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Research paper

Evaluation of facial paralysis using Image Computation

Banita [1] *, Dr. Poonam Tanwar [2]

[1] Research Scholar, Lingaya's University, Faridabad
[2] Associate Professor, Manav Rachana Institute of Research and Studies, Faridabad
**Corresponding author E-mail: banita861023@yahoo.com*

Abstract

Facial dimensions are of great interest to researchers in terms of Image processing and Computer Graphics. In recent years, various factors become popular which clearly affect the face model. Which are ageing, universal facial expressions, and muscle movement . Similarly in terms of medical terminology the facial paralysis can be peripheral or central depending on the level of motor neuron lesion which can be below the nucleus of the nerve or supra nuclear. The various medical therapy used for facial paralysis are electroaccupunture, electrotherapy, laser acupuncture, manual acupuncture which is a traditional form of acupuncture. Imaging plays a great role in evaluation of degree of paralysis. There is a wide research in terms of facial expressions and facial recognition but limited research work is available in facial paralysis. House- Brackmann Grading system is one of the simplest and easiest method to evaluate the degree of facial paralysis. During evaluation common facial expressions are recorded and are further evaluated by considering the focal points of the left or the right side of the face. This paper presents the classification of paralysis and degree of facial paralysis by use of pixel points along x-axis and y-axis.

Keywords: *Classification of Paralysis; Grading System; Pixel Distance Computation; Facial Regions.*

1. Introduction

To improper or non-functioning of facial muscles. Ageing plays a great role in observation of the facial expressions because of physiological changes and decrease in energy in the tissues [1]. Following are the common Changes due to ageing:

1) Slow muscles movements
2) Reduced nerve velocity
3) Reduces muscular performance
4) Decrease in number of fiber due to degeneration.

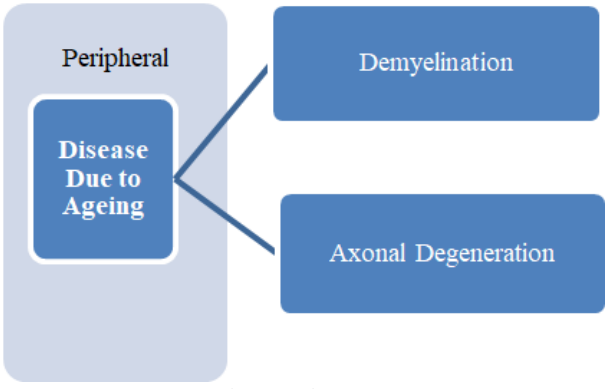

Fig. 1: Classification of Peripheral Diseases.

There are generally two groups for peripheral diseases which can be caused due to ageing "Fig.1".

1) Demyelination when there is damageto the myelin sheath which surrounds the nerve fiberdue to the damage to myelin sheath the nerve conduction will work as a continuous nerve impulse rather than its jump from one node of Ranvier to other node of the Ranvier.
2) Axonal Degeneration when there is sudden breakdown of nerve conduction which can be due to focal injury to the nerve fibers that leads to the axonal degeneration Axon once damaged cannot be replaced if its cell body is damaged.

2. Classification of paralysis

Paralysis is a disorder in movements of muscles. When the facial muscles slow down there functioning or stop working then it is termed as facial paresis or facial paralysis. Facial paralysis is further categorized in to two parts:

- Facial Palsy: When there is damage to the branches of Facial nerve which results in non- functioning of particular facial region like: Eye lids, Lips due to which there is a change in the dimensions of muscles while performing facial expressions.
- Bell's palsy: When there is damage in the Facial nerve which results in non-functioning of half portion of face whether it is left side or right side of face.
- As far as the Paralysis term is concerned, paralysis is classified in to four ways:

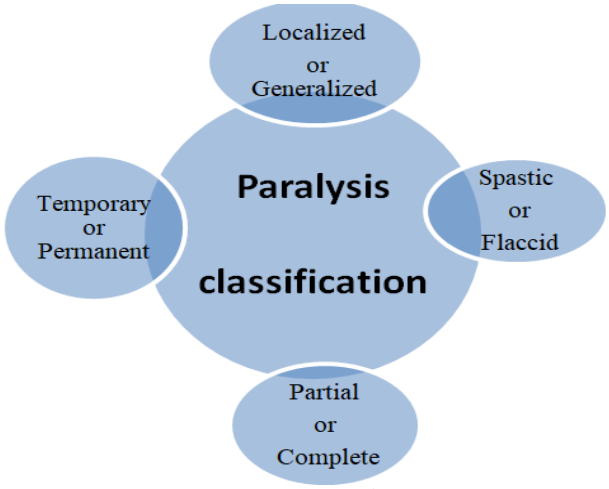

Fig. 2: Paralysis Classification.

1) Localized or Generalized: Disorder is said to be Localized when specific body part is affected e.g. Hand, Leg, Arm. Generalized is when more area is involved e.g. one limb. Generalized is further classified in to four classes:
- Monoplegia: When one part of the body part is not working or slow working of muscles.
- Paraplegia: When lower portion of body parts are not working or weakness in muscles due to which slow working.
- Quadriplegia: When both legs and both arms are affected.
- Hemiplegia: When half side of the body parts get affected. Either left side or right side of body.

2) Temporary or Permanent: Disorder is said to be temporary or permanent when there is some serious injury like Spinal injury. Disorder can be recovered by taking precautions as early as possible. If the treatment is delayed then it can leads permanent paralysis
3) Partial orComplete: Partial paralysis occurs when muscles of a particular region of body unable to work properly but sensation is there in the affected region. Complete paralysis occurs when muscles can't work which results in non-functioning of body parts.
4) Spastic or Flaccid: Spastic paralysis means when there is a constant contraction of muscles e.g. in the upper motor neuron lesions the part become stiff and unable to work in a proper way. Flaccid paralysis means when there is less or no muscular tone in the muscular due to lesion at the neuromuscular junction.

3. Grading system

Grading system plays a vital role in evaluation of degree of paralysis. In case of Facial Paralysis patients facial grading systems used to evaluate the degree of facial paralysis. House-Brackmann Facial grading system is commonly used for evaluating the degree of facial paralysis.HBGS is able to successfully distinguish finer levels of cranial nerve. Degree of facial paralysis is totally dependent on facial movements and their respective distance. In Bell's palsy patients HBGS is mainly used for evaluating the degree of paralysis. Various Facial regions given below:

1) Forehead Region
2) Eyebrow Region
3) Nose Region
4) Lips Region
5) Cheeks

Two main points i.e. Key points and reference points are taken before evaluating the degree of facial paralysis. Change in facial dimensions results in facial asymmetry which is not constant in all cases. Traditionally Medical image technology researchers have been using Two-Dimensional (2D) medical imaging and then reconstructing them into Three-Dimensional (3D) for analyzing the image for better result quality. 3D image reconstruction technologies used are:

- Computed Tomography Scan [CT Scan]
- Magnetic Resonance Imaging Scan [MRI Scan]
- 3D Laser Scan Imaging.

Even preprocessing and segmentation are also used to improve imaging modalitiesfor interpretation for better diagnosis

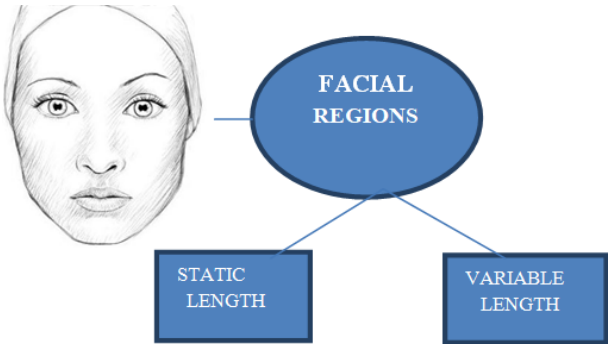

Fig. 3: Facial Model.

The facial dimensions can be in the length during facial movements shown in "Fig.3"All the facial expressions are used to evaluate the degree of facial paralysis for which House Brackmann Grading System (HBGS) is more reliable. The descriptions are shown in "Table1". HBGS include the grading levels; lower the grading level means the region is less affected. Patients has to performs a series of facial expressions which will further evaluate a grade of Paralysis ranging from Grade I to Grade VI in HBGS.Grade -I represent the normal functioning of face during facial expressions. Grade II-Grade V represent the facial paralysis can be recovered or cannot be recovered. Grade-VI represents total facial paralysis which cannot be recovered.

Table 1: Classification of Grading by House-Brackmann Grading System (HBGS)

Grade	Description	Characteristics
I	Normal	Normal Facial function
II	Mild Dysfunction	Slight synkinesis, weakness, slight asymmetry
III	Moderate Dysfunction	Slightly weak with maximum effort
IV	Moderately ServeDysfunctioning	Disfiguring Asymmetry
V	Severe Dysfunctioning	Asymmetry at Rest
VI	Total Paralysis	Nonfunctioning of muscles

4. Distance computations

The various facial images of patient at rest and with various expression has been taken and can be used for evaluating distance between respective key points and reference points of facial regions. .Change in Facial dimensions may be due to weakness of facial muscles. When there is weakness of muscles on both sides of face, it leads to poor facial expressions. This weakness is generally due ageing. Before describing for finding pixel distance for facial regions at rest and at facial expressions author in this section has been used for describing the various face dimensions in 2D and Temporalis Tendon Transfer (TTT) for better understanding of pixel distance computations.

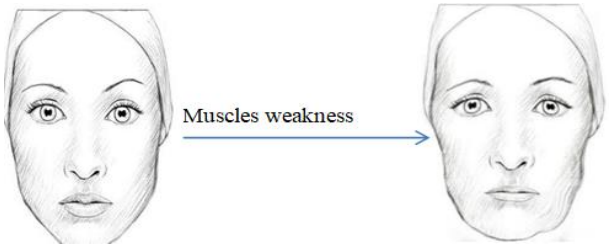

Fig. 4: Effect of Age on Facial Muscles.

Muscles weakness does not leads to paralysis but paresis. It is due to aging but doesn't show the variable distance while implementing pixel distance between left side and right side of same facial regions.

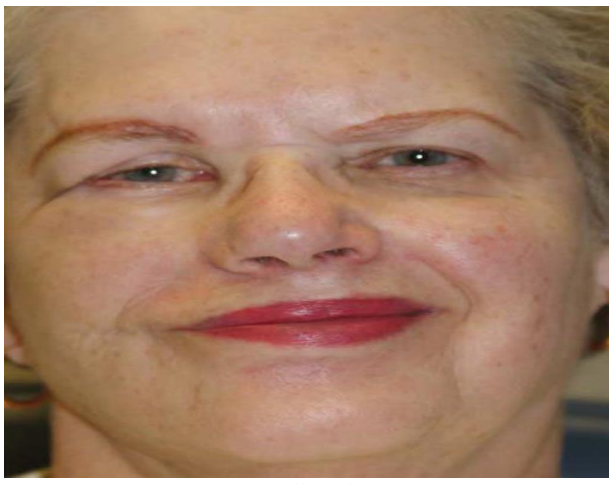

Fig. 5: Bell's palsy [6].

Whenthe expressions of left and right side of the face doesnot match it may leads to facial paralysis. As in "Fig.5" which represents the Bell's palsy on the right side of the face. The VIIth Cranial nerve on right side is affected due to which dimensions during facial expressionmay vary. During evaluation Dimensions of left side of face are compared with the dimensions of right side of the face. "Fig.5" clearly shows the differencein dimensions in eye region, lips region where the distance is increased from key point on the affected side to reference point. Morethe variation in distance,more affected area. Counseling is given to the facial paralysed patients so as to early recovery and chances of permanent paralysis become less.

Fig. 6: Dimensions of Face in 2D [6].

"Fig.6"represents the method to analyze facial paralysis patient by use of photography. Here the pupil of the patient has been outlined manually [6]. Distance of right side of face w.r.t eye region is evaluated with left side of face w.r.t. eye region.
"Fig.6"determines that the patient is suffering from facial paralysis with left side of face as affected face. Due to which facial muscles of left side of face were weaken which leads to change in distance while performing facial expressions. Whereas facial muscles on right side of face are working properly thus exact dimensions during expressions are on right side of face. It concludes that left VIIth Cranial Nerve has been affected which results in improper functioning of facial muscles on left side of face. "Fig.6" also represent the evaluation in terms of lips region during smiling expression. There is a key point which is at the corner of mouth and its reference point which is marked as the midpoint of the lips. Angle is calculated and similar process is used to evaluate the dimensions of right side of the face.

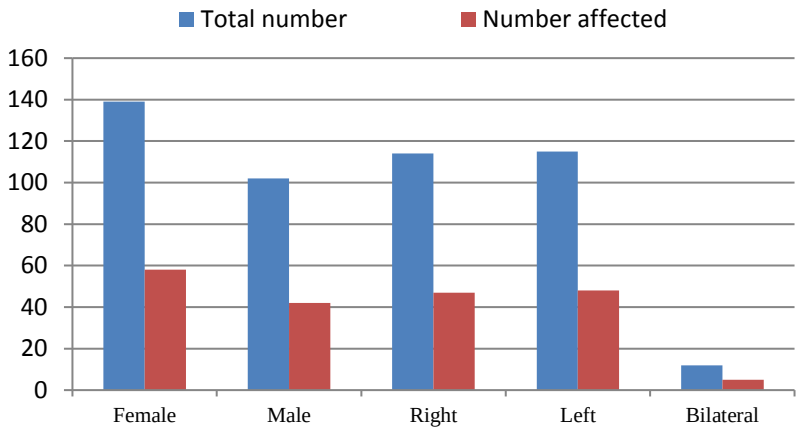

Fig. 7: Distribution of Gender, Side of Palsy of the Patients. [3].

Number of patients= n

After evaluation paralyzed patients are in "Fig.7" which concludes that out of 140 female patients examined 58 were having facial paralysis whereas out of 100 males 42 were having facial paralysis[3]. The average rate of affected on the right facial paralysis out of 110 were 47 and the left side 48 were affected and rest were having bilateral paralysis.
Facial paralysis is higher in females as compared to males of different age groups.
In terms of 3D video-analysis system following are the fields of applications which are in use [3]:

1) Plastic and Reconstructive surgery.
2) Ophthalmic surgery.
3) Oral and maxillofacial surgery.
4) Otolaryngology surgery
5) Skin Graphing.

6) Neurosurgery
7) Neurology
8) Physical medicine and rehabilitation
9) Psychiatry and psychology

Video analysis system is very useful during pixel distance calculation. It is a real time system in which video is recorded along with facial expressions. With the use of video analysis applications each expression will be evaluated.

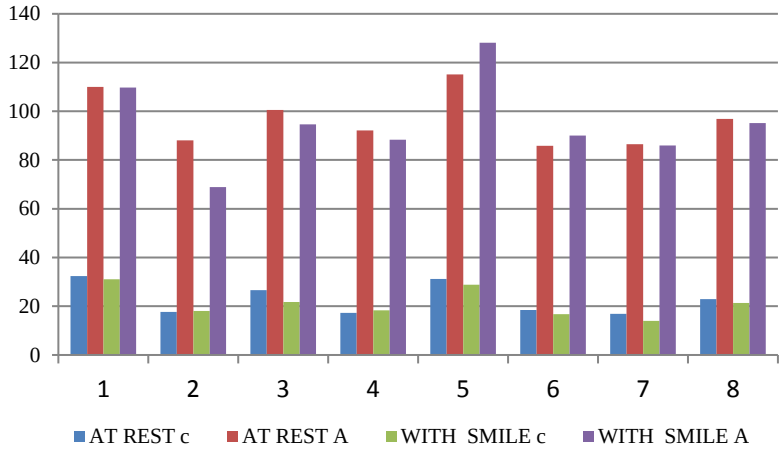

Fig. 8: Pre-TTT Measurements of Paralyzed Side of Face [6].

"Fig.8"represents the variation in facial expressions at rest and in smiling expression.
Here c =Hypotenuse of facial movement A= Angle formed with the vertex (Measures in degrees) [6].

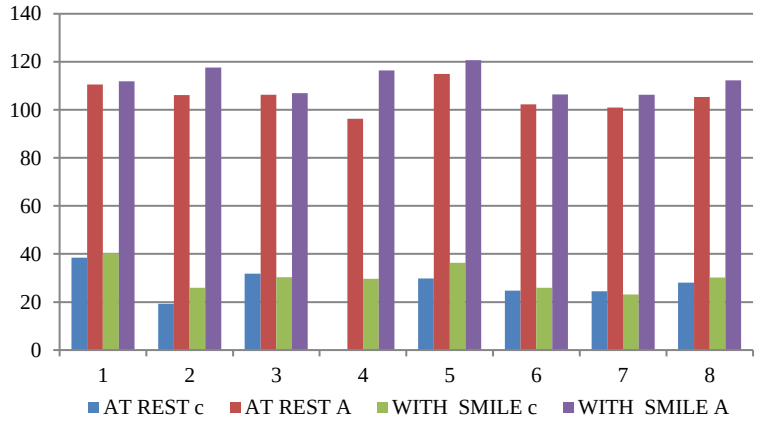

Fig. 9: Post-TTT Measurements of Paralyzed Side of Face [6].

"Fig.9"represents the evaluation of Temporalis Tendon Transfer (TTT) in irradiated patients. "Fig.9" includes the value of angle formed with the vertex of paralyzed side of face during Pre-TTT Measurements. "Fig.9" represents the dimensions of paralyzed side of face during Post-TTT Measurements.The only limitation of the study is it includes on one facial expression as smiling expression. It deals with the patients who have not received the parotid bed prior to the facial reanimation surgery [6]. The study includes the complete evaluation of pre TTT time points as well as post TTT time points. Focus is on smiling expressions and hence angle formed during expression is recorded. Lips region is basically considered and manual formation of pupil is drawn which helps in evaluation the degree of paralysis.
Four expressions has been recorded for evaluation of degree [8] of facial paralysis:

1) Closure of eyes
2) Raising of eyebrows
3) Opening of Mouth
4) Nasal Folds

With the help of four expressions Minimum and Maximum value is evaluated which arerecorded and are used to calculate the degree of facial paralysis. Higher are the distance, more is the affected area of facial regions. These four expressions have been used in Feature point Selection algorithm (FPSA) [8]. In FPSA evaluation has been done by marking landmarks on different facial regions in different facial expressions.
There are three common distances measured between two pixels duringfacial evaluation:

1) City Block Distance:City Block distance measures the path between two pixels based on four connected neighborhood. Hence it is also termed as D4 distance. Distance between two points A and B is:

$D4 = \left| (x1-x2) + (y1-y2) \right|$ [8]

2) Chess Board Distance: Chess Board Distance measures the path between two pixels based on eight connected neighborhood. Hence it is also termed as distance. Distance between two points A and B is:

$D_8 = \max (|(x1-x2)|, |(y1-y2)|)$ [8]

3) Euclidean Distance: Euclidean distance in facial expressions is sensitive to deformation. It is used to calculate the value of distance between reference point and point belonging to curve. Euclidean distance generally denoted by λ. It is also termed as De.

$D_e = \sqrt{(x1-x2)^2 + (y1-y2)^2}$ [8]

Here x1 = key point along x-axis

X2 = reference point along x-axis

Y1 = key point along y-axis

Y2 = reference point along y-axis

Most Common method is Euclidean distance in terms of Pixel distance computations. Higher is the distance value result in more affected facial region. Different facial regions have same or different reference point. Every key point has its own reference point. Key point may have same or different reference point.
The common method for evaluating distance in terms of pixels is Feature Point Selection Algorithm (FPSA) [8]. FPSA is used to calculate the overall degree of facial paralysis by capturing different facial expressions.

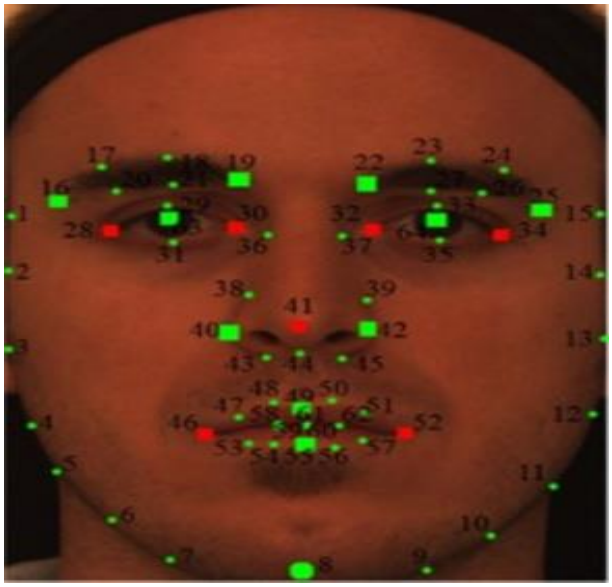

Fig. 10: Common Facial Landmarks [9].

"Fig.10"represents 64 landmarks which are manually located on face at rest. Location of landmarks changes while performing facial expressions. Fig.10. represent landmark set which includes squares as primary landmarks.

Red square= Most fiducial points.

Green Dots= Secondary Landmarks.

One of the easiest method for landmark localization is to use manually the Annotated Ground-Truths (AGT) [9]. If AGT positions are available the localization performance can be expressed as Normalized Root Mean Square Error (NRME) [9].

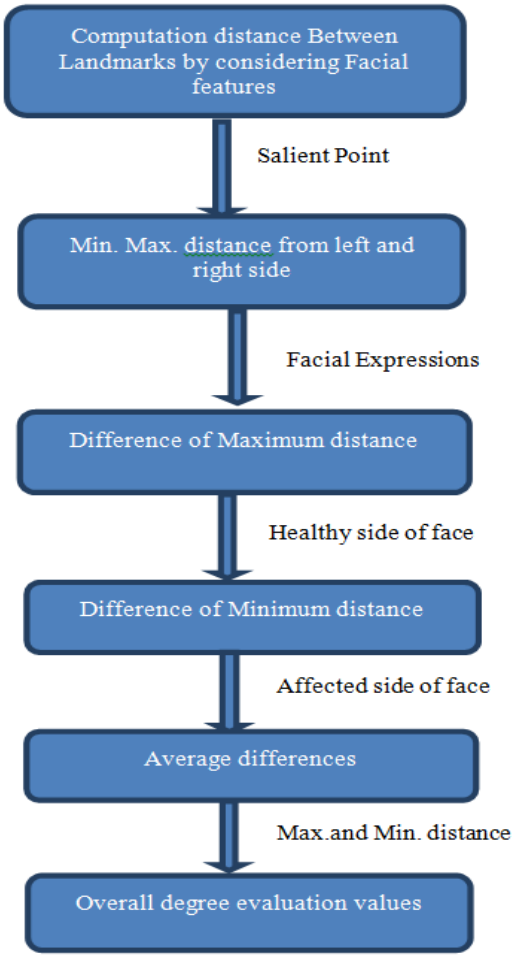

Fig. 11: Feature Point Selection Algorithm [8].

Feature Point Selection Algorithm is used to evaluate the degree of paralysis by calculating the Maximum distance and Minimum distance between the key points and its respective reference points as in "Fig.11".FPSA is implemented on four facial expressions:

- Closing eyes
- Raising eyebrows
- Opening of mouth
- Nasal folds.

Every individual expression has its maximum and minimum distance. More expressions can be considered which results in more accuracy using FPSA. FPSA helps to evaluate the severity of facial paralysis. FPSA deals with the automation of calculating distance between the healthy and sick side of the face.

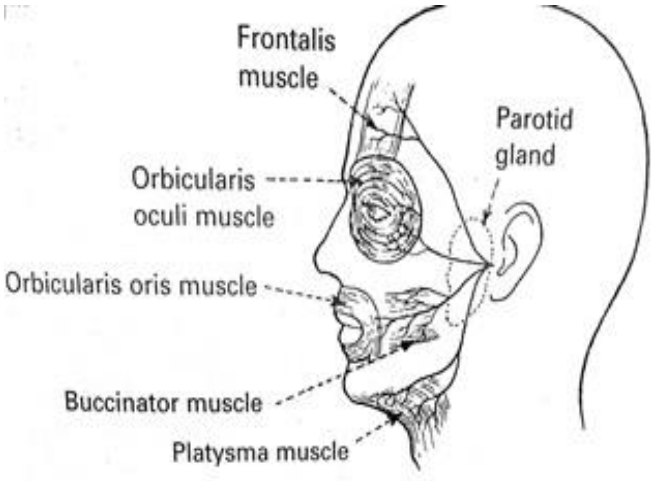

Fig. 12: Branches of Facial Nerve.

VIIth Cranial Nerve have six branches which is spread over the different facial regions. Each facial regions is controlled by different muscles of respective facial nerve branch. "Fig.12" represents various facial branches which is controlled by their respective muscles. For Forehead regiontemporal branch of facial nerve is considered. Forehead dimensions are recorded by performing facial expressions for which Orbicularis muscles functions. Similarly for Eyes, Cheeks, Lips, Nose, Chin regions along with muscles Zygomatic major, Zygomatic minor, Buccinators muscles, and Mentalis muscles work while performing facial movements respectively.

Table2: Comparison between Various Techniques Used for Detecting Facial Paralysis and their Outcomes.

S.No.	Work	Methodology	Outcomes
1	Jagga,M,Lehri, A, Vol.7,No.1, 2011 [1]	• Explore the sural sensory conduction velocity which had a none significant negative relationship with BMI.	• No significant difference between race and nerve conduction.
2	Chan Chao et.al. 2012 [2]	• Mesh deformation	• 47 expressions blend shape for each person, representing most expressions for human face.
3	Chieh-Han John Tzou et.al., Annals of plastic surgery , Vol.69,No. 2,2012 [3]	• Facialis software and FaciShow were used to calculate 3D coordinates of the landmarks.	• There are no comparable tools to acquire video, photographs and 3D motion analysis documentation.
4	Philipp Meyer-Marcotty, Vol.33, 2011 [4]	• Raters • 3 Dimensional facial stimulus	• Findings provide clinicians with a greater understanding of how faces are perceived.
5	David F Mayor, No.84, 2007 [5]	• Polarity, Frequency, Amplitude, Waveform, Mode. • Low frequency stimulation. • High intensity stimulation.	• Treatment twice a week may be as effective as daily treatment when using EA.
6	Garret R Griffin, Waleed Abuzeid et.al. Vol.14, No.6 , 2012 [6]	• Retrospective medical chart review comparing dynamic movement of oral commissure and resting symmetry. • Delectable point.	• No significant difference between 2 groups of patients in terms of age, baseline lip position or follow up time.
7	M.Gaianu, G.Cristescu et.al. Vol.8 , No.3 [7]	• Interest point of mimic. • Univalve segment assimilating Nucleus.	• Increased accuracy may occur if another kind of metric is used.

5. Conclusion

Study focus on evaluating the degree of Facial Paralysis using Facial expressions measurement with pixel distance computation. Classification of Paralysis has been discussed. It also focuses on the evaluation of severity of disease. Variation in distance using FPSA has been discussed. FPSA computes the Overall degree evaluation value for facial paralysis patient. Likewise FPSA a common algorithm can be generated to evaluate the degree of facial paralysis with more accuracy. Higher accuracy can be achieved by considering more facial expressions. By use of facial expressions distance is calculated which is easy to use and results in easy findings of level of facial paralysis. Study concludes that higher the deviation in the facial dimensions results in more affected facial region which is captured at rest or during facial expressions. FPSA includes only four facial expressions which are common for Facial palsy as well as Bell' palsy. For better accuracy more facial expression is recorded.

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