Malar augmentation with zygomatic osteotomy in orthognatic surgery: Bone and soft tissue changes threedimensional evaluation: Malar Augmentation in Orthognatic Surgery

MALAR AUGMENTATION WITH ZYGOMATIC OSTEOTOMY IN ORTHOGNATIC SURGERY : BONE AND SOFT TISSUE CHANGES THREEDIMENSIONAL EVALUATION

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SUMMARY

Background:

The aim of this ~~report~~ prospective study is to objectively assessed 3D soft tissue and bone changes of malar ~~augmentation technique~~ region by using the malar valgization osteotomy in concomitant association with orthognatic surgery.

Materials and Methods:

From January 2015 to January 2018, 10 patients underwent single stage bilateral malar valgization osteotomy in conjunction with maxillo-mandibular orthognatic procedures for aesthetic and functional correction were evaluated.

Clinical and surgical reports were collected and patient satisfaction was evaluated with VAS score.

For each patient, maxillofacial CT-scan were collected 1 month preoperatively (T0) and 6 months after the operation(T1). DICOM data were imported and elaborated in the software MatLab which creates 3D soft tissue model of the face. 3DBone changes were assessed importing DICOM data into iPlan (BrainLAB 3.0) software and superimposition process was achieved using

autofusion .Descriptive statistical analysis were obtained for soft tissue and bone changes.

Results:

Considering bone assesement the comparison by superimposition between T0 and T1 showed an increase of the distance between bilateral malar prominence (Pr – Pl) and a slight forward movement (87,65 ±1,55 to 97,60 ± 5,91); p-value 0,007. All of the patients had improvement of α angle, ranging from 36,30 ±1,70 to 38,45 ±0,55, p-value 0,04 (αr) and 36,75 ± 1,58 to 38,45 ± 0,35; p-value 0,04 (αl) . The distance S increased from 78,05 ± 2,48 to 84,2 ± 1,20; p-value 0,04 (Sr) and 78,65 ± 2,16 to 82,60 ± 0,90 (Sl); p-value 0,03. Considering the soft tissue the comparison by superimposition between T0 and T1 showed an antero-lateral movement (p-value 0,008 NVL ; p-value 0,001 NVR) of the the malar bone projection together with an increase in width measurements (p-value 0,05 VL ; p-value 0,01 VR) . Angular measurement confirmed the pattern of the bony changes (p-value 0,034 αL; p-value 0,05 αR).

Conclusion:

The malar valgization osteotomy in conjunction with orthognatic surgery is effective in improving zygomatic projection ~~creating prominent malar regions which~~ contributing to a balanced facial correction in midface hypoplasia.3Dgeometrical based volume and surface analysis demonstrate

an increase in transversal and forward direction. The osteotomy can be safely performed in conjunction with orthognatic procedures.

Keywords: Malar augmentation; zygomatic osteotomy, Orthognatic surgery

INTRODUCTION

Patients with maxillary hypoplasia and excessive relative mandibular growth often present flat cheekbones , which contributes to an unattractive facial feature.

In the western societies, prominent malar regions, the so called “high slavic cheeckbones”, are considered a sign of beauty and youth. (Mommaerts, 2013).

In correction of dentofacial deformities, maxillo-mandibular osteotomies address skeletal malocclusion and improve the aesthetics of the lower third of the face, the lips and the paralateronasal area but a greater fullness of the zygomatic area is sometimes required to reach an harmonious facial balance.

Several techniques have been proposed to increase the volume and definition of the zygomatic area. (Mommaerts, 2013; Raffaini and Pisani, 2014; Brusati et al. 1997; Tessier,1971; Denny and Rosenberg,1993;

Yaremchuk, 2008; Moreira-Gonzalez et al., 2003; Gonçales et al, 2009; Grybauskas et al.,2016; Guevara-Rojas et al., 2014; Egyedi P, 1977; Hernández-Alfaro et al, 2015; Coleman and Grover, 2006; Raffaini and Pisani, 2015;)

Mommaerts described a malar “sandwich” osteotomy (MVO) with rotational augmentation (valgization). (Mommaerts, 2013; Mommaerts et al., 1995)

Aim of this prospective study is to report our experience of malar augmentation using the malar valgization osteotomy in concomitant association with orthognatic surgery . Specific aims of this study were:

1. to objectively evaluate 3d soft tissue and bone changes by means of referential measurements of ct scan images; 2. to assess patient satisfaction.

MATERIALS AND METHODS

The present study followed the declaration of Helsinki protocol and was approved by the local institutional review board. Informed written consent was obtained from all the participants.

From January 2015 to January 2018, 14 consecutive patients underwent single stage bilateral malar valgization osteotomy in conjunction with maxillo-mandibular orthognatic procedures for aesthetic and functional correction were evaluated at Division of Maxillofacial Surgery, San Giovanni Battista Hospital, University of Turin, were considered for this prospective study.

Inclusion criteria were as follows: 1. maxillary hypoplasia with relative excess mandibular growth and negative overjet of at least 4 mm; 2.inadeguate cheekbone projection; 3. completion of growth (age range 18-45); 4. follow up of at least one year; 5.complete clinical and radiological records.

Exclusion criteria were continued growth, history of craniofacial fractures or syndrome and incomplete clinical and radiological records.

The collected data included patient demographics, diagnosis , medical records, operative reports, imaging studies,discharge paperwork, intra and perioperative complications, and follow-up . Data were collected 1 month preoperatively (T0) 6 months after the operation (T1), one year after operation (T2).

Surgical procedures were performed by the same surgeon under general anaesthesia after prophylactic antibiotic subministration. Zygomatic valgisation osteotomy was performed after completion of standard LeFort I osteotomy according the more recent Mommaerts pubblished technique.[21]

1. **BONE ASSESMENT**: For each patient, maxillofacial non-contrast multislice CT scan was taken at T0 and T1.The CT data in Digital Imaging and Communications in Medicine (DICOM) format were imported into iPlan (BrainLAB 3.0) software.

Analysis of the zygomatic complex was based on axial scans oriented parallel to the Frankfort horizontal plane**.** The image slice in which malar prominence(***P***) appeared to be most prominent was selected.(Zou et al, 2015).

This allowed plotting the simmetry axis of facial bones,passing through the midline from the tip of nose(***N***) to the posterior edge of the clivus(***C***),which served as the reference origin. (Lerhe et al.,2016)

Three measurements were plotted in a bilateral manner on the pre-operative and post operative CT-Scan: (*fig*1).

- The distance ***S*** to the malar prominence, corresponding to the maximum of anterior-lateral bone projection, located between the **P** and **C** point.
- The α angle located between ***S*** and the midline(α_r; α_l).
- The distances between bilateral malar prominence (**P_r –P_l**)

Measurements were performed 3 times on the CT scan T0 and CT scan T1 by 2 trained investigators to increase accuracy. (Lerhe et al., 2017)

In accordance to Lerhe published report (Lerhe et al.,2016) one investigator was in charge of repositioning the CT in the orbito-meatal plane, in order to refocus the 3 spatial planes. This allowed the standardized axial cut of interest to be isolated and presented for double reading analysis, performed by himself and by the other observer. ~~The latter~~ Observers placed the references ***N***,***C***,***P*** allowing their respective values to be measured and recorded.The measurement reliability and the results were subsequently analyzed via Wilcoxon test and variance analysis.

The superimposition process was achieved using autofusion among pre-operative and post-operative CT-scan which revealed the different position of malar prominences and the comparison of measurements on T0 and T1.

2. SOFT TISSUE ASSESSMENT

For each patient, DICOM data of maxillofacial non-contrast multislice CT scan at T0 and T1 were imported into the software MatLab and elaborated with an automatic algorithm which creates 3D soft tissue model of the face. This way, depth maps are generated.

Relying on Swennen's definitions , the following soft-tissue landmarks have been manually allocated: Nasion, Exochantion (EX), Tragion (TR), Alare (AL), Chelion (CH), Zygion (ZY) Subaurale (LMA) was identified. (Swennen, 2005) (*fig*.2).

Between these landmarks a theoretical triangle called ZYGO has been created by the intersection of the geodesic distances (namely the shortest distance laying on the facial surface) EX-LMA, TR-AL, EX-CH, in order to better define the zygomatic area. The geodesic distances are calculated based on a methodology relying on Dijkstra's algorithm. (Vezzetti et al., 2014; Vezzetti et al. 2018; Marcolin F. 2017; Dagnes et al., 2019; Olivetti et al. 2019)

Soft tissue measurements

The following features were evaluated at T0 and T1 and represented in tab.1 :

- *ZYGO area:* it is the area of the triangle described by the geodesic distances. The side of each square of the grid X,Y,Z was measured as an Euclidean distance; the total area was calculated adding iteratively the calculated area of each square
- *ZYGO volume*: similarly to the area, the total volume underlying the triangular patch was obtained through the iterative sum of the volume of each underlying squared portion of the patch (*Angle*: the angle describing the openness of the zygoma according to Lehre.(Lehre and Nguyen, 2017). This angle, indicated by α ($α_{DX}$ for the right side and $α_{SX}$ for the left side), is the angle between the symmetry axis of the face, a point P, which was located combining the coordinates of nasion, zygion and tragion, and the zygion
- *ZYGION slice volume:* the volume of a slice defined by the symmetry axis passing for P point, and the squared patch (8x8 sized) defined around the zygion
- *ZYGION Displacement vector: A*lignment of the pre and post operative depth maps is completed with the Iterative Closest Point (ICP)

methodology by adopting the nasion as confidence point.(Zhang and Sui, 1994). The Zygion displacement vector has the origin in the preoperative zygion point and the tip in the Zygion of the postoperative model, thus it effectively describes the displacement of this landmark

- *Zygion Normal Versor*: by definition, the normal vector to a surface is the perpendicular vector to the surface at a defined point, with module equal to 1

Statistical analysis

Descriptive statistics including the mean and SD were calculated for the measurements obtained for bone and soft tissue analysis.

Concerning the features evaluated on the bone and soft tissues, the paired samples Wilcoxon test, also known as Wilcoxon signed-rank test for paired groups (a non parametric alternative to paired t-test), was used to assess differences between T0 and T1. The levels of significance was 0.05. R software has been adopted for this analysis.

3. CLINICAL ASSESSEMENT

Clinical and subjective evaluation was performed by measuring patients satisfaction about malar projection and symmetry at T0, T1 and after one year follow up (T2) by mean a visual analogous scale (VAS) where 0 meant complete dissatisfaction and 10 complete satisfaction.

RESULTS

From January 2015 to July 2018, 10 patients (4 women,6 men) fulfilled inclusion criteria and were included in the study. 4 patients were excluded for incomplete radiological records.

Demographics and orthognatic jaw movements are summarized in table 2.

No intra and perioperative complications were recorded.

Bone assessment : The measurements at T0 and T1 are summarized in table 3 . All of the patients had improvement of **α** angle, ranging from 36,30 ±1,70 to 38,45 ±0,55($\boldsymbol{\alpha}_r$) and 36,75 ± 1,58 to 38,45 ± 0,35 ($\boldsymbol{\alpha}_l$) .

The distance ***S*** increased from 78,05 ± 2,48 to 84,2 ± 1,20 ($\boldsymbol{S}_r$) and 78,65 ± 2,16 to 82,60 ± 0,90 ($\boldsymbol{S}_l$).

The comparison by the superimposition between T0 and T1 showed an increase of the distance between bilateral malar prominence ($\boldsymbol{P}_r – \boldsymbol{P}_l$) from 87,65 ±1,55 to 97,60 ± 5,91.

The p-value of all features are reported in Table 4.

The interobserver difference about the bone assessment for ***S***(p=0,7534), **α** (p=0,8746) and $\boldsymbol{P}_r – \boldsymbol{P}_l$ (p=0,8610) were not statistically significant. These achievements confirm that the method used in this study is reliable and reproducible.

Soft tissues assessment: The soft tissues measurements are reported in table 5**.** The ZYGO triangle area, ZYGO triangle volume and the ZYGION slice volume presented *p*-value greater than 0.05., The p-value was lower than 0.05 for the angle and the normal versor.

The displacement vector has a consistent behavior in all the case studied, attesting an outward and forward movement of the zygion point.

Clinical assessment : all patients had an increase in perceived malar projection and symmetry with an average VAS score from 4.4 (range 2-10) at T0 and 9.6 at T2.

Figure 3 shows the preoperative view and the postoperative clinical outcome at 1-year follow-up of one patient that underwent MVO.

DISCUSSION

The present study reports 3D bone and soft tissue changes following malar valgization osteotomy performed in conjunction with orthognatic surgery.

No similar study could be found in literature providing quantitative preoperative and postoperative measurements of bone and soft tissue changes of the malar area.

Bone assessment showed an antero-lateral movement of the the malar bone projection together with an increase in width measurements. Angular measurement confirmed the pattern of the bony changes.

The ZYGO volume defining the malar eminence increased postoperatively, demonstrating a 3D expansion of soft tissues. Angular soft tissue measurements, the normal versor and analysis of soft tissue landmark vector movement confirmed malar projection variations.

There was a notable increase in malar projection in outward and slightly in anterior direction leading to a more attractive malar fullness and thus contributing to reach an harmonious facial balance.

Hinderer (Hinderer, 1975) reports that prominence of the malar area could be associated with a younger appearance. Skeletal expansion increases support of the soft tissues which will appear more highlighted and defined, thus in perspective reducing the potential soft tissue sagging correlated with facial aging (Rosen, 1990). A well defined malar prominence, with an harmonious cheekbone –nasal base line is considered attractive (Niamtu and cuzalina, 2011; Reyneke, 2003; Terino, 1992) , whereas a flat , hypoplastic malar segment makes the face appear “dull and uninteresting.” (Robiony et al, 1998; Petersen et al.,2018).

Different techniques to increase malar projection have been described in literature. High Le Fort 2 and 3 osteotomies , originally described by Tessier and then modified by Brusati and Denny (Brusati et al, 1997; Tessier, 1971; Denny and Rosenberg,1993), are no longer extensively used in modern orthognatic surgery because of surgical invasiveness and technical difficulties in controlling rotational and 3D movement of the skeletal segments.

Standard shape alloplastic implants of different materials have been widely used to enhance zygomatic projection. (Yaremchuk, 2008; Freihofer and Borstlap, 2011; Zim, 2004; Metzinger et al.,1999; Frodel and Lee, 1998).

Infection, incorrect implant placement and size are correlated of a removal rate about 10-12 % (Zhang and Sui, 1994). Robiony, Peterson (Robiony et al, 1998; Petersen et al., 2018) reported implant placement in conjunction with orthognatic surgery but no quantitative data about soft tissue modifications were provided.

Onlay augmentation and contouring for the craniomaxillofacial skeleton with hydroxyhapatite granules and blocks has been proposed in order to produce better results and reduce the rate of complications. (Moreira-Gonzalez et al.,2003; Gonçales et al.,2009; Byrd et al., 1993; Medelson et al., 2010). Infection rate seems low, D’ Agostino et al. (D’Agostino et al.,2016) in a large series reported as main drawback the long learning curve needed to prepare on site the grafts by hand and in creating an adequate sized and located subperiosteal pocket. There are concerns regarding long term predictability, as Grybauskas (Grybauskas et al.,2016) reports a resorption rate of 18,6 % in volume in 4 months and 21% in one year. It must be remembered that any kind of alloplastic implants require an extracost that it is not negligible, especially if we consider patient specific custom implants that have been recently used (Guevara-Rojas et al.,2014).

Soft tissue augmentation techniques as pedicled buccal fat pad transposition, (Egyedi,1997; Hernandez-Alfaro et al.,2015) lipofilling with microinjections (Coleman and Grover, 2005; Raffaini and Pisani,2014) have been reported. Hernandez Alfaro (Hernandez-Alfaro et al.,2015) reported that the volume increase of malar area was 3,52% at one year follow up with buccal fat pad transposition. When using fat grafts is generally more difficult to achieve stable results in symmetry and projection in severe malar atrophy. (Bucky and Kanchwala, 2007). It is technically difficult to use fat grafts in the same operation with orthognatic osteotomies except for the Bichat transposition. Both soft tissue and skeletal augmentation can contributes to midface augmentation procedures.(Yaremchuck. Yaremchuk, 2008; Yaremchuk and Kahn, 2009).

Skeletal augmentation determinates an increase in projection and contour, which is very appropriate for hypoplastic midface of III class patients, while soft tissue procedures augmenting soft tissue thickness could result in inflation and blunting with less definition effect.

Zygomatic sandwich osteotomy with rotational augmentation was introduced by Mommaerts (Mommaerts, 2013; Mommaerts et al.,1992). In follow up studies, (Mommaerts et al.1995; Mommaerts, 2018; Mommaerts et al. 1999; Bettens et al., 2002) minimal complications and superior patients and clinicians satisfaction are reported. Following the advice of Mommaerts (Mommaerts, 2013) the original technique was modified avoiding the use of any interpositional material in the osteotomy gap in order to reduce costs and infectious risks.

The osteotomy must include a sufficient amount of the malar bone for maximizing the aesthetic results keeping mind that is mandatory to avoid fracturing orbital floor and rim.

Due to the pivoting nature of the movement at the temporalis root, the zygoma moves not only laterally but also in forward direction. Different analysis of midface (Hinderer, 1975; Terino, 1992; Mladick, 1991; Powell et al., 1988; Wilkinson, 1983; Whitaker, 1987) have been proposed for identification of the proper area for malar augmentation with graft and/or implant. ZVO consistently and reliably augments a well defined area, which we defined as ZYGO triangle, which is located in a lateral and superior position corresponding to the Whitaker middle central malar area (Whitaker, 1987). Other studies report soft tissue variation of the midface and cheek area following the LeFort I advancement while our report focus on a more defined region. (Nkenke et al 2003; Nkenke et al. 2008) The ZVO does not address specifically infraorbital area deficit but it could enhance the positive effect of LeFort1 maxillary advancement which decreases the scleral show expecially in patients with long faces. (Posnick and Sami, 2015) Mommaerts reports the use of this osteotomy for the treatment of negative vector orbit (Mommaerts, 2018)

In the present series main indications was patient esthetic complaints for malar deficiency associated with midface hypoplasia. There are no cephalometric or quantitative criteria to decide when there is an indication, but the decision is mainly clinical based on surgeon philosophy to manipulate skeletal volume in order to achieve the goal of a visually well balanced and projected face with soft tissue expansion. (Rosen, 2017) Our threshold for using this procedure is not low and in our opinion it must be reserved in severe malar hypoplasia. Consequently the magnitude of the surgical movement must be consistent, more than 8 mm. Normally in case of mild or moderate malar hypoplasia most patients will achieve a subjective improvement in facial convexity with Le Fort1 advancement alone. (Mommaerts et al.,1995)

Three dimensional soft tissue and bone evaluation protocol used in the study based on Ct scans superimposition of pre and post op datasets is justified considering that computer tomography is the state of the art tool for orthognathic surgery planning.

In particular, the possibility of studying the 3D shape of the facial surface with tailored geometrical features including volumes and angles shows that the third dimension improves the level of monitoring and accurately supervises the changes on the soft tissues.

Limitations of this study includes the small sample of our investigation which hinders the chance of attempting to find ratio between bony movement and soft tissue changes, which will be a valuable aid in selecting indications and planning. Stability and long term soft tissue adaptation could be studied only with longitudinal clinical observation, not being feasible repeating CT exam for economical and radiation exposure reasons.

CONCLUSION

Zygomatic valgization osteotomy in concomitant conjunction with traditional orthognatic osteotomies provides a notable malar augmentation leading to a more attractive lateral midface definition and thus contributing to reach an harmonious facial balance .

The procedure is easily accomplished with the same surgical approach of the Le Fort1 osteotomy with low morbidity, predictable and stable results.

The zygomatic valgisation osteotomy should be considered in the surgeon armamentarium for correction of midface hypoplasia in orthognatic surgery patients, representing a viable alternative for malar augmentation.

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CAPTION TO ILLUSTRATIONS:

Figure.1 Relative measurement at the anterolateral maximal projection of the zygoma: ***P*** malar eminence,***N*** tip of nose, ***C*** posterior edge of clivus. ***Green dot*** simmetry axis of facial bones, ***S(red dot)*** the distance located between the ***P*** and ***C*** point; α the angle located between ***S*** and the midline. The ***Line (Pr-Pl)*** shows the distances between bilateral malar prominence (**P**r **–P**l). The light blue contour represents the superimposition of the postoperative CT scan

Figure 2. A. Left. Soft tissue landmark. LMA: Subaurale point. Centre. ZYGO triangle (yellow) describing the zygomatic area with geodesic distances (red) between landmarks. Right. Geodesic distance (green) passing by the Zygion point. **B.** Zygo triangle is superimposed on the facial depth map.

Figure 3 Preoperative and postoperative view of one patient that underwent malar osteotomy valgization during orthognatic procedure.

Video: summary of surgical technique