3D SOFT TISSUE LASER SCANNING TECHNOLOGY TO EVALUATE SOFT TISSUE CHANGES AFTER ORTHOGNATIC SURGERY

Dissertation submitted to

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In partial fulfillment for the Degree of

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BRANCH III

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CERTIFICATE

This is to certify that this dissertation titled **"3D SOFT TISSUE LASER SCANNING TECHNOLOGY TO EVALUATE SOFT TISSUE CHANGES AFTER ORTHOGNATIC SURGERY"** is a bonafide record of work done by **Dr.Krishnakumar MG** under our guidance and to our satisfaction during his postgraduate study period **2010-2013.**

This Dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY,** in partial fulfillment for the award of the Degree of **MASTER OF DENTAL SURGERY – ORAL AND MAXILLOFACIAL SURGERY, BRANCH III.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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ABSTRACT

Introduction: Different technologies can be used to evaluate soft tissue changes after orthognathic surgery. Each technology comes with its own limitations, advantages, and costs. We compared 2D and 3D Soft tissue evaluation techniques.

Aim: The purpose of this study is to evaluate the limitations, advantages and cost factor of two different techniques for evaluation of soft tissue changes after orthognathic surgery.

Methods: Pre surgical lateral cephalogram and laser soft tissue scan taken. Postsurgical cephalogram and laser scan taken 6 months after orthognathic surgery. Soft issue evaluation was done using Arnett and Bergman analysis. Both presurgical and postsurgical values compared to asses soft tissue changes. 2D and 3D soft tissue evaluation techniques evaluated to asses advantages and disadvantage of each technique.

Result: Laser soft tissue scanner is an effective, more accurate, and convenient tool for soft tissue change evaluation.

Conclusion: Advanced 3D laser scanner gives exact 3D information of a 3D object. Technique is easy, and needs less processing time. All measuring tools are incorporated in data reading software. Measurements show accuracy in micron level. Lateral cephalogram is cost effective, but it represents 2D aspect of a 3D object. Examiner level error in measurement is common in 2D soft tissue evaluation technique.

Key words: 3D Laser soft tissue scan, Lateral cephalogram, soft issue change assessment, Orthognathic surgery.

INTRODUCTION

Correction of facial deformities with orthognathic surgery is the solution for many people who are not happy with their facial appearance. Osteotomies performed on facial bones to correct deformities, but patients perceives the results on their final soft tissue position.

Many studies have reported various results in measuring facial soft tissue changes after orthognathic surgery. Lateral cephalograph is a conventional tool used to evaluate profile changes in soft tissue, but it is not the apt imaging technique for soft tissue assessment.

The soft tissues may not be observed clearly due to low resolution of the radiographic image and superimposition of structures on soft tissues, resulting in landmark identification errors. Most important problem is, it can't show the 3-dimensional (3D) changes of a 3D object, hence, the search for a good 3D imaging tool for pre and post-operative soft tissue evaluation continues.

Conventional facial moulage, Optical systems like Stereo photogrammetry, Telecentric photogrammetry, Moire topography, and 3D computed tomography scans are common techniques for imaging facial soft tissue changes. The laser surface scanning system was introduced by Linney in the Department of Medical Physics at University College London. Laser light sources were used to record the facial soft tissue image in 3D to evaluate effects of soft tissues changes after orthognathic surgery. The system is, easy to use, accurate, minimally invasive, cost-effective, repeatable, has high resolution, carries most of the advantages of a 3D imaging tool. Many different technologies can be used to build these 3D scanning devices; each technology comes with its own limitations, advantages, and costs. We have used PERCEPTRON 2M LASER SCANNING DEVICE to evaluate pre surgical and post surgical soft tissue changes in 5 patients under went orthognathic surgery in the department.

AIMS AND OBJECTIVES

The purpose of this study is to evaluate the limitations, advantages and cost factor of two different techniques for evaluation of soft tissue changes after orthognathic surgery.

REVIEW OF LITERATURE

Spadafora A et al (1946)[76] Used poly ethylene implants for malar augmentation.

Hinderer U et al (1971)[31] Surgeons previously used unilateral bone grafts or silicone implants to correct facial asymmetries, bilateral malar augmentation to improve facial proportions was first described.

Freihofer HP (1977)[21] It is important that patient must be informed about the potential side effects of orthognathic surgery, inform about the need for future nasal surgery. Patient satisfaction ultimately be derived from the final positions of soft tissues, rather than the skeletal movement.

Radney LJ et al (1981)[63] Found that soft-tissue chin landmarks follow horizontal bony movements in 1:1 ratio after setbacks, advancements, and autorotation.

Collins PC et al (1982)[16] It is accepted that the alar base of nose experiences some degree of widening after maxillary impactions and advancements. First describe alar widening after LeFort I osteotomy, they suggested alar base cinch to prevent this undesirable side effect.

Quast DC et al (1983)[62] Several soft tissue lip, chin landmarks are found to move posteriorly around 1.9 to 2.5 mm between average time points of 3.7 and 18 months after mandibular advancements. All hard tissue landmarks move posteriorly during same time span. These changes attributed to "functional adaptations" following sudden changes after surgery.

Schendel SA et al (1983)[71] Some degree of overcorrection is needed because relapse can happen, and alar base cinch will result in an alar base width less than the original is very rare.

Mansour S et al (1983)[43] Their study revealed tendencies toward upward and forward movement of nasal tip after maxillary advancement, without any impaction.

Carlotti AE et al (1986)[13] Reported a tendency toward upward and forward movement of tip of nose after maxillary advancement, even without impaction of maxilla.

Waite PD et al (1986)[79] The major primary advantages of porous alloplastic materials, such as polyethylene or hydroxyapatite, is the porosities allow ingrowth of tissue into the pores, it improve stability of implant.

Phillips C et al (1986)[60] After maxillary intrusion surgery in 30 patients, they noticed an average increase in alar base width of 3.4 mm.

Guymon M et al (1988)[25] Bilateral stitch is placed through the periosteum, the alar soft tissues, and the nasalis muscle for a proper alar cinch. Appropriate nasal width and contour is achieved by adjusting tightness of the stitch.

Rosen HM et al (1988)[66] Reported average increase of 3.4 mm for all maxillary movements in anterior or superior direction

Hernandez-Orsini R et al (1989)[30] For calculating two-dimensional soft tissue changes involves lateral cephalograms. High quality lateral cephalograms is needed to visualize midline region. Comparing pre-surgical to post-surgical lateral cephalogram gives an idea of soft tissue changes .This is a traditional method for assessing soft tissue changes after orthognathic surgery

O'Ryan F et al (1989)[58] Maxillary setbacks have little effect on the width of alar bases but it will depress nasal tip, resulting in " parrot's beak appearance".

Farahni M et al (1991)[20] Radiation therapy is an effective treatment modality for the management of malignancy. Radio resistant shields are used to protect healthy tissues from harmful effects of radiation. Conventional fabrication of this shield on facial, and intra oral regions found to be very difficult and painful to patient. Facial moulage is commonly used to fabricate these shields. Now 3D laser scanning provides options of non invasive, non painful facial reconstruction with more accurate surface details. sterio lithographic technique is used to fabricate more adaptable radio resistant shields.

Westermark AH et al (1991)[80] Those patients with good preoperative nasolabial angle and aesthetics, the surgeon should consider the effects of maxillary surgery on these structures and take steps to avoid any undesirable alterations.

Schendel SA et al (1991)[70] Alar base of nose shows some degree of widening after maxillary impactions and advancements

Klein HM, Schneider W et al (1992)[40] Paediatric cranio facial surgeons used 3D reconstructed images for comparing CAD- CAM milling models steriolithographic models and found steriolithographic models are more accurate than CAD-CAM models.

A .M. McCance et al (1992)[4] Laser scanning has proved to be a simple non-invasive method of measuring three-dimensionally, and is a very useful tool in auditing surgical outcome and measuring surgical relapse.

McCance AM et al (1992)[45] Three months after surgery, the alar bases moved an average of 4-5 mm anterior to their pre-surgical positions in a sample of 16 skeletal Class III patients who underwent LeFort I maxillary advancements. No measurements for the maxillary advancements are provided. The alar bases moved on another 3 mm anteriorly after next nine months in nine females. Relapse of the mandibular setbacks and forward drift of the maxillary arches due to solid intercuspation.

Hack GA et al (1993)[27] Soft tissue positions may lose some of their dependence on hard tissue position over a period of time. They noted that greater than 10% change at some landmarks after one to five years post-surgery, they also conceded that long-term studies run the risk of bringing more variables, including weight gain, weight loss, and growth

Betts NJ et al (1993)[8] Found that a shortening of nose after maxillary set up surgery. The noticed significant shortening of nose measurement in nose models.

Moss JP et al (1994)[52] They described very little facial soft-tissue changes from three months to one year after surgery.

Aung SC et al (1995)[6] Laser scanning is effectively using in anthropometric studies .Landmark placement and measurement accuracy is more in this technique. It reduces processing time markedly.

Facial anthropometry is a means of standardizing objective measurements to supplement visual assessment. This technique involves calculating a large number of direct facial measurements and takes a considerable amount of time. Optical surface scanner can reduce the amount of time taken for this process by using laser stripe triangulation to digitize facial surfaces. These measurements were then compared to assess the mean difference between standard measurements and laser scan measurements. The laser scan measurements could then be grouped according to their reliability. Laser measurements found to be more reliable.

Nakajima T et al (1995) [55] Laser based steriolithography has allowed the creation of life sized skeletal models .CT based steriolithography gives an idea of skeletal pattern of complex cranio facial defects. However skeletal model alone do not reveal the special relationship of soft tissues. So we can incorporate CT based data and laser based data to construct a sterio lithographic model with both skeletal and soft tissue details. This model can provide baseline data for evaluating facial growth after surgical repair of clefts.

Mommaerts MY et al (1995)[50] Patients with mid face deficiency included in study. Common finding in these patients is scleral display due to poor lower eyelid support.

Girod S, Keeve et al (1995)[23] 3D simulation and visualisation plays an important role in interactive cranio facial surgical planning. Conventional methods are cast model surgery, cephalometric prediction, photo evaluation, facial moulage. Now surgeons incorporate two 3D reconstruction techniques to predict planned surgical outcome. CT data used for skeletal virtual surgery, and laser scanned soft tissue data for soft tissue change assessment. Animation software helps surgeons to predict soft issue change after their planned hard tissue movement.

Bailey LJ et al (1996)[7] Found horizontal and vertical soft tissue changes are stable after one year. Post surgical oedema has no effect on this. Other soft tissue changes likely related to normal aging process, or due to hard tissue remodelling

Lee D-Y et al (1996)[41] Estimated that 25% of patients undergo maxillary impaction experience long-term mild downward relapse of the maxillary soft tissue beyond the normal downward movement that expected due to aging.

Stewart A et al (1996)[77] Found a gradual increase in alar width after maxillary advancements. No consistent change in nasolabial angle or nasal tip position. But the authors admit that scarring due to the cleft repair surgeries may contributed to the variability seen in measurements.

McCance AM et al (1997)[46] Found that soft tissues of the maxillary canine and alar bases advanced with the maxilla at a ratio of 1.25:1 to 1.5:1

Mommaerts M et al (1997)[51] Sparing anterior nasal spine (the anterior nasal spine is generally destroyed during Le Fort I osteotomy) and reducing muscle detachments by a sub spinal Le Fort I-type surgery shown to be as effective as alar cinch suture in preventing alar base width increase.

Robiony M et al (1998)[64] Midface-deficient patients with Class I malocclusions, orthodontically compensated occlusions, maxillary advancements create Class II molar relation. One technique of creating a more oval, youthful face without orthognathic surgery is malar augmentation

Motohashi N, Kuroda et al (1999)[53] Orthodontists using this technology to virtually move teeth according to their treatment plan. Data collected by scanning dental casts. In ortho surgical cases, they can move maxilla or mandible to achieve good occlusion. Compared to handmade models, this technology provides high speed processing, more accurate data acquisition, quantitative evaluation of 3D object, and allows individual tooth movements according to craniofacial plane. Laser scanning and reverse engineering eliminates need of time consuming model surgeries, and techniques like kesling's set up.

G. William Arnett et al (1999)[26] This article present a new soft tissue cephalometric analysis. This analysis may be used by the surgeon and orthodontist as an aid in diagnosis and treatment planning.

Betts NJ et al (2000)[9] Factors like surgical technique, incision closure technique, amount of surgical movement, muscle stripping, growth, post-surgical orthodontic treatment, and soft tissue shape, thickness, and elasticity all contribute the final soft tissue outcome.

Mobarak KA et al (2001)[48] found that lower facial width (distance from right soft tissue gonion to left soft tissue gonion) decreased in all seven female patients who underwent mandibular setback in their study.

Romo T et al (2001)[65] Autogenous bone graft was traditionally most common method of malar augmentation, they reported a preference for alloplastic material because of elimination of donor site morbidity, predictability, and elimination of the resorption found with autogenous graft.

Hajeer MY et al (2002)[29] Laser based 3D scanning is used to evaluate reproducibility of land mark identification as well as assessing facial soft tissue growth and development of the cranio facial complex.

Carboni A et al (2002)[12] Autogenous bone grafting was traditionally the most popular technique of malar augmentation. They give preference for alloplastic implants due to increased predictability, no donor site morbidity, and no unpredictable resorption that is found with autogenous graft.

Zim S et al (2004)[86] Midface deficiency cases usually have scleral show and protruded eye ball and nose. This anatomical changes results in chin and cheek sag .Scleral show due to lack of eyelid support

Ru¨diger Marmulla et al (2004)[68] Comparative studies using CT data and laser based data reveals high resolution laser scan of skin surface allows for a precise patient registration of land marks.

QixD et al (2004)[61] 3D Laser scanned data used for the standard measurements of nasal orbital fossa in plastic surgery. Software like Polyworks, Geomagic used to obtain the standard facial contour.3D measurements exhibited the three dimensional facial shape at every meaningful angle with the advantages of high precision of 0.01mm.This is a new approach for pre operative plans, operation simulation, and post operative evaluation

Mohammad Y etal (2004)[49] Surgeons using laser scanning technique to evaluate facial asymmetry scores .landmarks designed on 3D model. New method of 3D facial asymmetry analysis also developed with the help of this technology

Murat Soncul et al (2004)[54] Evaluation of the soft tissue changes after correction of Class III dento skeletal deformity with orthognathic surgery using the optical sururface scanner as a 3-dimensional imaging tool and thin-plate splines as a morphometric analysis. Lateral cephalogram can be digitalized and 2D evaluation is possible using digitalizing software. This is to confirm whether the preoperative surgical plan was applied. Soft tissue changes depends on different factors. So exact soft tissue prediction is impossible.

J.A. Harrisona et al (2004)[34] Used laser scanner for the evaluation of postoperative changes of soft tissue swelling after different anti inflammatory drug administration. Minimising variability in position by using more advanced laser based positioning techniques will increase the accuracy of this technique and is a focus for future work

Soncul M et al (2004)[75] Even with procedures like alar cinches and malar implants to help control soft tissue positions, the soft tissue response to orthognathic surgery is complicated. Factors such as the, method of incision closure, surgical technique ,amount of surgical movement, growth, muscle detachment, post-surgical orthodontics, and soft tissue thickness, soft tissue shape, and elasticity all involved in the final soft tissue position

Roy D et al (2005)[67] The main advantages of using porous alloplastic material like hydroxyapatite , polyethylene is that the pores allow ingrowths of bone tissues, this mechanism gives stability and limiting movement of the implants.

Ju rgen Hoffmann I et al (2005)[36] Image-data-based navigation plays an important role during surgical treatment of anatomically complex regions. Conventional patient-to-image registration techniques on the basis of skin and bone markers require time-consuming logistic support. A new marker less, laser surface scan technique for patient registration has been tested in experimental and clinical settings. Three-dimensional laser surface registration offers an interesting approach for selected image-guided procedures in craniofacial maxillary surgery.

XiaD et al (2005) [81] 3D prototyping helps to evaluate facial changes after traumatic injury.

Yaremchuk MJ et al (2005)[83] For a patient with severe Class III malocclusion, midface deficiency and, the midface projection can be increased surgically with LeFort III osteotomy and maxillary advancement. But in midface-deficient patients with Class I malocclusions, orthodontically compensated occlusions, maxillary advancements would create Class II relation. Creating a more oval, face without orthognathic surgery is malar augmentation

Honrado CP et al (2006)[33] Found that, even with alar base cinching placed in all their patients, the inter-alar width increase ranged from -0.293 mm to 6.128 mm, with only 2 of the 32 patients showing decreases in interalar width after maxillary advancements. They found varying results while measuring the nasolabial angle. Even though their sample includes Class II and Class III patients who undergone a variety of maxillary movements, the only significant change noted was decrease in nasolabial angles of Class III patients who underwent maxillary advancements with upward rotations

Day CJ et al (2006)[17] Found that settling of facial swelling was neither steady nor symmetrical. Consistent reduction while time passed. They also noted that the regions most affected is midline

R¨udiger Marmulla et al (2006)[69] Recording landmarks on facial skin without use of markers have become increasingly accepted in image guided surgery. But position and muscular activity may change skin geometry and shows errors between pre operative positions and intra operative positions. Laser scanning based studies revealed significant influence of gravitational pull and muscular activity in land mark precision.

Kau CH et al (2006)[38] Reported a mean increase facial swelling of 60.35% one day after surgery using laser scanning device. After Observing1 week, 1 month, and 3 month post-surgical scans, they Found that 17.15%, 70.51%, and 81.54% reductions in facial swelling, respectively, when compared to the 6 months postsurgical scans. The study included three subjects and undertaken with the assumptions that surgical relapse is negligible. (Rigid fixation was employed) they concluded that swelling is negligible after 6 months.

Chung How Kau et al (2006)[15] Three-dimensional facial morphologic changes of children can be assessed effectively using laser scanning device and reverse engineering. This technology helps craniofacial surgeons to create templates for comparing different craniofacial anomalies. Surgeons can asses' facial and cranial morphologic changes of male and female children by comparing standard average faces. For this study we can use laser imaging technology and deviation colour mapping system effectively

Altman JI et al (2007)[2] Alar base cinch to prevent most of the undesirable side effect of surgery on nasal morphology. A bilateral stitch is placed through the periosteum, alar soft tissues, and the nasalis muscle which has been detached from the nasal spine. Appropriate nasal width and contour is achieved by adjusting tension on the cinch suture.

Silva DN et al (2008)[74] Laser scanned facial or cranial data is used to fabricate 3D steriolithographic, laser sinterd, rapid prototyped, or laser printed models. Studies revealed that these models show satisfactory reproduction of anatomical details. Foramina and acute elevation not reproduced accurately. Still this technology can be use effectively in complex craniofacial anomalies.

Schwenzer et al (2008)[72] Scanning technology helps in systematic analysis of a broad verity of cleft lip and palate. Pre and post surgical data can be evaluated qualitatively and quantitatively. Data usually expressed by ratios and scores. Laser scanner is an effective and precise tool for recording complex anatomical details of cleft lip. It helps surgeon for a presurgical planning, but in infants change in head position while scanning results in multiple images in an overlapping manner. Motion tackling advanced laser scanners solved this problem.

Chung C et al (2008)[14] Some patients have narrow alar base preoperatively. Some degree of widening of alar base is desirable in such cases. In patients with normal alar base width, surgeon must take steps to avoid this undesirable alteration.

B Khambaya et al (2008)[10] Laser scanning using in Studies focusing on reproducibility of landmarks on face. Operator error in reproducing land mark can be compared to internationally accepted gold standards using 3D laser imaging technology.

Alves PVet al (2009)[3] 3D laser scanner based analysis is a new tool that can navigate away from limitations of 2D analysis techniques. Can effectively used as a tool for diagnosis, treatment planning, simulation, follow up evaluation, future comparison of treatment stability, and to asses post operative swelling.

Xu H, Han D et al (2010)[82] Cranio maxillofacial traumatic bone defects are currently reconstructed by using CAD-CAM technology. Laser scanning technology can be used to assess accuracy of detail reproduction of these milled models.

Sholts SB et al (2010)[73] Laser technology is widely using in forensic surgeons for volumetric evaluation of cranium. This technology helps them to predict age, sex, population details, racial details, from unidentified human remaining. Precision of laser scanning improved the efficiency of forensic surgeons while dealing with complex and complicated medico legal cases

Jayarathne P et al (2010)[35] Colour mapping option is incorporated in laser scanning related software. Surgeons can merge pre and post surgical scanned images together. Stable anatomical areas will merge over another, but surgically altered areas won't merge. Using colour mapping system we can calculate the changes more accurately than any other analytical tool

Ghanai S et al (2010) [22] Model surgery and splint fabrication is a very important step in dysgnathia correction surgeries. Using a 3D laser scanner device, surgeon can scan dental plaster models. Advanced software provides options for virtual articulation, virtual model surgery and splint fabrication.

Zhihong Feng 1 et al (2010)[85] Maxillofacial prosthodontists now prefer soft tissue laser scanned data for fabrication of realistic facial prostheses. Facial reconstruction done using rapid prototyping technology. Conventional facial reconstruction techniques like facial moulage is difficult to fabricate, and may damage soft tissues of operated area. It's painful and cause discomfort to patients who already under stress and depression. Laser scanning technology is non invasive and gives more accurate details of face. over that model, prosthodontist can fabricate more natural looking and well fitting maxillofacial prosthesis.

Hinderer U et al (2011) [32] To increase overall aesthetic outcome is the placing malar implants in patients with midface deficiency. Midface deficiency cases frequently appear to have prominent noses and eyes. They suffer from premature aging of the face due to lower eyelids and cheeks sag.

L.H.H. Cheng et al (2011)[42] Surgeon can evaluate effect of Botulinam toxin on masseteric hypertrophy management using pre and post treatment laser scanning .this helps surgeon to determine timing of Botulinam toxin A injection. It gives in depth data of changes in facial contour and symmetry. It produces high degree of patient and clinician satisfaction using BTTA on patients with recurrent hypertrophic masticatory muscles. Effective tool to educate patient about need of repeated injections. Botulinam toxin is commonly used for the treatment of masseteric hypertrophy and lower facial contouring. Patients with facial dysmorphic syndrome or recurrent muscle hypertrophy often request unnecessary or premature treatment. Using 3D laser scanning clinician can avoid premature, or unnecessary injections. Scanned image act as a good tool to educate patient.

G. Logan Khambay et al (2011)[24] Laser scanned facial data is used to compare base line accuracy of superimposition of laser and photogrametry over a CT based reconstruction.

Michael Krimmel et al (2011)[47] Image guided navigation surgery won't be accurate in all cases. Landmarks used in navigation surgery may vary during surgical procedure. 3D imaging technique can be used to assess facial surface changes after cleft alveolar bone grafting. It help cleft surgeon to evaluate alar base augmentation after alveolar bone grafting.

Yan Dong et al (2011) [84] Laser technology used in evaluation of sexual dimorphism among same population. Normative 3D models for both gender fabricated based on normal mean value. Facial deformity can evaluate by referring to the normative 3D facial models.

Tian H et al (2011)[78] High resolution 3D model of maxillofacial soft tissue reconstructed allowed exact evaluation with the help of analytical tool provided by the software. This program gives exact measurement of nasolabial angle and distance from aesthetic plane to different land marks.

Bo-Ram Kim et al (2012)[11] Laser scanning superimposition technique can be used to assess soft tissue changes in single jaw and double jaw surgeries. Quantitative volumetric changes calculated by superimposition of pre and post operative 3D data.

Ahcanu etal (2012) [1] used breast replica cast to avoid repeated breast augmentation corrective surgeries. They used Laser scanning technology to fabricate replica cast

Zfukltd etal (2012) [89] Laser scanners are very analogous to cameras. Like cameras, they have a cone-like field. Like cameras, they can only collect information about surfaces that are not obscured. While a camera collects colour information about surfaces within its field of view, a 3D scanner collects distance information about surfaces within its field of view. The OBJECT produced by a 3Dscanner describes the distance to a surface at each point in the object. This allows the three-dimensional position of each point in the object to be identified to a common point in a given plane.

MATERIALS AND METHODS

Study was done with five orthognathic surgical cases that underwent surgical corrections to improve their facial aesthetics. Patients were selected randomly for the study. Cleft osteotomy cases, gross asymmetry correction cases omitted. Patients were informed about this study, their informed consent was obtained before starting study. Data collection included a detailed case history, OPG, Lateral cephalogram, Dental models and a Laser facial scan.

SOFT TISSUE EVALUATION USING LATERAL CEPHALOGRAM

Presurgical lateral cephalogram was taken in standard head position, and muscles in a relaxed position. Facial landmarks were marked with 3mm stainless steel balls. Stainless steel balls were positioned over soft tissue landmarks using micro pore stickers.

MIDLINE LANDMARKS

1. Glabella
2. Nasion
3. Pronasale
4. Subnasale
5. Labisuperioris
6. Labi Inferioris
7. Point B
8. Pogonion
9. Menton
10. Point C

LATERAL LANDMARKS

1. Zygomatic prominence
2. Orbitale
3. Point X
4. Paranasale
5. Porion
6. Chelion

Patient was positioned in standard head position with the help of cephalostat. Second Lateral cephalogram was taken 6 months after surgery. Soft tissue change assessment was done using Arnett and Burgman 2 D soft tissue analysis. True vertical line (TVL) created 90° from Frankfort horizontal plane. TVL passing through subnasale point. All measurements projected from TVL to centre of stainless steel land marks. Pre surgical and post surgical values compared and soft tissue change assessed.

Fig.1: LATERAL CEPHALOGRAM WITH STAINLESS STEEL BALL LANDMARK

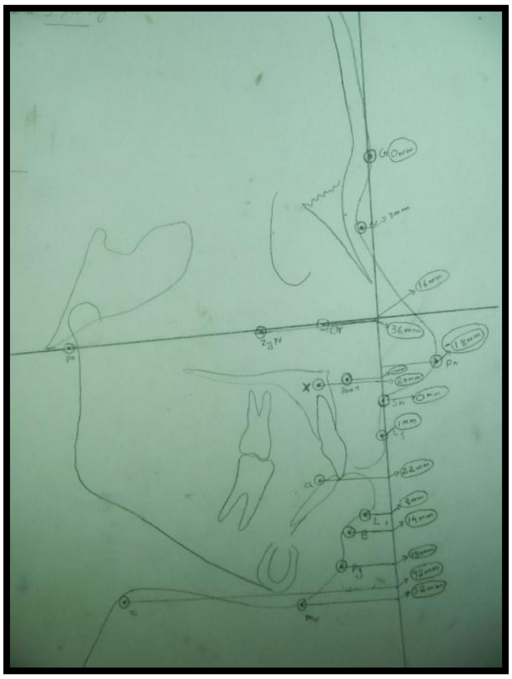

Fig.2: LATERAL CEPHALOGRAM WITH TRACING AND MEASUREMENTS

3D FACIAL LASER SCAN

Presurgical laser scan of facial soft tissue done in standard head position (Frankfort plane parallel to floor). Scanning done with facial muscles in relaxed position. Soft tissue land marks were marked using 1mm thick bindhi sticker. The lateral landmarks were kept on both the right and left side. Bilateral representation of landmarks was not possible in lateral cephalogram.

AQURING LASER SCAN DATA

PERCEPTRON 2 M LASER GUN was used to scan patient's facial soft tissue. Scanned image was saved as STL format data. Poly work software is used to create Frankfort horizontal plane and true vertical plane. Vectors were projected from TRUE VERTICAL PLANE to each facial land marks. 20 landmarks were evaluated in each scanned face. Point X was marked at a point by dropping a perpendicular line from pupil to ala tragal line. Vectors were projected from true vertical plane to each landmark using POLYWORKS SOFTWARE. Length of each vectors was measured and recorded in a tabular column .Both presurgical and post surgical values were compared to assess soft tissue changes. 2D and 3D soft issue evaluation methods were assessed separately to understand advantages and disadvantages of each technique.

Fig.3: PERSEPTRON 2 M LASER SCANNER

Fig.4: LANDMARKS ON PATIENT'S FACE

(BILATERAL MARKING POSSIBLE)

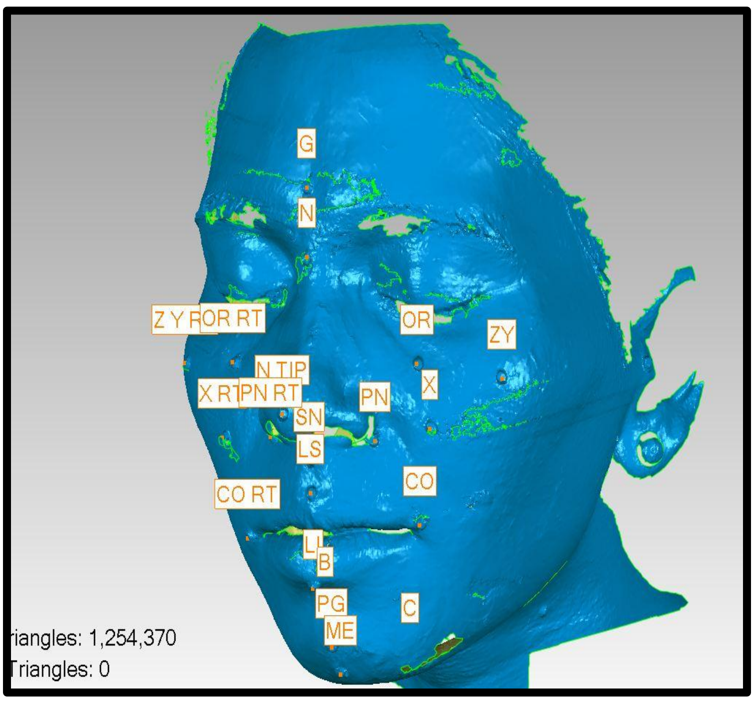

Fig.5: SCANNED PATIENT FACE WITH LANDMARKS

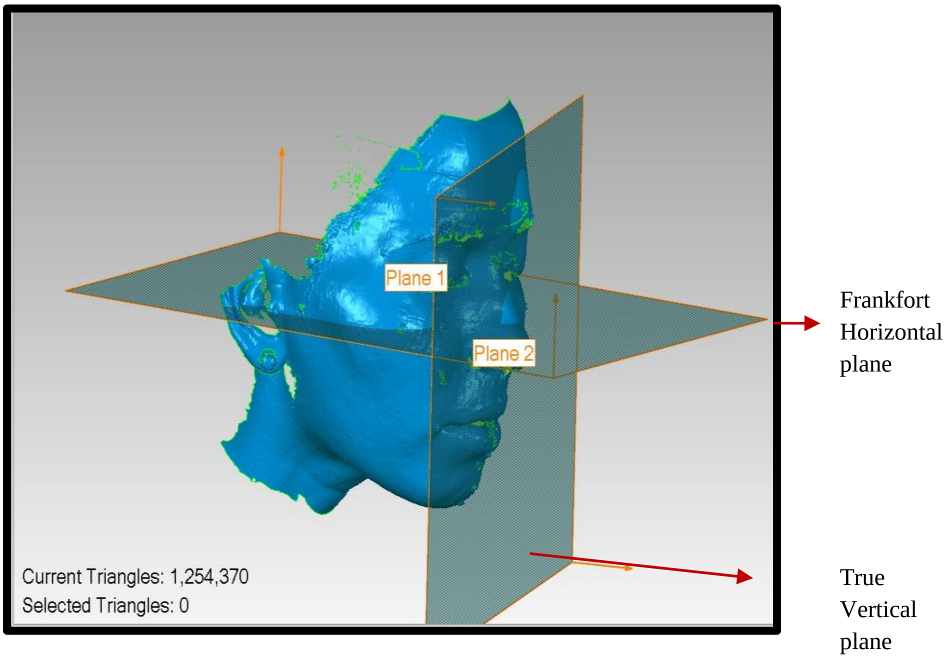

Fig.6: FRANKFORT HORISONTAL PLANE AND TRUE VERTICAL PLANE CREATED (Plane creation using *Polywork* software)

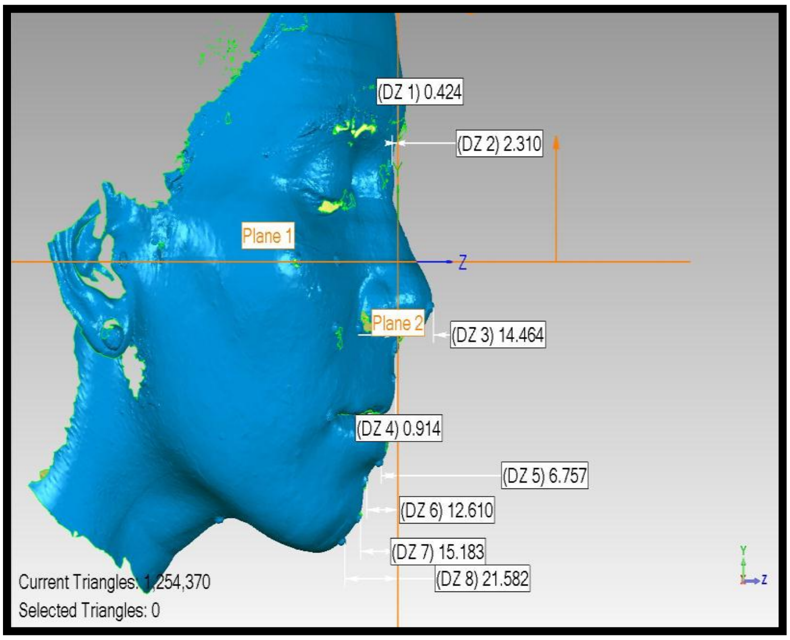

Fig.7: PLANE CREATION AND VECTOR PROJECTION FOR MEASUREMENTS (Measurements done using poly work software)

After plane creation, vectors were projected from true vertical plane to each landmark. Length of each vector was recorded using Polywork software. Presurgical and post-surgical values were recorded in the same manner.

RESULTS

Fig.8: PATIENT 1. PRE SURGICAL LATERAL CEPHALOGRAM MEASUREMENTS (Patient 1 undergone BSSRO set back 6 mm)

Fig.9: PATIENT 1 POST SURGICAL LATERAL CEPHALOGRAM MEASURMENT

Table 1: Patient 1 Presurgical values (length of vectors projected from true vertical line to each landmarks. Landmarks ahead of true vertical line give negative values)

Lateral landmarks		Midline landmarks	
Malar prominence	48mm	Glabella	10mm
Point X	28mm	Nasion	17mm
Orbitale	32mm	Pronasale	-12 mm
Paranasale	19mm	Subnasale	0 mm
Chelion	16mm	Labi superioris	- 2mm
		Labi inferioris	- 4mm
		Point B	3mm
		Pogonion	7mm
		Menton	18mm
		Point C	61mm

Table 2: Patient 1 Post surgical values

Lateral landmarks		Midline landmarks	
Malar prominence	55mm	Glabella	12 mm
Point x	33 mm	Nasion	15 mm
Orbitale	35mm	Pronasale	- 12 mm
Paranasale	15mm	Subnasale	0mm
Chelion	18mm	Labi superioris	-3mm
		Labi inferioris	-6mm
		Point B	1mm
		Pogonion	5mm
		Menton	16mm
		Point C	54mm

Table 3: Soft tissue changes of patient 1 six months after surgery

Lateral landmarks		Midline landmarks	
Malar prominence	7 mm moved posteriorly	Glabella	2mm moved posteriorly
Point x	5mm moved posteriorly	Nasion	2mm moved anteriorly
Orbitale	3mm moved posteriorly	Pronasale	0mm
Paranasale	4mm moved posteriorly	Subnasale	0mm
Chelion	2mm moved posteriorly	Labi superioris	1 mm moved anteriorly
		Labi inferioris	2mm moved anteriorly
		Point B	2 mm moved anteriorly
		Pogonion	2 mm moved anteriorly
		Menton	2 mm moved anteriorly
		Point C	7 mm moved anteriorly

PATIENT 1: PRESURGICAL SCANNED IMAGES

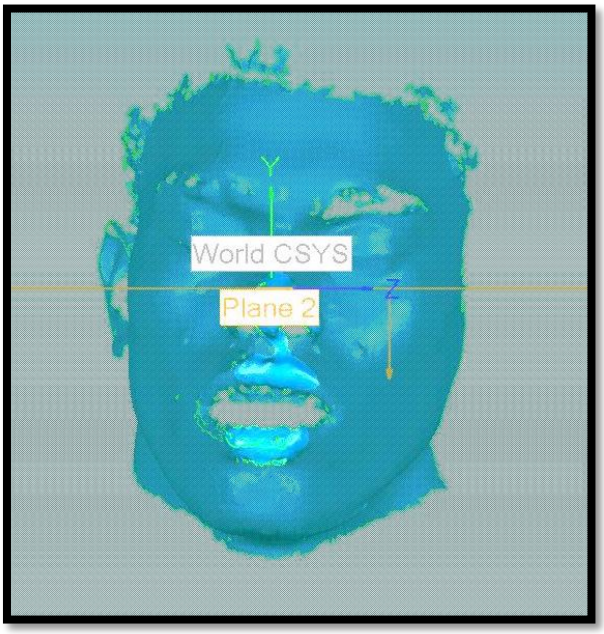

Fig.10: FRONTAL VIEW

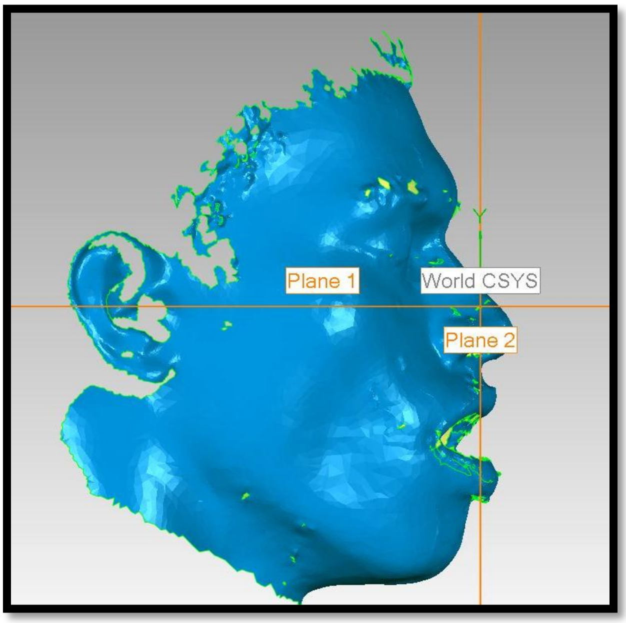

Fig.11: RIGHT LATERAL VIEW

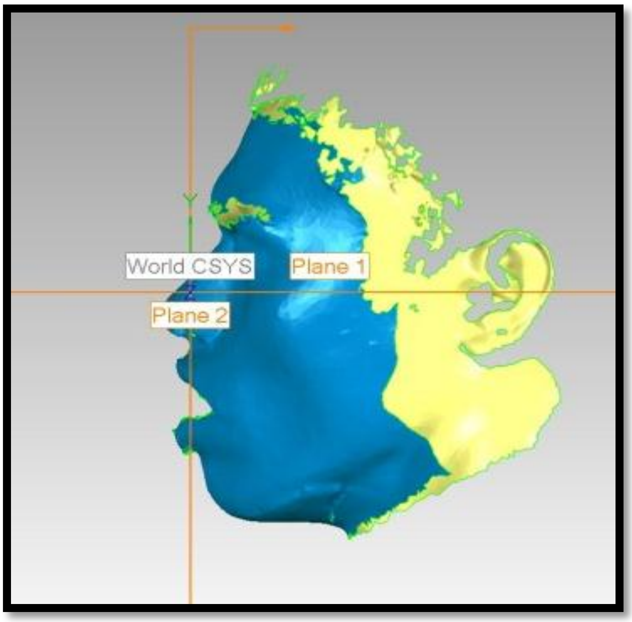

Fig.12: LEFT LATERAL VIEW

PATIENT 1: POST SURGICAL SCAN

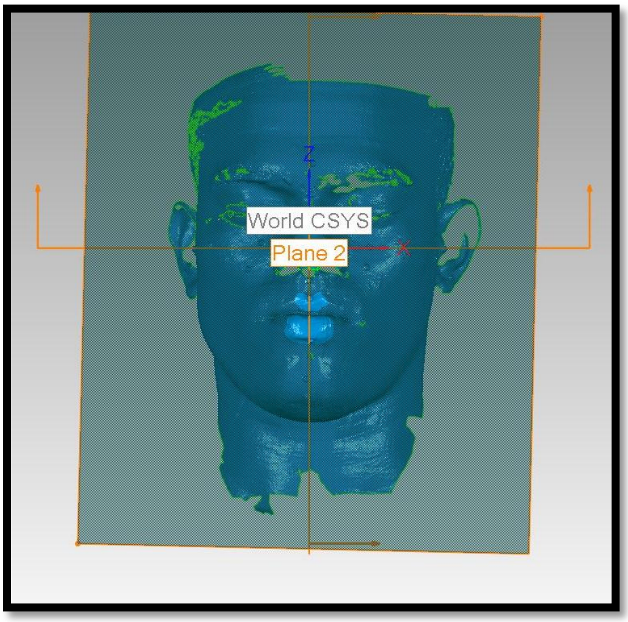

Fig.13: FRONTAL VIEW

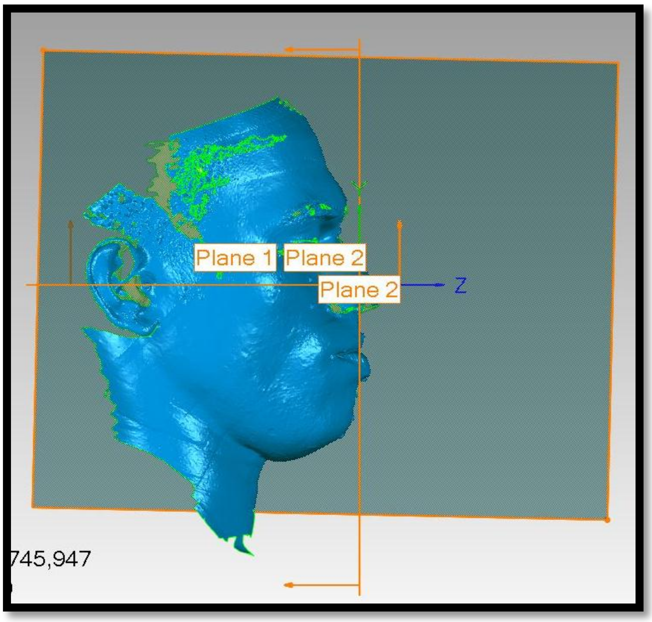

Fig.14: RIGHT LATERAL VIEW

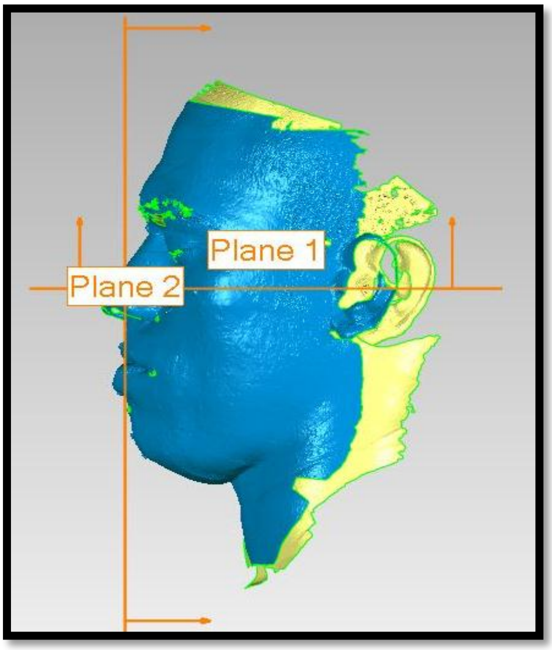

Fig.15: LEFT LATERAL VIEW

Table 4: Patient 1 Presurgical values (length of vectors projected from true vertical plane to each landmarks. Landmarks ahead of true vertical plane give negative values)

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	53.794mm	Glabella	12.948mm	Malar prominence	37.249 mm
Point x	20.073mm	Nasion	10.021mm	Point x	17.347 mm
Orbitale	28.979mm	Pronasale	-11.667mm	Orbitale	23.837 mm
Paranasale	12.686mm	Subnasale	0mm	Paranasale	7.452 mm
Chelion	18.166mm	Labi superioris	-5.610mm	Chelion	10.606 mm
		Labi inferioris	-2.466mm		
		Point B	4.726mm		
		Pogonion	8.956mm		
		Menton	20.999mm		
		Point C	60.993mm		

Table 5: Patient 1 Post surgical values

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	41.582mm	Glabella	6.834mm	Malar prominence	31.823 mm
Point x	23.879mm	Nasion	9.840mm	Point x	20.195 mm
Orbitale	25.073 mm	Pronasale	-12.922mm	Orbitale	24.623 mm
Paranasale	15.337mm	Subnasale	0mm	Paranasale	13.689 mm
Chelion	13.127mm	Labi superioris	-2.641mm	Chelion	12.113 mm
		Labi inferioris	-3.356 mm		
		Point B	1.057mm		
		Pogonion	2.845 mm		
		Menton	8.814 mm		
		Point C	50.101mm		

Table 6: Soft tissue changes of patient 1 six months after surgery

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	12.212mm Moved anteriorly	Glabella	6.114 mm moved anteriorly	Malar prominence `	5.426 mm moved anteriorly
Point x	3.806 mm moved posteriorly	Nasion	0.181 mm moved anteriorly	Point x	2.848mm moved posteriorly
Orbitale	3.906 mm moved anteriorly	Pronasale	1.255 mm moved anteriorly	Orbitale	0.786mm moved posteriorly
Paranasale	2.651mm moved posteriorly	Subnasale	0	Paranasale	6.237 mm moved posteriorly
Chelion	5.039mm moved anteriorly	Labi superioris	2.969 moved posteriorly	Chelion	1.507 mm moved posteriorly
		Labi inferioris	0.89 mm moved anteriorly		
		Point B	3.669mm moved anteriorly		
		Pogonion	6.111mm moved anteriorly		
		Menton	12.185 mm moved anteriorly		
		Point C	10.892mm moved anteriorly		

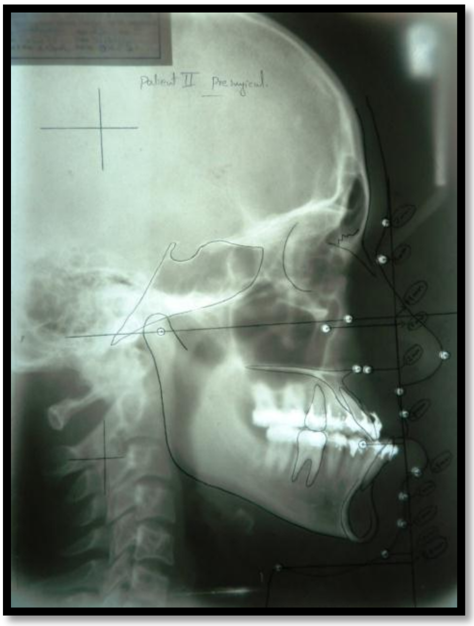

Fig.16: PATIENT 2 PRE SURGICAL LATERAL CEPHALOGRAM MEASUREMENTS (Patient 2 undergone high Lefort 1 advancement and BSSRO set back)

Fig. 17: PATIENT 2 POST SURGICAL LATERAL CEPHALOGRAM MEASUREMENT

Table 7: Patient 2 presurgical values (length of vectors projected from true vertical line to each landmarks. Landmarks ahead of true vertical line give negative values)

Lateral landmarks		Midline landmarks	
Malar prominence	28 mm	Glabella	2 mm
point x	16 mm	Nasion	4 mm
Orbitale	19 mm	Pronasale	-19 mm
Paranasale	12 mm	Subnasale	0 mm
Chelion	17mm	Labi superioris	-1mm
		Labi inferioris	-5 mm
		Point B	1 mm
		Pogonion	2 mm
		Menton	10 mm
		Point C	54 mm

Table 8: Patient 2 post surgical values

Lareral landmarks		Midline landmarks	
Malar prominence	35mm	Glabella	9 mm
Point x	16 mm	Nasion	12mm
Orbitale	27 mm	Pronasale	-15 mm
Paranasale	11 mm	Subnasale	0 mm
Chelion	22 mm	Labi superioris	-3 mm
		Labi inferioris	-1 mm
		Point B	7 mm
		Pogonion	11 mm
		Menton	25 mm
		Point C	57 mm

Table 9: Soft tissue changes of patient 2 six months after surgery

Lateral landmarks		Midline landmarks	
Malar prominence	7 mm moved posteriorly	Glabella	7 mm moved posteriorly
Point x	0 mm	Nasion	8mm moved posteriorly
Orbitale	8 mm moved posteriorly	Pronasale	4 mm moved posteriorly
Paranasale	1 mm moved anteriorly	Subnasale	0 mm
Chelion	5 mm moved posteriorly	Labi superioris	2 mm moved anteriorly
		Labi inferioris	4 mm moved posteriorly
		Point B	6 mm moved posteriorly
		Pogonion	9 mm moved posteriorly
		Menton	15 mm moved posteriorly
		Point C	3 mm moved posteriorly

PATIENT 2: (PRE SURGICAL LASER SCAN)

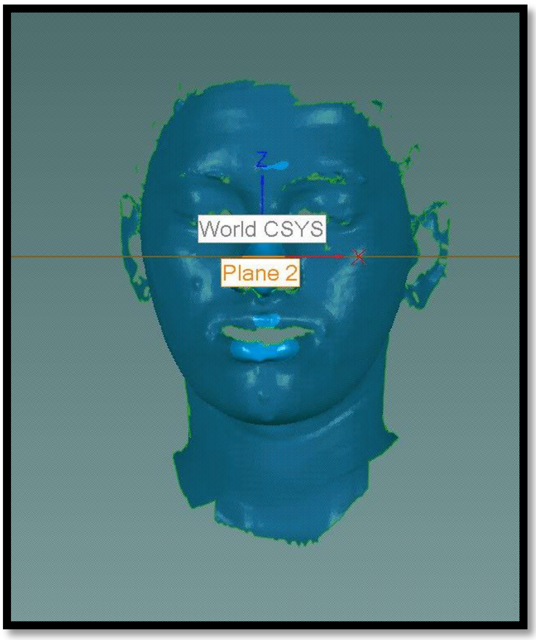

Fig.18: FRONTAL VIEW

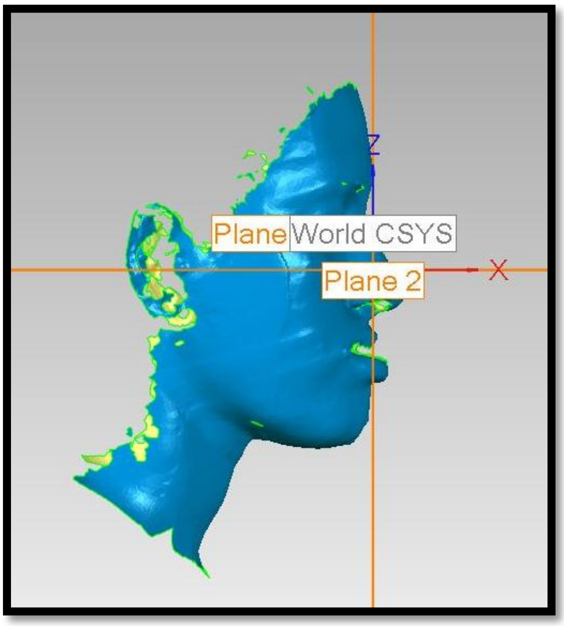

Fig.19: RIGHT LATERAL VIEW

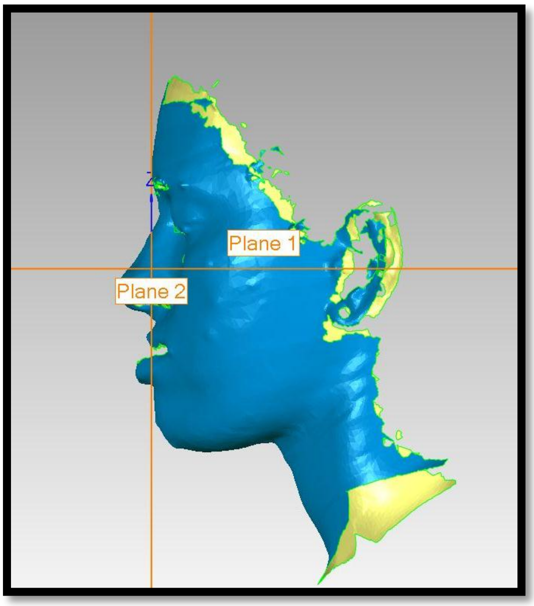

Fig.20: LEFT LATERAL VIEW

PATIENT 2: (POST SURGICAL SCAN)

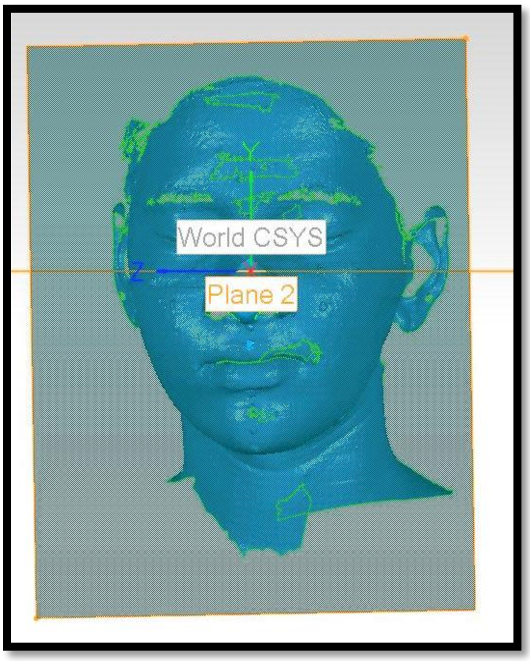

Fig.21: FRONTAL VIEW

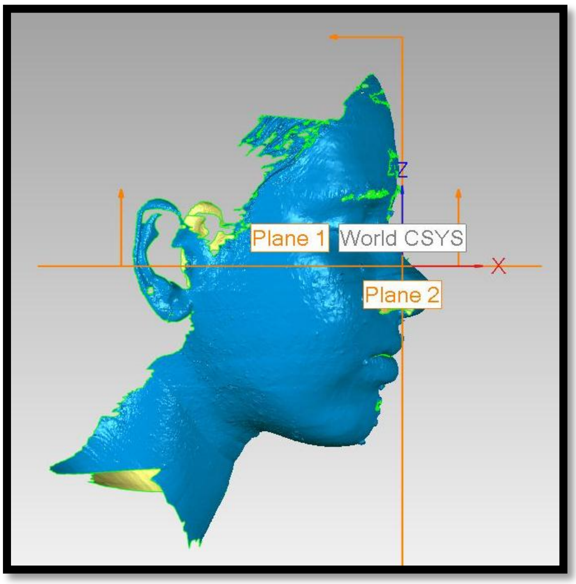

Fig.22: RIGHT LATERAL VIEW

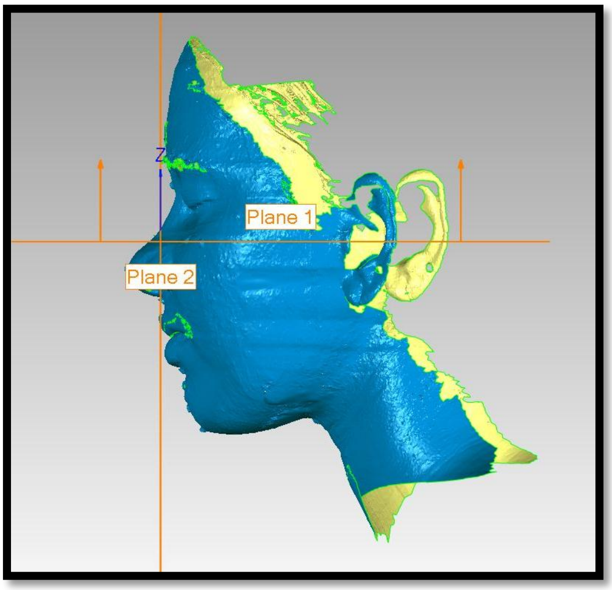

Fig.23: LEFT LATERAL VIEW

Table 10: Patient 2 Presurgical values (length of vectors projected from True Vertical Plane to each landmarks. Landmarks ahead of true vertical plane give negative values)

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	28.268mm	Glabella	0.176 mm	Malar prominence	29.901 mm
Point x	16.864mm	Nasion	3.257 mm	Point x	17.847 mm
Orbitale	18.713mm	Pronasale	-15.132 mm	Orbitale	14.830 mm
Paranasale	11.857mm	Subnasale	0 mm	Paranasale	10.435 mm
Chelion `	11.061mm	Labi superioris	-1.375mm	Chelion	7.782 mm
		Labi inferioris	-4.641 mm		
		Point B	1.203 mm		
		Pogonion	2.271 mm		
		Menton	10.303 mm		
		Point C	51.198 mm		

Table 11: PATIENT 2 POST SURGICAL VALUES

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	28.030mm	Glabella	1.971 mm	Malar prominence	16.939 mm
Point x	16.524mm	Nasion	4.321 mm	Point x	5.818 mm
Orbitale	17.388mm	Pronasale	-14.962mm	Orbitale	10.251mm
Paranasale	10.570mm	Subnasale	0mm	Paranasale	4.716 mm
Chelion	16.199mm	Labi superioris	-0.577mm	Chelion	11.269 mm
		Labi inferioris	9.193mm		
		Point B	9.875mm		
		Pogonion	11.890mm		
		Menton	18.409mm		
		Point C	68.416mm		

Table 12: Soft tissue changes of patient 2 six months after surgery

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	0.238MM moved anteriorly	Glabella	1.795mm moved posteriorly	Malar prominence `	12.962mm moved anteriorly
Point x	0.34mm moved anteriorly	Nasion	1.064 mm moved posterior	Point x	12.029mm moved anteriorly
Orbitale	1.325 mm moved anteriorly	Pronasale	0.17mm moved posteriorly	Orbitale	4.579mm moved anteriorly
Paranasale	1.287 mm moved anteriorly	Subnasale	0mm	Paranasale	5.719 mm moved anteriorly
Chelion	5.138mm moved posteriorly	Labi superioris	0.798mm moved posteriorly	Chelion	3.487 mm moved posteriorly
		Labi inferioris	13.834mm moved posteriorly		
		Point B	8.672mm moved posteriorly		
		Pogonion	9.619 mm moved posteriorly		
		Menton	8.106mm moved posteriorly		
		Point C	17. 218 mm moved posteriorly		

PATIENT 3: PRESURGICAL LATERAL CEPHALOGRAM MEASUREMENTS

Fig.24: Patient 3 undergone Lefort 1 set up and set back

PATIENT 3 POST SURGICAL LATERAL CEPH MEASUREMENTS

Fig 25. (Patient 3 lateral cephalogram measurment)

Table 13: Patient 3 presurgical values(length of vectors projected from true vertical line to each landmarks. Landmarks ahead of true vertical line give negative values)

Lateral landmarks		Midline landmarks	
Malar prominence	29 mm	Glabella	4 mm
Point x	21 mm	Nasion	6 mm
Orbitale	20 mm	Pronasale	-15 mm
Paranasale	12 mm	Subnasale	0 mm
Chelion	22 mm	Labi superioris	-3 mm
		Labi inferioris	10 mm
		Point B	17 mm
		Pogonion	22 mm
		Menton	38 mm
		Point C	83 mm

Table 14: Patient 3 post surgical values

Lateral landmarks		Midline landmarks	
Malar prominence	36mm	Glabella	0 mm
Point x	20 mm	Nasion	3 mm
Orbitale	16 mm	Pronasale	-18 mm
Paranasale	11 mm	Subnasale	0 mm
Chelion	22 mm	Labi superioris	1 mm
		Labi inferioris	8 mm
		Point B	14 mm
		Pogonion	18 mm
		Menton	32 mm
		Point C	92 mm

Table 15: Soft tissue changes of patient 3 six months after surgery

Lateral landmarks		Midline landmarks	
Malar prominence	7 mm moved posteriorly	Glabella	4 mm moved anteriorly
Point x	1 mm moved anteriorly	Nasion	3mm moved anteriorly
Orbitale	4 mm moved anteriorly	Pronasale	3 mm moved anteriorly
Paranasale	1 mm moved anteriorly	Subnasale	0 mm
Chelion	0mm	Labi superioris	4 mm moved posteriorly
		Labi inferioris	2 mm moved anteriorly
		Point B	3 mm moved anteriorly
		Pogonion	4 mm moved anteriorly
		Menton	6 mm moved anteriorly
		Point C	9 mm moved posteriorly

PATIENT 3: (PRE SURGICAL SCAN)

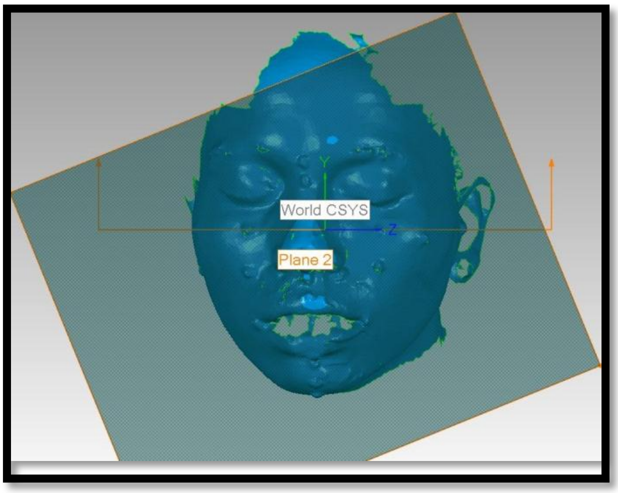

Fig.26: FRONTAL

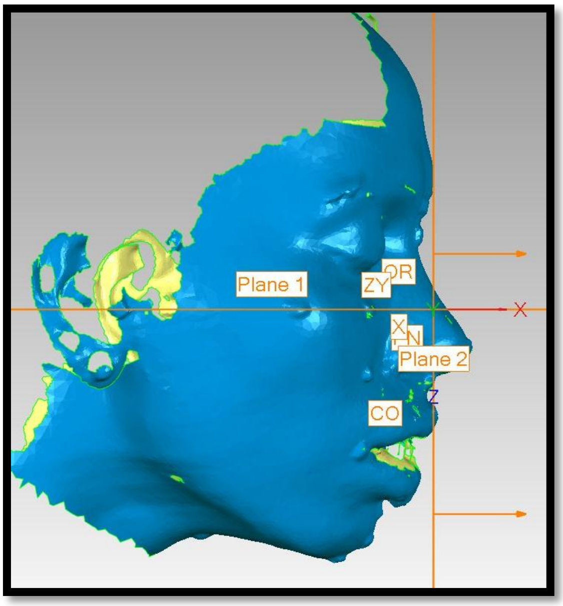

Fig.27: RIGHT LATERAL VIEW

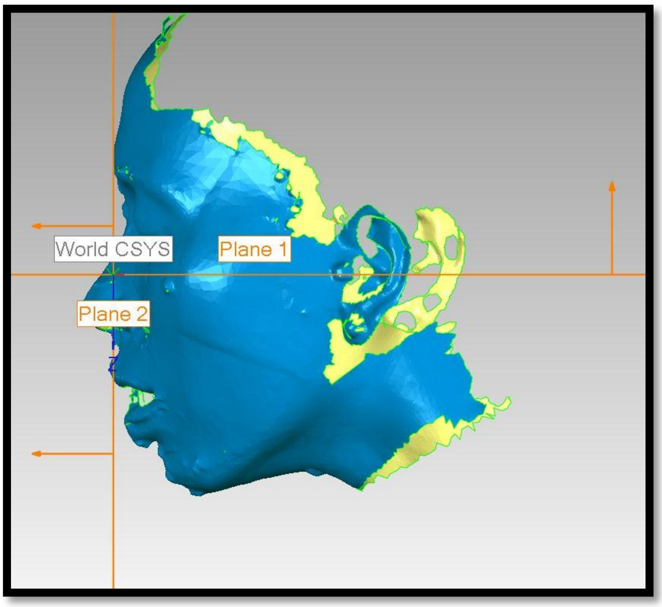

Fig.28: LEFT LATERAL VIEW

PATIENT 3: (POST SURGICAL SCAN)

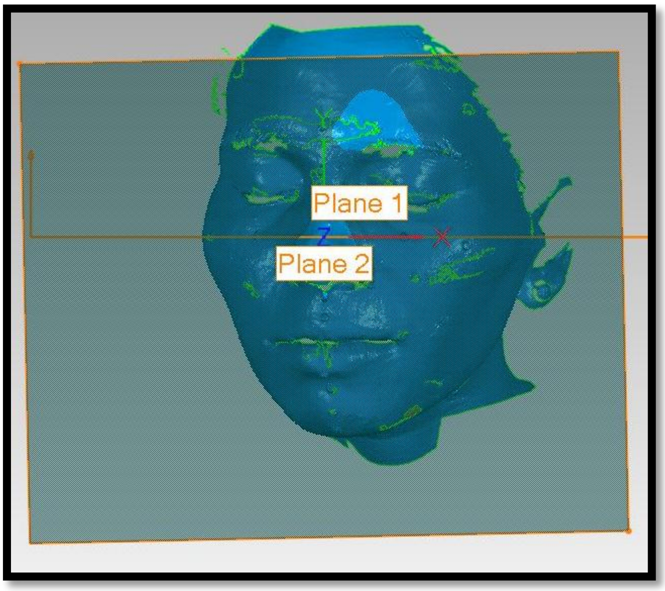

Fig.29: FRONTAL VIEW

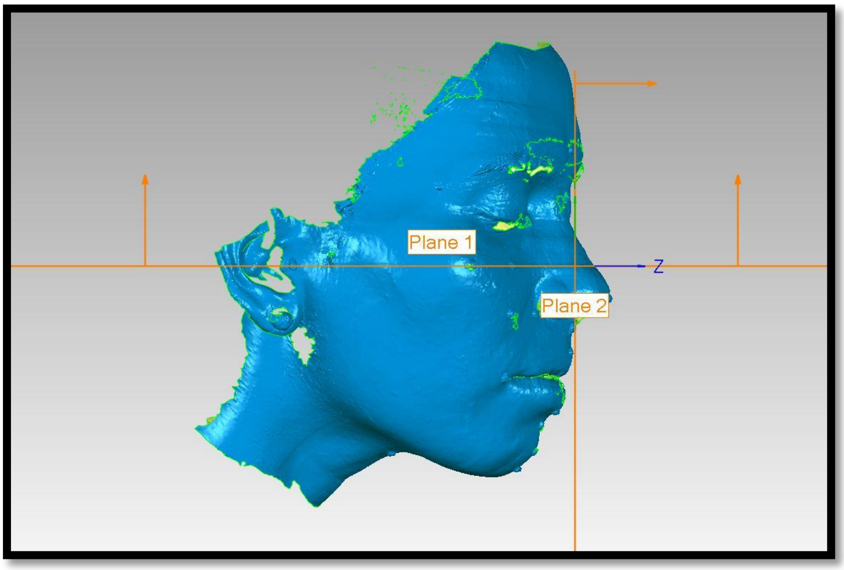

Fig.30: LEFT LATERAL VIEW

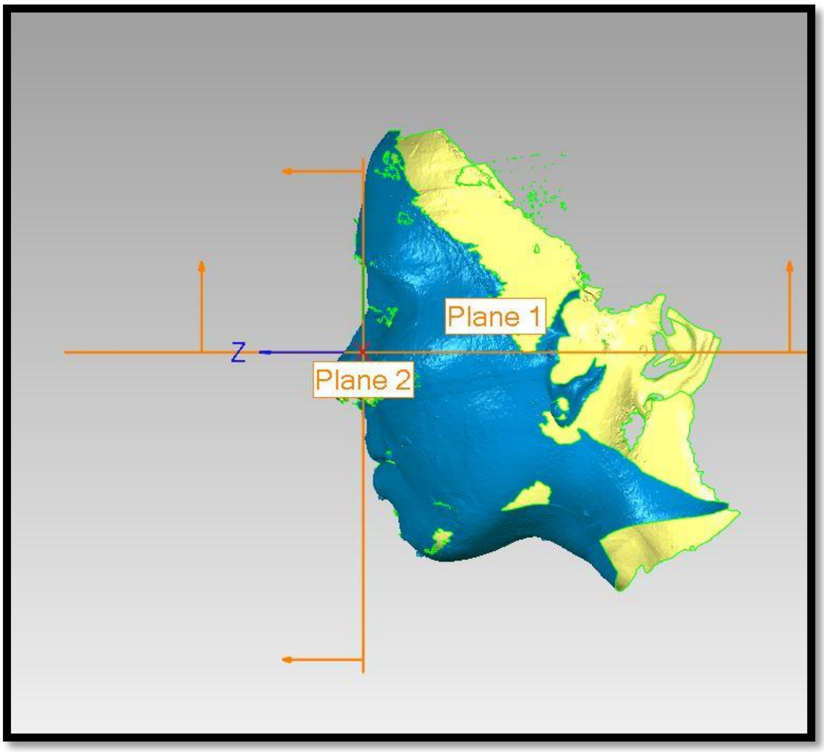

Fig.31: RIGHT LATERAL VIEW

Table 16: Patient 3: Presurgical values(length of vectors projected from truevertical plane to each landmarks. Landmarks ahead of true vertical plane give negative values)

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	44.526mm	Glabella	1.754 MM	Malar prominence	19.397MM
Point x	20.707mm	Nasion	3.482 MM	Point x	11.723MM
Orbitale	20.671mm	Pronasale	-16.557 MM	Orbitale	11.778MM
Paranasale	14.101mm	Subnasale	0 MM	Paranasale	8.871MM
Chelion	24.035mm	Labi superioris	-0.940MM	Chelion	16.302MM
		Point B	17.353 MM		
		Pogonion	21.607 MM		
		Menton	31.635 MM		
		Point C	77.116 MM		

Table 17: Patient 3 post surgical values

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	39.467MM	Glabella	0.424 MM	Malar prominence	7.150 MM
Point x	24.198 MM	Nasion	2.310 MM	Point x	2.635 MM
Orbitale	23.399MM	Pronasale	-14.469MM	Orbitale	4.909 MM
Paranasale	14.517MM	Subnasale	0MM	Paranasale	4.832 MM
Chelion	27.092MM	Labi superioris	0.914MM	Chelion	9.358 MM
		Labi inferioris	6.757 MM		
		Point B	12.614 MM		
		Pogonion	15.183 MM		

Table 18. Softtissue changes of patient 3 six months after surgery

Right side landmarks		Midline landmarks		Left side landmarks	
Malar prominence	5.057mm moved anteriorly	Glabella	1.33 mm moved anteriorly	Malar prominence	12.247 MM anteriorly
Point x	3.419mm moved posteriorly	Nasion	1.172mm moved anteriorly	Point x	9.088 moved anteriorly
Orbitale	2.728mm moved posteriorly	Pronasale	2.088 mm moved posteriorly	Orbitale	6.869 mm moved anteriorly
Paranasale	0.416mm moved posteriorly	Subnasale	0mm	Paranasale	4.039 mm moved anteriorly
Chelion	3.057mm moved posteriorly	Labi superioris	0.026mm moved posteriorly	Chelion	6.944 mm moved anteriorly
		Labi inferioris	4.739mm moved anteriorly		
		Point B	4.739mm moved anteriorly		
		Pogonion	6.424 mm moved anteriorly		
		Menton	10.053mm moved anteriorly		
		Point C	5.607mm moved anteriorly		

DISCUSSION

Soft tissue changes are inevitable outcome of most of maxillofacial surgical procedures. Assessment of soft tissue changes is a challenge for maxillofacial surgeons. These assessments and soft tissue response help surgeons to predict possible outcome of the surgical procedure. Hard tissue movements during maxillofacial surgery will definitely affect the soft tissue of face. Patient is mainly concerned of their soft tissue outcome than hard tissue movements. Patient can appreciate the soft tissue change only after the surgery. Soft tissue change assessment can be done in different methods.

1) LATERAL CEPHALOGRAM

Lateral cephalogram is the traditional tool used to evaluate soft tissue changes by surgeons. Most popular techniques are Arnett and Bergman analysis, Burston soft tissue analysis, Hold Away analysis etc. Pre surgical and post surgical cephalometric studies give an idea about soft tissue changes of patients after surgical procedure. Anatomical landmarks are identified by placing metal markers and a cephalostat is used to keep the head position in the same position for pre operative and post operative cephalometric x-ray

Cephalometrics can be used as an aid in the diagnosis of skeletal and dental problems and a tool for simulating surgery by the use of acetate paper overlays (Tracing sheets). It is a cost effective and simple to do.

Disadvantages are, it represents 2D aspect of a 3D object. It represents only midline structures clearly. Landmarks like chelion is very difficult to identify, due to radio opaque orthodontic bracket overlap. Bilateral representation of non midline land marks is not possible. Cephalogram is not easy to store for a long time. Quality of film may change over a period of time. To avoid such difficulties in soft tissue analysis, surgeons prefer 3D SOFTTISSUE RECONSTRUCTION techniques such as Photogrammetry, 3D Laser scanners, White light 3d scanning, Facial Moulage

2) FACIAL MOULAGE

Casts moulded from direct facial impression are ease of availability ease of manoeuvrability, no radiation exposure, cost effective and accurate. Disadvantages are cumbersome procedure, no any definitive assessment procedure, assessment done only by visualisation, difficulty in storage, weight of dental stone may distort alginate facial impression, patient cooperation is necessary, and difficult to transport.

3) PHOTOGRAMMETRY

It has been defined by the American Society for Photogrammetric and Remote Sensing (ASPRS) as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena.

Photogrammetric is more accurate in the x, y and z direction. It provides a permanent photographic record. Disadvantages are it needs sophisticated instruments and very costly

4) CT 3D CEPHALOMETRY

The acquired CT images are stored in DICOM (Digital Imaging and Communications in Medicine) format. It can be imported into any software. Advantages: (1) real-size and real-time 3D cephalometric analysis, (2) truly volumetric 3D depiction of hard and soft tissues of the Skull, (3) high accuracy and reliability, and (4) no superimposition of anatomic structures. A high end computer is needed to reconstruct the CT data. A Pentium CPU with 1GB memory is a must[38].

CT 3D Cephalometry has marked advantages over conventional cephalometry, data acquisition still has some drawbacks: (1) horizontal positioning of the patient during record taking falsifies the position of the soft tissue facial mask, (2) lack of a detailed occlusion due to artefacts, (3) limited access for the routine craniofacial patient because of relatively higher cost, and (4) higher radiation exposure than other craniofacial x-ray acquisition systems.

5) CBCT 3D CEPHALOMETRY

It has some interesting advantages for the future:

1) Reduced radiation exposure, natural shape of the soft-tissue facial mask because of the vertical scanning procedure.
2) Reduced artefacts at the level of the occlusion,
3) Increased access for the routine dento facial patient because of in-office imaging. To be installed in oral surgery outpatient clinics and private practices
4) Reduced costs.

The current limitations of CBCT 3D cephalometry are the scanning volume and positional dependency of the image value of a structure in the field of view of the scanner[24].

6) WHITE LIGHT 3D SCANNING

White light scanning is a 3D scanning technology that uses white light source to project fringes onto the object being scanned. The sensor of the white light scanner takes multiple images of the object during measurement and sends these images through software that triangulates the 3D coordinates of numerous points spaced all over the surface of the object.

Advantages are

1) Creates a very high density point cloud.

2) Can scan small parts with intricate details.

Disadvantages are

1. It requires photogrammetry targets and/or surface spray
2. Structured measurement environment - no freeform measurement
3. Lengthy setup and post processing time
4. Must 'stitch' snapshots together using photogrammetry techniques or post processing software
5. Limited to scanning - no dynamic tracking or probing capabilities

7) 3D LASER SCANNING

Laser scanners are very analogous to cameras. Like cameras, they have a cone-like field of view, and like cameras, they can only collect information about surfaces that are not obscured. While a camera collects colour information about surfaces within its field of view, a 3D scanner collects distance information about surfaces within its field of view. The picture (OBJECT) produced by a 3Dscanner describes the distance to a surface at each point in the object. This allows the three-dimensional position of each point in the object to be identified to a common point in a given plane[89].This has been used in this study. We used laser scanning device for facial 3d reconstruction. The polygonal mesh derived from a 3D scanner can be used for reverse engineering, to make changes to prototypes, or even create moulds and dies. Complex surface structures are easily captured as a polygonal mesh by 3Dscanners. The polygonal mesh can be converted to a format native to various CAD applications. Once converted, CAD can be used to make slight adjustments to the original object for better fitment or make even more dramatic changes such as combining a polygonal mesh with CAD objects to create personalized ergonomic parts. Simple moulds can be made by subtracting the polygonal mesh from a box with a part line. The resulting CAD model can be quickly fabricated using Rapid Prototyping machines and used to pour various materials.Advantages include, it gives more accurate soft tissue reproducibility, Easy manuverability, better reproduction of details, easy reconstruction of 3d image, and no radiation exposure[89]. Disadvantages of laser scanner unit are, not cost effective, lack of availability of technology, unavailability of cephalostat like head positioning system, the size of scanned files.

Although laser scanners produce flawless data results that can be edited and repurposed in a variety of ways using polygon mesh models, solid surface models and solid CAD models, it needs high-end computer hardware to accommodate the significant memory requirements of the data. 3D laser scanning costs more; still 3Dlaser scanning is an ideal tool for soft tissue assessment. Surface scanning is a safe, non-invasive technique able to record complex three-dimensional shapes, such as the face, accurately and rapidly. It has significant advantages over existing two- and three-dimensional methods of facial soft-tissue analysis and would seem to be a very suitable technique for measuring the three-dimensional changes in facial surface anatomy resulting from orthognathic surgery.

Orthognathic surgery is the most popular surgical field of maxillofacial surgery to improve patients function and aesthetics. All these procedures results in marked skeletal movements. Soft tissue change depends on the skeletal movement. Exact soft tissue change prediction is almost impossible. Because soft tissue response may vary from person to person, soft tissue changes depends on inflammatory response, presurgical tissue thickness, severity of instrumentation, nutritional factors, post op care and a lot of other factors. Soft issue changes can effectively evaluate using 3D facial reconstruction techniques like laser scanning[76]. This technique is more superior compared to Lateral Cephalogram based evaluation. The software which reads the 3D data loaded with lot of features and measuring tools, provides options for plane creation, vector projection, point projections, angle measurements, length measurements, volumetric assessments & superimposition.

Application of laser scanning is not limited to orthognathic surgery alone, this technology can be used in other fields of Facio - maxillary surgery.

Plastic surgeons, cosmetic surgical specialists, and orthodontists also prefer this technique to assess their treatment outcome[79, 67].

Soft tissue changes also occur in cleft lip repair, alveolar bone grafting, malar augmentation, muscle debulking surgeries, liposuctioning surgeries, fat transfer surgeries, dental implantology related surgeries, tumour & cyst management, cancer related resection and reconstruction surgeries. Facial aesthetic surgeries like facelift, brow lift, blepharoplasty etc[66].

Studies evaluating post operative swelling can be effectively measured using pre and post surgical laser scanner. Software provides an option called superimposition of scanned image. Both pre and post surgical scans superimpose and merged together, and changes evaluated by software. Such studies shows more accurate results than conventional studies.[11]

Storing dental casts are very important in clinical practice. These casts help surgeon for future references. But this plaster models are difficult to store in normal clinical set up. Changes due to chipping of model also can happen. These dental cast scan be valuable evidence in medico legal cases. Forensic experts may need dental casts for their investigations. In such conditions instead of keeping all models, surgeon can make use of 3D laser scanner to scan all dental casts, as this is digital data; can be stored in a compact disc or in a pen drive. Whenever it is required surgeon can fabricate a stereolithographic model of it.

In cleft lip cases, scanned 3D facial data helps surgeon to evaluate the defect properly. Cleft lip, nasal deformities can be studied in computer and surgeon can plan his surgical technique according to that. Rubber based replica of the scanned image can be used as an effective tool to try incision plans, flap rotations before surgery [21].

Laser scanner is used for the evaluation of postoperative changes of soft tissue swelling after different anti inflammatory drug administration[34] . Laser scanning is effectively used in anthropometric studies. Landmark placement and accuracy in measurement is more in this technique. It reduces the processing time markedly[6]. Laser scanning used in Studies focusing on reproducibility of landmarks on face. Operator error in reproducing land mark can be compared to internationally accepted gold standards using 3D laser imaging technology[10].

Laser scanning superimposition technique can be used to assess soft tissue changes in single jaw and double jaw surgeries. Quantitative volumetric changes calculated by superimposition of pre and post operative 3D data.[11]. Three-dimensional facial morphologic changes of children can be assessed effectively using laser scanning device. This technology helps craniofacial surgeons to create templates for comparing different craniofacial anomalies[15].

Surgeon can evaluate effect of Botulinum toxin on Masseteric hypertrophy management using pre and post treatment laser scanning .this helps surgeon to determine timing of Botulinum toxin A injection. It gives in depth the data of changes in facial contour and symmetry. It produces high degree of patient and clinician satisfaction using Botulinum toxin A on patients with recurrent hypertrophic masticatory muscles. It is the effective tool to educate patient about need of repeated injections[42]. Laser scanned facial data is used to compare base line accuracy of superimposition of laser and photogrametry over CT based reconstruction by some surgeons[24]. 3D laser scanner based analysis is a new tool that can navigate away from limitations of 2D analysis techniques. Can effectively used as a tool for diagnosis, treatment planning, simulation, follow up evaluation, future comparison of treatment stability, and to asses post op swelling[3]. Laser scanning has proved to be a simple non-invasive method of measuring three-dimensionally, and is a very useful tool in auditing surgical outcome and measuring surgical relapse[4]. Facial anthropometry is a means of standardizing objective measurements to supplement visual assessment. This technique involves calculating a large number of direct facial measurements and takes a considerable amount of time. Optical surface scanner can reduce the amount of time taken for this process by using laser stripe triangulation to digitize facial surfaces. These measurements were then compared to assess the mean difference between standard measurements and laser scan measurements. The laser scan measurements could then be grouped according to their reliability. Laser measurements found to be more reliable[6].

Surgeons can assess facial and cranial morphologic changes of male and female children by comparing standard average faces. For this study we can use laser imaging technology and deviation colour mapping system effectively[15]. Radiation therapy is an effective treatment modality for the management of malignancy. Radio resistant shields are used to protect healthy tissues from harmful effects of radiation. Conventional fabrication of this shield on facial, and intra oral regions found to be very difficult and painful to patient. Facial moulage is commonly used to fabricate these shields. Now 3D laser scanning provides options of non invasive, non painful facial reconstruction with more accurate surface details .stereo lithographic technique is used to fabricate more adaptable radio resistant shields[20].

Model surgery and splint fabrication is a very important step in orthognathic correction surgeries. Using a 3D laser scanner device, surgeon can scan dental plaster models. Advanced software provides options for virtual articulation, virtual model surgery and splint fabrication[22]. 3D simulation and visualisation plays an important role in interactive craniofacial surgical planning. Conventional methods are cast model surgery, cephalometric prediction, photo evaluation, facial moulage. Now surgeons incorporate two 3D reconstruction techniques to predict planned surgical outcome. CT data used for skeletal virtual surgery, and laser scanned soft tissue data for soft tissue change assessment. Animation software helps surgeons to predict soft issue change after their planned hard tissue movement[23]. Laser based 3D scanning is used to evaluate reproducibility of land mark identification as well as assessing facial soft tissue growth and development of the craniofacial complex[29].

Colour mapping option is incorporated in laser scanning related software .Surgeons can merge pre and post surgical scanned images together. Stable anatomical areas (eg; frontal bone of face) will merge over another, but surgically altered areas won't merge. Using colour mapping system we can calculate the changes more accurately than any other analytical tool[35]. Image-data-based navigation plays an important role during surgical treatment of anatomically complex regions. Conventional patient-to-image registration techniques on the basis of skin and bone markers require time-consuming logistic support. A new marker less, laser surface scan technique for patient registration has been tested in experimental and clinical settings .Three-dimensional laser surface registration offers an interesting approach for selected image-guided procedures in craniofacial maxillary surgery[36]. Paediatric craniofacial surgeons used 3D reconstructed images for comparing CAD-CAM milling models steriolithographic models and found steriolithographic models are more accurate than CAD-CAM models [40].

Surgeons using laser scanning technique to evaluate facial asymmetry scores. Landmarks designed on 3D model .new method of 3D facial asymmetry analysis also developed with the help of this technology[49]. Orthodontists using this technology to virtually move teeth according to their treatment plan. Data collected by scanning dental casts. In orthognathic surgical cases, they can move maxilla or mandible to achieve good occlusion. Compared to handmade models, this technology provides high speed processing, more accurate data acquisition, quantitative evaluation of 3D object, and allows individual tooth movements according to craniofacial plane. Laser scanning and reverse engineering eliminates need of time consuming model surgeries, and techniques like kesling's set up[53].

Evaluation of soft tissue changes after correction of Class III dentoskeletal deformity with orthognathic surgery is done using the optical surface scanner as a 3-dimensional imaging tool. Lateral cephalogram can be digitalized and 2D evaluation is possible using digitalizing software. This is to confirm whether the preoperative surgical plan was applied. A soft tissue change depends on different factors. So the exact soft tissue prediction is impossible [54].

Laser based stereolithography has allowed the creation of life sized skeletal models. CT based stereolithography gives an idea of skeletal pattern of complex craniofacial defects. However skeletal model alone does not reveal the special relationship of soft tissues. So we can incorporate CT based data and laser based data to construct a stereo lithographic model with both skeletal and soft tissue details. This model can provide baseline data for evaluating facial growth after surgical repair of clefts [55].

3D laser scanned data used for the standard measurements of nasal orbital fossa in plastic surgery. Software like Polyworks, Geomagic used to obtain the standard facial contour. 3D measurements exhibited the three dimensional facial shape at every meaningful angle with the advantages of high precision of 0.01mm. This is a new approach for pre operative plans, operation simulation, and post operative evaluation [61]. Recording landmarks on facial skin without use of markers have become increasingly accepted in image guided surgery. But the position and muscular activity may change skin geometry and shows errors between pre operative positions and intra operative positions. Laser scanning based studies revealed significant influence of gravitational pull and muscular activity in land mark precision[69]. Comparative studies using CT data and laser based data reveals high resolution laser scan of skin surface allows for a precise patient registration of land marks [68].

Scanning technology helps in systematic analysis of a broad verity of cleft lip and palate. Pre and post surgical data can be evaluated qualitatively and quantitatively. Data usually expressed by ratios and scores. Laser scanner is an effective and precise tool for recording complex anatomical details of cleft lip. It helps the surgeon for presurgical planning. But in infants changes in the head position while scanning results in multiple images in overlapping manner. Motion tackling advanced laser scanners solved this problem[72].

Laser technology is widely using in forensic surgeons for volumetric evaluation of cranium. This technology helps them to predict age, sex, population details, racial details, from unidentified human remaining. Precision of laser scanning improved the efficiency of forensic surgeons while dealing with complex and complicated medico legal cases[73].

Laser scanned facial or cranial data is used to fabricate 3D steriolithographic, laser sintered, rapid prototyped, or laser printed models .studies revealed that this models shows satisfactory reproduction of anatomical details. Foramina and acute elevation not reproduced accurately. Still this technology can be use effectively in complex craniofacial anomalies[74].

High resolution 3D model of maxillofacial soft tissue reconstructed allowed exact evaluation with the help of analytical tool provided by the software. This program gives exact measurement of nasolabial angle and distance from aesthetic plane to different land marks[78]. 3D prototyping helps to evaluate facial changes after traumatic injury[81].

Craniomaxillofacial traumatic bone defects are currently reconstructed by using CAD-CAM technology. Laser scanning technology can be used to assess accuracy of detail reproduction of this milled models[82].

Laser technology is used in evaluation of sexual dimorphism among same population. Normative 3D models for both gender fabricated based on normal mean value. Facial deformity can evaluate by referring to the normative 3D facial models[84].

Maxillofacial prosthodontists now prefer soft tissue laser scanned data for fabrication of realistic facial prostheses. Facial reconstruction is done using rapid prototyping technology. Conventional facial reconstruction techniques like facial moulage is difficult to fabricate, and may damage soft tissues of operated area. It is painful and cause discomfort to patients who already under stress and depression. Laser scanning technology is non invasive and gives more accurate details of face. Over that model, prosthodontist can fabricate more natural looking and well fitting maxillofacial prosthesis[85].

Studies conducted to assess the stability and reliability of laser scanning technology. Repeated scanning of same facial molauge at different time period was done. There was no significant difference between each scanned images. So studies revealed that laser scanner is a reliable, repeatable, stable tool for 3D surface reconstruction[87]. This technology empowers revolutionary growth of different branches of surgical and medical fields.

SUMMARY AND CONCLUSION

Science is developing through different stages of evolution. New thoughts and technology always helped innovative mind to polish science even brighter. Conventional technology always stands as a guide for development of newer technology. Newer techniques always try to rectify demerits of older one. Science provides different options to solve a common problem. Scientist can opt a specific technique to solve a problem, or they can combine different techniques. Each technique has its own merits and demerits.

In our study we tried two different technologies to understand pros and cons of each technique. soft tissue evaluation after orthognathic surgery can be done by a 2D tool (Lateral cephalogram) or using a 3D tool (3D laser scanning).Lateral cephalogram based evaluation was cost effective, and needs only cheaper equipments, availability of this tool also easy compared to 3D tool. But we can’t consider this as a good tool for soft tissue change evaluation. It represents 2D information of a 3D object.

Advanced 3D laser scanner gives exact 3D information of a 3D object. Technique is easy, and need less processing time. All measuring tools are incorporated in data reading software. Measurements show accuracy in micron level. This will reduce examiner level error in measurements .Time required to finish measurements negligible compared to conventional technique. It represents face as a whole. We found that laser scanning technology has wide field of application in maxillofacial surgery. In our study, we had included five patients who underwent different orthognathic procedures. Three patients cooperated well. Two patients did’t come for follow-up. Laser based scanning technology is not cost-effective, especially in a developing country like India. Still we can utilise this technology in research field with the help of research oriented organisations. 3D soft tissue analysis study can be conducted with more sample size. Such studies definitely reveal the secrets behind soft tissue response after aesthetic surgeries.

All technologies are expensive when it is introduced recently. Over a period of time cost factor will come down and it will reach common man. Laser based soft tissue evaluation is a relatively advanced and recent technique. Now Laser scanner Giants focusing on developing convenient, and cost effective medical soft tissue scanners. This movement definitely helps surgeons like maxillofacial surgeons to provide more accurate and predictable surgical out come.

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