001	0.95	0.0001
Nonaffected side	0.93	0.0001	0.92	0.0001

ICC: Intraclass correlation coefficient. * Significant at $p < 0.05$.

4. Discussion

Facial appearance and our expressive behaviors have a major impact on how we perceive ourselves and how others in society perceive us. For an individual with a facial functional impairment and/or disfigurement, however, these interactions and associated perceptions may be very different. To aid in the diagnosis, treatment planning, and outcome assessment for these individuals, it is important that objective and quantitative methods are available to measure the severity of impairment and to compare the effectiveness of different operative or medical procedures [19, 32].

Table 5: Intraclass correlation coefficients (ICC) for testing interrater reliability (agreement between raters)

	Contract		Relax	
	ICC	p-value	ICC	p-value
Frontal (1, 3, 5)				
Affected side	0.95	0.0001	0.92	0.0001
Nonaffected side	0.90	0.006	0.91	0.004
Palpebral (12, 8, 14)				
Affected side	0.92	0.003	0.91	0.034
Nonaffected side	0.90	0.002	0.91	0.012
Nasolabial (16, 19, 21)				
Affected side	0.97	0.0001	0.90	0.006
Nonaffected side	0.91	0.003	0.94	0.0001
Smile (17, 21, 22)				
Affected side	0.92	0.022	0.90	0.002
Nonaffected side	0.90	0.004	0.91	0.014

ICC: Intraclass correlation coefficient. * Significant at $p < 0.05$.

Table 6: Intraclass correlation coefficients (ICC) for testing intrarater reliability (agreement between raters) of the FDI.

FDI	Trial A	Trial b	ICC	p-value
FDI physical function subscale	56.83 ± 13.03	59.83±12.49	0.92	0.0001
FDI social function subscale	56.40 ± 15.08	57.33 ± 12.48	0.93	0.0001

ICC: Intraclass correlation coefficient. FDI: Facial disability index

Three-dimensional motion analysis may help in assessing facial movements in cases of Bell's palsy, but the system must have good reliability and be clinically feasible [33]. This study was conducted to evaluate the reliability of Qualisys Motion Capture System as a 3-D motion analysis method for assessment of Bell's palsy quantitatively. The findings of the present study proved that, Qualisys Motion Capture System has highly accurate intrarater and interrater reliability for the measurement of the facial angles in both the affected and nonaffected sides. These findings confirm the preliminary results of other studies that proved that 3-D analysis is appropriate and reliable for detecting clinical differences in facial function [15, 18, 30, 34, 35], because the visual qualitative assessment is often insufficient. For instance, skeletal asymmetries of less than 3% are not clinically discernible [36].

Manual muscle testing is the most commonly used reliable method of strength testing in the clinical setting. Among its advantages it is a quick and simple procedure providing information that can be useful in differential diagnosis, prognosis and treatment of neuromuscular and musculoskeletal deficits [37]. FDI is another testing procedure which produces a reliable measurement with construct validity for measuring disability of individuals with disorders of facial motor system [28]. The results of the present study proved a strong correlation between the measured facial angles and the grades of MMT of the corresponding muscles. Moreover, the reliability values attained for the FDI subscales were close to the reliability values for the facial angles measured by the Qualisys Motion Capture System. These results, therefore, suggest that Qualisys Motion Capture System is a consistent and reliable evaluation tool. In view of the results of this study, physical therapists should consider supplementing their MMT and FDI subscale scores with 3-D motion analysis system for evaluation of facial movement. This comes in agreement with Voepel-Lewis *et al* [33] who mentioned that clinical feasibility, or the ability to readily adapt an instrument for routine assessment and documentation, may depend on a tool's compatibility with other tools used in the clinical setting, as well as on the ability to use the tool across settings or populations of patients.

One way to quantitatively measure facial movement is to detect surface changes during facial expression [38, 39]. Meier-Gallati *et al* [40] and Scriba *et al* [41] presented their experience with the objective scaling of facial nerve function based on area analysis. With this approach, the subject must first be stabilized to avoid any movement of the head and considerable time is required for digitization. Yuen *et al* [42] used Moire topography to produce contour lines representing the 3-D facial shape. However, none of these techniques allows measurement of small face movements after facial reconstructions and no dynamic information about the face movement is provided.

Another way of measuring facial movements is to use facial point systems. Movements of selected points are representative of the movements of the particular face expression. The simplest technique is to hold a hand-held ruler against the patient's face to measure distances. Frey *et al* [43] used hand-held calipers to measure the distances between fixed landmarks. By this way, the caliper does not provide the direction of movement of the facial point and the angle of movement is very difficult to determine.

Burres [44] applied linear measurements of displacement. Surface electromyography recordings were made for each side of the face at rest and during movement, during each of seven standard facial expressions. Distances between specified facial landmarks at rest and during defined facial expressions were also measured with handheld calipers and the differences were converted to percentage of displacement. However, simultaneous multiregional assessments of facial movement could not be performed and the calculations were time consuming and complex.

More recently, Tomat and Manktelow [16] used a video editing programme that overlies frames with the patient again at rest and smiling. The overlaid image is imported into Adobe Photoshop, where measurements are obtained using tools available in the programme. Although the system seems to be simple, the patient's head has to be moved to a semi profile view to capture the z-axis and a central nose point is used as a static reference point to overlay frames to measure the distances. Moreover, the system is time consuming.

Computerized measurement of movement of selected landmarks on the face was applied. Sargent *et al* [45] used a camera to take a sequence of images of facial expression and transferred them to a computer. These images were overlaid and the movements of selected points were tracked. The results obtained showed that this method had high intersubject variability and no 3-D dynamic information is shown with this system.

Frey *et al* [46] reported a 3-D measuring system to track the movements of selected points on the face. This system uses a video camera, precise mirrors, and a customized computer programme. The main problem with this system is that a specific and complex data analysis must be carried out only in Vienna and the calibration of mirrors is time consuming.

Isono *et al* [47] presented a landmark-based system in which 24 reflective markers were placed on the face before recording with a video camera at a rate of 10 frames for computer analysis. The resulting data were expressed both as a graphic representation and as a ratio of mean right versus left facial movements. The time lag between capture of the visual movement, digitization, and graphic display is a temporary delay and, again, no 3-D facial movement is showed.

Qualisys Motion Capture System has advantages compared with the other systems mentioned above. It only needs from a few seconds to up to one minute for each patient to fully automatically acquire the information about facial motion and generate statistical data. It also provides information for the analysis of different facial movements on all three axes in the same study. Another advantage is that calibration process requires few minutes because of the advanced calibration algorithms used in Qualisys Motion Capture System. On the other hand, traditional capture systems require slow and tedious calibration processes. Moreover, the output represents the angles at which key points move, which we think is the essential information to compare different techniques to follow up neurological disorders affecting the patient's face. Another advantage of Qualisys Motion Capture System is that it is not necessary to control the head movement of the patient to align any facial points or to record the z axis, as would be necessary using other methods. This system provides reliable findings that the clinician needs to evaluate the regeneration of facial paralysis over time, and the treatment of neurological disorders affecting the face.

The study had some limitations. The possible effects of skin vs muscle movements of the face. The facial muscles insert directly into the skin of the face [26]. As such, movements of the face are due mainly to the movement of the underlying muscle, and any skin movement can be expected to be minimal compared with the muscle movement [30]. Additionally, the patients who participated in this study were all female. This was intended to exclude the effect of sex on the expression of facial movement. In general, male had greater 3-D displacement than female [30, 48]. Further studies are recommended to target both sexes to enable comparisons of the reliability of Qualisys Motion Capture System across males and females. Moreover, the patients who participated in this study were all suffering from Bell's palsy and this might be considered another limitation of the study. Future investigations can be suggested to compare the reliability of 3-D Motion Capture System across different types of neurological disorders affecting the patient's face. This study was restricted to the measurement of four facial movements only and this might limit the generalization of the study results. Future studies are recommended to study the reliability of the system for the assessment of other facial movements.

Conclusion

Three-dimensional motion analysis by Qualisys motion capture system can be considered as a reliable method for assessment of Bell's palsy and can detect and characterize a wide range of clinically significant facial functional deficits. With the use of this system, patients affected with Bell's palsy can be compared between different specialists so that the effectiveness of treatment can be evaluated objectively. However, indisputably, we feel that both qualitative and quantitative measurement systems and even the patient opinion are all necessary data to obtain complete information about the effectiveness of a treatment technique for the paralyzed face.

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