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# TAKING ON THE CHIN— THE ART OF GENIOPLASTY

**Kevin L. Rieck, DDS, MD**

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# TAKING ON THE CHIN – THE ART OF GENIOPLASTY

*Kevin L. Rieck, DDS, MD*

## INTRODUCTION

The chin represents one of the most recognizable structures on the human face. Numerous methods to alter the contour and appearance of the chin and lower facial esthetic subunit have been described in the past. Currently osseous surgery of the chin is utilized to provide esthetic enhancement, as an adjunct for facial balance and harmony in orthognathic surgery and as a means to provide airway improvement in patients with severe obstructive sleep apnea.[1-4] This article will describe methods for facial analysis of the chin, review concepts and techniques associated with genioplasty approaches and contrast osteotomies and implants with respect to modification of the chin itself.

### History

As a surgeon I have always felt it important to have some knowledge of the historical aspects associated with procedures we entertain and perform for our patients. Guyuron in his textbook ***Genioplasty*** nicely outlines this topic.[5] Historical descriptions of Egyptian and Greek statues are referenced. The Egyptian statues reflect a round face with prominent eyes, a straight nose, thick lips and a positive appearing chin. Greek statues by contrast reflect an oval face that tapers to the chin and blends proportionately with the lower face.[5] Woolnoth in 1865 published ***The Study of the Human Face*** in which he describes the three facial profiles as straight, convex and concave.[6] He further indicates that the straight face is deemed most attractive, the convex youthful and the concave profile as older appearing.[5,6] We continue to utilize these basic descriptions in contemporary facial analysis.

Chin augmentation historically has utilized a number of materials for enhancement, including various metals and non-metallic implants, such as ivory, all of which have now been discontinued due to complications or poor results.[7] In 1934, Aufricht described the use of nasal cartilage as a means for chin augmentation.[8] In 1942, Hofer had been observing with Drs. Obwegeser and Trauner and subsequently published the first article describing an extraoral approach to sliding osseous genioplasty.[9]

The 1950s saw the introduction of inlay bone grafts, bovine cartilage grafts, dermis grafts and some acrylic implants for genioplasty.[5,10,11] In 1957, Trauner and Obwegeser published the first article on intraoral sliding osseous genioplasty,[12] which continues to be used throughout the world today. Interestingly, Hofer was observing Trauner and Obwegeser as they were exploring some of these early surgical techniques. Dr. Obwegeser was disappointed that Hofer had published the first article regarding genioplasty but comments that the Hofer article describes the technique in a cadaver and not a living patient. He further notes that Hofer did not go on to perform these procedures in living patients.[13]

In the 1960s Converse and Wood-Smith as well as Hinds and Kent described the versatility of the sliding genioplasty.[5,14.15] As expected with a relatively new procedure longer, postoperative follow-up began to show some concerns that surgeons sought to improve. In the 1970s Gonzales-Ulloa, Loeb and Field all described various methods to address "witch's chin" and deep submental folds.[16,17,18] The 1980s heralded the introduction of hydroxyapatite for use as an inlay or onlay graft or to augment the lower facial height of the osteotomized chin.[19,20] In the late 1990s through 2007, Zide and his colleagues wrote a series of articles addressing numerous contemporary aspects of genioplasty evaluation, approaches, complications and refinements that serve as an excellent foundation for surgeons undertaking this procedure.[21-27] Genioplasty today is used to address a variety of facial concerns from a balancing procedure in conjunction with orthognathic surgery to assisting with soft tissue contours and chin-neck enhancement for patients undergoing elective facial surgery.

**Anatomy**

In addition to the historical aspects associated with procedures, I feel surgeons must have a sound knowledge of the relevant anatomy as well. Although, this article will not review the detail to which most should be familiar, it will discuss basic salient and pertinent aspects associated with genioplasty procedures.

The primary sensory innervation to the chin area is from the paired mental nerves that exit the body of the mandible near the apices of the premolar teeth. These nerves are the terminal extension of the inferior alveolar nerve from the third division of the trigeminal nerve. The position of the mental nerves in reference to the mental foramen and planned osteotomies is well described by Hwang et al.[28] The authors looked at 30 fresh cadaveric mandibles and 50 dry specimens documenting the position of the mental nerve relative to the mental foramen and other aspects of the mandible by dissection.

Information regarding the anatomic position of the mental nerve is seen in Figure 1. The authors point out that, based on their study, a planned osteotomy of the chin must stay a minimum distance of 4.5mm below the mental foramen to avoid nerve injury and advised a plain preoperative radiograph to document nerve position.[28] Incidence of injury and paresthesia of the mental nerves after sliding genioplasty has been reported to be as high as 12%.[29,30]

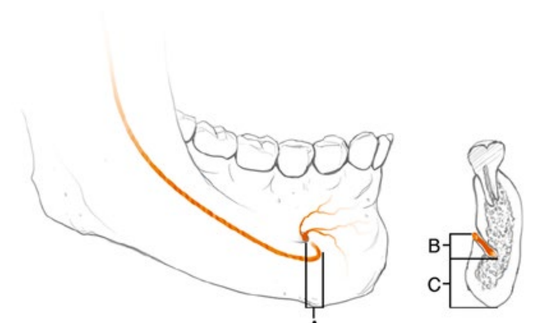



Figure 1: Salient nerve anatomy as described by Hwang et al. depicting the position of the mental nerve in relation to the mental foramen and inferior border of the mandible. A: 5 ±1.8 mm, B: 4.5 ± 1.9 mm, C: 9.2 ± 2.7 mm.[28]

The primary motor component to the muscles associated with the anterior aspect of the chin are from the buccal and marginal mandibular branches of the facial nerve. These muscles include the depressor labii inferioris, depressor anguli oris, mentalis and orbicularis oris muscles.[31] The lingual muscle pedicle of the genioplasty will include the geniohyoid, mylohyoid and anterior digastric muscles, which obtain their innervation from the hypoglossal nerve (geniohyoid) and inferior alveolar nerves (mylohyoid and anterior digastric), respectively.[31]

The primary muscle involved with the genioplasty procedure itself is the mentalis muscle, which provides the primary vertical support to the lower lip.[5,31] Aspects associated with this muscle will be detailed later in the article. The other muscles associated with the chin are usually not stripped completely nor disrupted to the same degree as the mentalis muscle.

Maintaining a broad pedicle to the chin is paramount to the blood supply of this osteotomized segment.[32] Improper repositioning of the mentalis muscle can result in unsightly disfigurement of the chin known as a "witch's chin" deformity.[17,33] The arterial supply to the muscles of the chin area is from the inferior labial arteries, which are terminal extensions from the facial arteries.[31] The bony chin is supplied from the inferior alveolar artery. Venous drainage is via the inferior labial, facial, maxillary and submental veins, ultimately connecting with the facial or anterior jugular veins.[5]

The osseous dimensions of the chin are greatest at the midline, varying between 9 mm and 15 mm in thickness. Soft tissue thickness varies between 8 mm and 11 mm and does not change appreciably after about eight years of age.[5]

**ANALYSIS OF THE CHIN**

Analysis of the chin will ultimately vary from surgeon to surgeon and be a function of their training and experience. However, there are basic components that should be present in all evaluations. These include photographic, radiographic, imaging analysis and Zide's Quick Analysis of the Chin (QUAC).[21] Photographic documentation of the preoperative state is an absolute medico-legal necessity in contemporary surgical practice. (See also *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 20, #3) Documenting the patient's appearance is needed to assist with the surgical plan, to critically evaluate postoperative results, and to act as a reference of patient's pre-existing features should that become necessary. A standard set of photographs with a uniform background, set distance to object, and set magnification, including different views at repose and smiling is ideal (Fig. 2, on p. 5) A short video of the patient in repose and with facial animation can also be considered.

Radiographic analysis can include a number of possibilities. Plain films, such as panoramic and lateral cephalometric images, are extremely helpful as screening tools to rule out any type of osseous pathology and provide a foundation for predicting anticipated osseous and soft tissue changes in the sagittal plane. CT or cone-beam CT (CBCT) images are also helpful in this regard if available, and the DICOM data sets can often be


Figure 2: 18-year-old female seeking chin augmentation. Photos illustrate importance of different pre-surgical views. **A**: repose, **B**: smiling, **C**: patient's "normal" posture with mentalis strain. Evaluation of all three views is important in making appropriate decisions regarding modification of the chin.

incorporated into some type of imaging software for study and prediction analysis.(See also *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 20, #1; Vol. 20, #6, Vol. 19, #5; Vol. 17, #6) These data sets can be utilized to generate panoramic or cephalometric images as desired or necessary for each patient. Additionally, assessment of mental nerve anatomy can be determined readily. Obtaining a CT or CBCT data set is not necessary for routine isolated genioplasty procedures regardless of how it will be performed.

Analysis of the chin can also be assisted with the use of various computer software based imaging programs. Dolphin Imaging®, Quick-Ceph® and Simplant OMS® are but a few examples of such sophisticated software. These can allow incorporation of patient photographs in addition to radiographic images to give some sense of anticipated change from the planned procedure. Creating a virtual osteotomy and repositioning the segment in the software will create some change in the associated soft tissue overlay. These programs can be used for patient demonstration purposes as well, although one must caution the patient that the predictions may not reflect actual outcomes. Morphing of the soft tissue contours can also be performed to assist with predictions of implant-based genioplasties.

Finally, the QUAC or "Quick Analysis of the Chin" as described by Zide, et al. is a useful and important aspect in assessing the chin in general and as a means of evaluation prior to considering surgical procedures.[21] Zide, et al. indicates this simply involves the surgeon's judgement and the patient's smile. The information obtained with the QUAC relates to the degree of lip eversion, the position of the anterior teeth, the chin pad thickness, the labiomental fold dimensions and dynamic chin pad motion.[21] Clearly this type of assessment is based upon years of experience and is predicated on the inherent knowledge of how these factors relate to the anticipated outcome.

The concept of the QUAC is profound because many surgeons practicing the specialties that encompass facial surgery make "snap" judgements regarding facial analyses when they meet people or examine them for procedures. A few examples show that this is born out frequently in the body of professional literature.

Robinson wrote that "the chin is essential to the beauty of human countenance…in the selection of one's mate, those deficient in this direction would be losers in life's race!".[34] Gonzaelz-Ulloa states that "for beauty, good facial architecture is necessary, whether in a man or woman, the position of the chin is fundamental".[35] Gui, et al. indicate "a person with a small or retruded chin seems weak, inactive and irresolute".[36] Hoenig writes, "the chin being one of the most obvious facial structures is the "basis" for judging human character".[3]

Interestingly, this can be found in lay press as well. A nice example is from *Time* magazine's 2010 Person of the Year article on Mark Zuckerberg, CEO of FaceBook. The article describes his life and character but at one point discusses physical features. Time indicates Mr. Zuckerberg's "most noticeable feature is his chin, which he holds at a slightly elevated angle".[37] Profile views of Mr Zuckerberg reveal a convex facial appearance with features such as a prominent dorsal nasal hump, obtuse nasolabial angle and a chin, which in this author's opinion, is not prominent by typical norms.

## FACIAL ANALYSIS

Clearly evaluation of the chin can and should involve all of the methods discussed above. We must keep in mind however that the chin is but one portion of the face (Fig. 3 on P. 7). Alterations to the chin, regardless of the means, must be congruent with overall appearance and contribute to facial harmony. In order to accomplish this surgically an understanding of facial analysis is paramount.

Several neoclassical canons for facial analysis exist but descriptions of each are beyond the scope or intent of this article. Differences, of course, exist between different ethnic and racial groups as well as between the sexes and these should be taken into account when planning surgical procedures.[38] This article will assume the reader has a baseline knowledge of facial topographical landmarks and both soft tissue and bony cephalometric landmarks.

The face is first evaluated from the frontal standpoint. Our faces are not completely symmetric and gross asymmetries should be noted. The face can be divided down the midline and the facial landmarks trichion, glabella, subnasale and menton should all coincide vertically. The face is subdivided into facial thirds from trichion to glabella as the

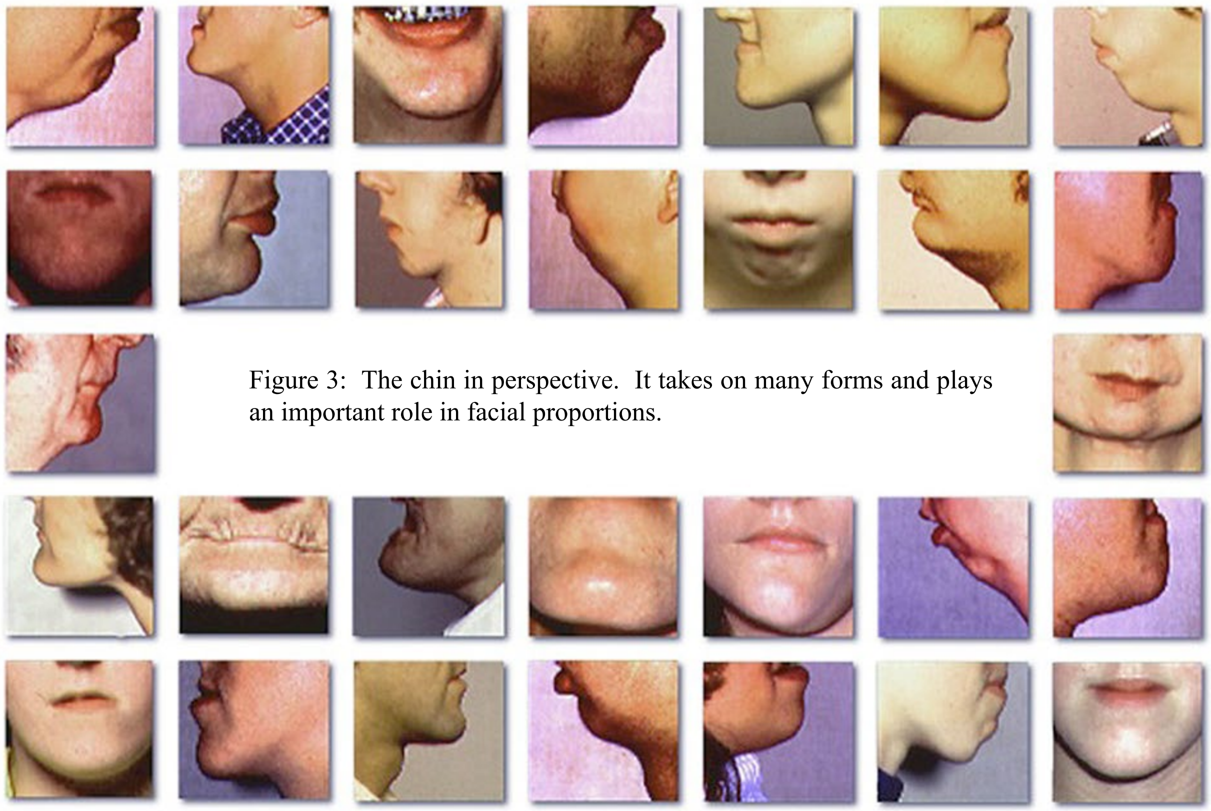


Figure 3: The chin in perspective. It takes on many forms and plays an important role in facial proportions.


Figure 4: Subdivisions of the face. **A.** Vertical facial fifths and horizontal facial thirds; **B.** Intercanthal distance averages approximately 35 mm. Interpupillary distance averages 65 mm.

superior third, glabella to subnasale as the middle third and subnasale to menton as the lower third. (Fig. 4A, on p. 7) This lower third is further subdivided into thirds as well. Subnasale to stomion represents the upper third and stomion to menton represents the lower two-thirds. In addition to these horizontal divisions, the face is often divided into vertical fifths as well. (Fig. 4B) The intracanthal width of one eye is typically thought to represent one fifth of the face vertically. The intercanthal width of the eyes also represents this same dimension ideally. This same distance projected laterally from the lateral canthus accounts for the final two-fifths dimensions vertically. The alar base is also often thought to have the same width as the intercanthal distance.

These same vertical midline landmarks are used to assess the face in the profile view, dividing the face into upper, middle and lower facial thirds with the additional subdivision of the lower third, as previously described. In addition to the gross division by thirds, numerical values of 22 mm for the upper third and 44 mm for the lower two thirds are often utilized. (Fig. 5) These measurements are generally taken with the head in natural or neutral position or referenced to Frankfurt horizontal (a horizontal line extending from the superior aspect of porion to the inferior aspect of the orbital rims as noted on a lateral cephalogram). This line generally parallels the horizon. There are also a number of soft tissue reference lines described in the profile view.

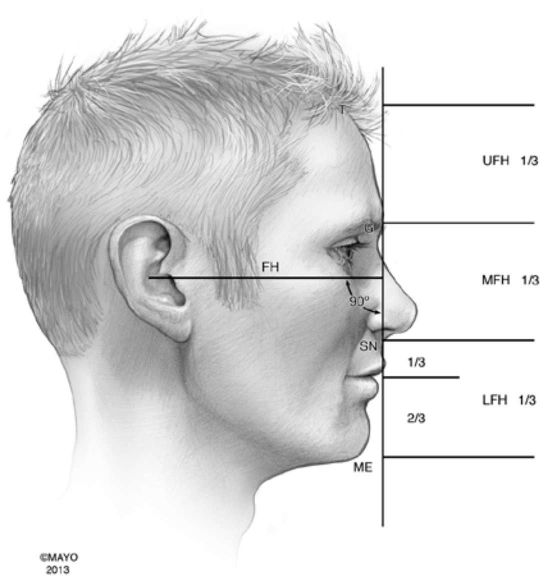



Figure 5: Profile view referencing Frankfurt horizontal and the facial thirds divisions.

These two-dimensional analyses have been the foundation of facial evaluation for a number of years. However, with the advent of contemporary three-dimensional surgical planning, a whole new set of angles and values can be added to describe similar historical analyses. These are still being investigated and are not presently utilized by most surgeons.

The Zero Meridian or Gonzalez-Ulloa line is a vertical line from nasion perpendicular to Frankfort horizontal. (Fig. 6A, on P. 9) A line drawn at 10° to zero meridian should intersect pogonion in males or be slightly anterior to it in females.[4]

Rickett's E–line is drawn from pronasale to pogonion. (Fig. 6B, on p. 9) The upper and lower lips should fall posterior to the line by 4 mm and 2 mm, respectively.

Byrd describes the Nose-Lip-Chin-Plane (NLCP) as a vertical line that intersects the midpoint of the nasal dorsum between the radix and tip (RT).[39] The nose and chin

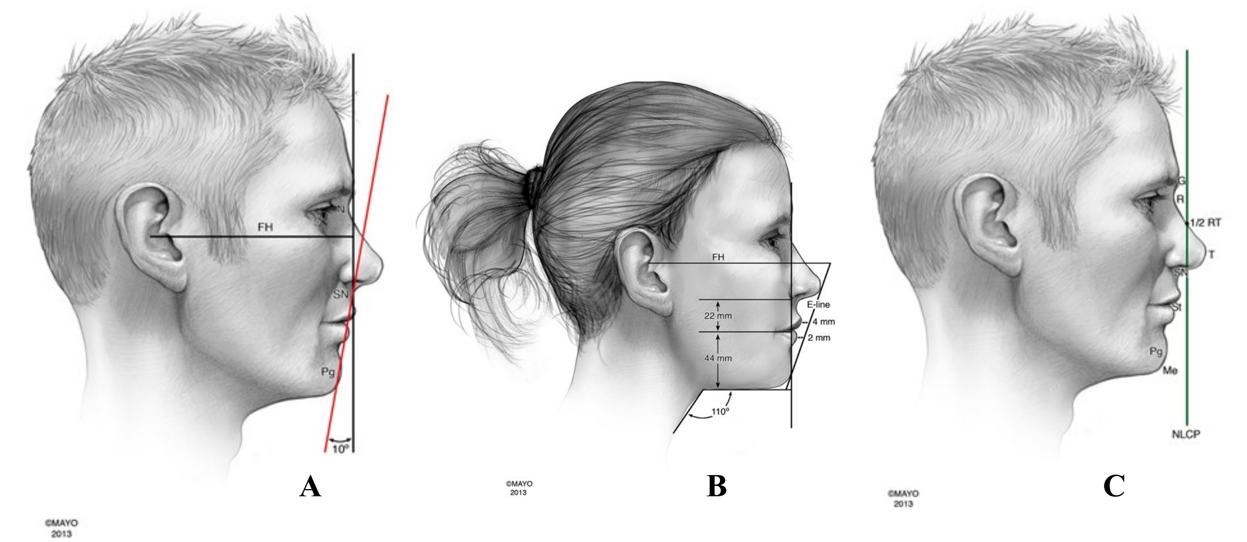



Figure 6: **A.** Gonzallez-Ulloa line depicting a vertical from Nasion with reference to Frankfort horizontal. A line drawn at 10° should intersect Pogonion in females or be slightly anterior to it in females; **B.** Rickett's E-line from Pronasale to Pogonion. The upper and lower lips should fall 4mm and 2mm posterior to the line respectively. Division of the lower facial third into thirds is also noted. The upper third generally corresponds to 22mm and the lower 2/3rds to 44mm; **C.** The Nose-Lip-Chin-Plane (NLCP). The ideal nasal length from the Radix to the Tip (RT) equals 67% of the Mid Facial Height from Glabella to Subnasale and also is equal to the Stomion to Menton distance.

are known to compliment one another esthetically. Chin enhancement in patients with nasal prominence often gives the illusion of a smaller appearing nose. The ideal nasal length RTi is equal to 67% of the middle facial height (MFH) or glabella to subnasale and equal to the chin measurement from stomion to menton (StMe).[4,39] Clearly, knowledge of these values assists the surgeon in planning for either rhinoplasty or genioplasty (Fig. 6C)

Goode has described a method of chin position analysis in which a line is drawn perpendicular to Frankfort horizontal and connects with the lateral aspect of the nasal ala. The chin prominence at pogonion should fall on this line or slightly anterior to it.[40] (Fig. 7A, on p. 10) Legan's angle of facial convexity is a measure of the angle between the lines from glabella through subnasale and subnasale to pogonion. This angle should measure 12°.[40] Merrifield's Z angle is measured between Frankfort horizontal and a line tangent to pogonion and the more procumbent lip. It's normative value is 80°+/- 5°.[40]

Gibson and Calhoun compared these analyses in a series of thirty-five female profile photographs in an effort to compare the inherent value of each analysis and to a new analysis they proposed.[40] They described the lower facial triangle as being based on three points. These include the tragion (T), subnasale (S) and the chin-defining point (C). The latter point occurs at the intersection of an arc tangent to the chin with the center at T.[40] (Fig. 7B, on p. 10) The location of point C is then a function of pogonion and menton and includes information about both the anterior

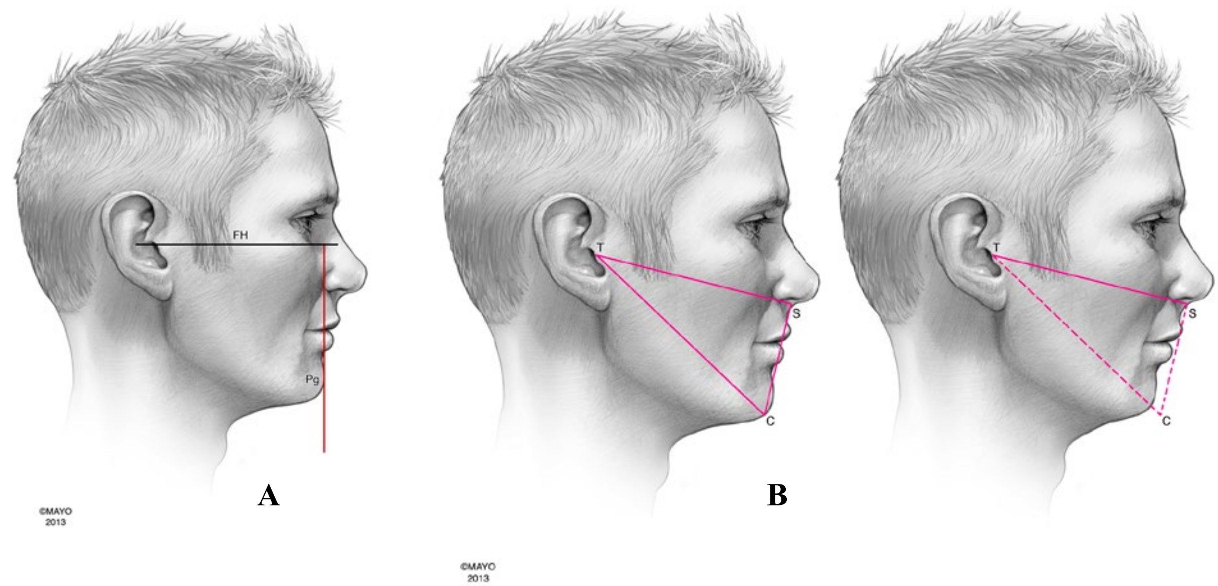



Figure 7: **A**. Goode's method for chin position. The chin should fall on a line drawn perpendicular to Frankfort horizontal and passing through the lateral ala of the nose; **B.** Gibson and Calhoun's lower facial triangle with key points being tragion (T), subnasale (S) and the chin-defining point (C). The TC/TS ratio and S angle can be determined. These values range from 1.15-1.19 and 88°-93°. Variations in these values helps to determine the correction needed. See text for details.[40]

projection of the chin and the inferior border of the mandible. The points generate a triangle whose internal angles as well as line segments can be measured. Line SC and angle T reflect lower facial height. TS or TC compared to SC provides an indication of total facial mass or the AP size of the face in profile view as well as the vertical height of the lower facial third. The T/C ratio and angles S and C reflect the chin position with respect to subnasale.[40] Figure 7B reflects these relationships and depicts a normal appearance on the left image and deficient image on the right side.

The objective statistical analysis undertaken in Gibson and Calhoun's paper revealed little value in the measurements obtained from Legan's angle, Merrifield's Z angle and the Gonzalez-Ulloa line interpretations when these measurements were made on subjectively perceived attractive and balanced facial profiles. Goode's analysis was the most accurate at predicting an esthetic profile. Gibson and Calhoun point out, however, that the aforementioned analyses have many inherent flaws. These include idealizing a bony landmark and projecting it onto the soft tissue as well as estimating the location of Frankfort horizontal topographically.[40]They describe an algorithm that can be utilized to determine whether alteration of the chin point need occur or what other possible anatomical areas might need to be addressed as well or in lieu of the chin. Based on their work and the development of the lower facial triangle, the TC/TS ratio and S angle can be determined. These values range from 1.15-1.19 and 88°-93°, respectively.[40] Utilizing their method and algorithm, easily defined surface landmarks can be referenced quickly to determine what, if any, modification to the chin need take place.

The Gonzalez-Ulloa zero meridian line describes three degrees of retraction or distance posterior to the vertical reference line. Ideally pogonion should fall on or just posterior to the line (Fig. 6A on p. 9). A first-degree retraction is when the chin falls less than 10 mm from the line, a second degree retraction positions the chin 10 mm to 20 mm from the line and a third degree retraction is greater than 20 mm from the line.[35]

Modification of the chin will vary according to the degree of retraction. Injectables or smaller implants can often correct first degree retraction, larger implants or osteotomies can address the second degree issues and a combination of procedures involving the TMJ or orthognathic surgery may be needed to address third degree deficiencies (See Figs. 44-46on pp. 42-44). While often cited, additional problems with Gonzalez-Ulloa analysis exist in that it does not take into account differences between the sexes, is based on individuals perceived to be beautiful throughout history and does not correlate well to cephalometric analysis.[41,42]

## CEPHALOMETRIC ANALYSIS

Cephalometric data points use various bony and soft tissue landmarks in order to construct linear and angular measurements for the purpose of evaluation, planning, prediction and or growth analysis and outcome comparisons in orthodontics and maxillofacial surgery.[43] A number of these analyses can be useful in assessing the chin. The use and interpretation of these cephalometric analyses generally comes quite easily for most maxillofacial surgeons; however, other facial surgical specialists may not have the background nor desire to utilize them for analysis of the chin.

The advent and expansion of virtual surgical planning and three-dimensional analysis brings with it the development of a whole new set of analyses for evaluation and planning of these surgical cases.[33] While details and comprehension of new three- dimensional analyses are being developed the contem-

| TABLE 1: SELECTED CEPHALOMETRIC ANALYSES |
|---|
| Facial Axis: Represents the intersection of a line from Nasion to Basion and PT point to Gnathion (Fig. 8A) and has a normative value of 90°. |
| Facial Angle: Represents the internal angle from Sella-Nasion an Nasion-Pogonion (Fig. 8B) and has a normative value of 88° to 92°. |
| Y-axis: Represents the intersection of Frankfort Horizontal (P-O) with a line from Sella-Gnathion (Fig. 8C) and has a normative value of 59°. |
| Holdaway Ratio: Represents the intersection of lines from the lone axis of the mandibular incisor teeth and a true vertical line through point B. It has a normative value of 4 mm or 25°. Pogonion should lie 4 mm anterior to the vertical line and the lower incisor tip 4 mm posterior to the line (Fig. 9). |

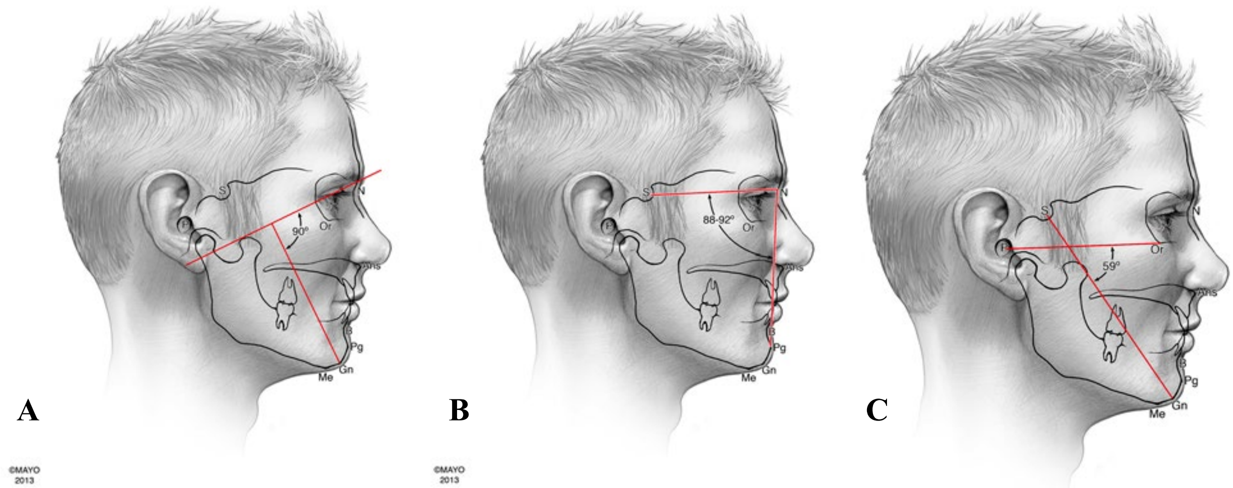



Figure 8. **A.** Facial Axis: This has a normative value of 90° and represents the intersection of a line from Nasion to Basion and PT point to Gnathion; **B**. Facial Angle: This has a normative value of 88-92° and represents the internal angle from Sella-Nasion and Nasion-Pogonion; **C.** Y Axis: This has a normative value of 59° and represents the intersection of Frankfort Horizontal (P-O) with a line from Sella-Gnathion.

porary surgeon must rely on the existing two-dimensional analyses used today. Examples of these selected analyses that are useful in assessing the chin are described in Table 1 (on p. 11) and in the associated figures.

These cephalometric measurements assist the surgeon in determining the relative position of the chin as compared to the cranial base, maxilla and mandible. Combined with the aforementioned analyses the surgeon is able to make an accurate assessment of the position of the chin and determine the most appropriate method for surgical correction. No single evaluation method can or should be utilized alone because it may not represent the entire clinical picture. Therefore, surgeon experience plays a key role in ultimately determining what procedure may be best for a given situation.

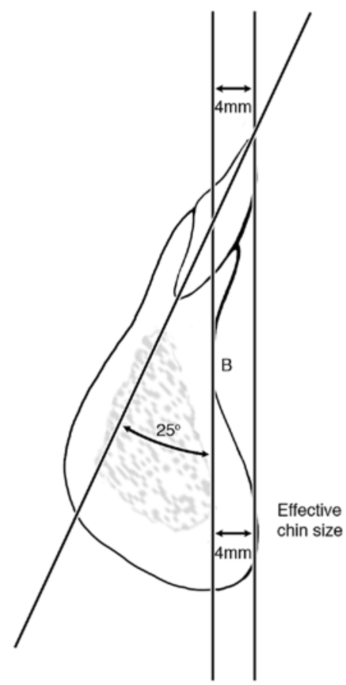



Figure 9: Holdaway Ratio: This has a normative value of 4 mm or 25° and represents the intersection of lines from the long axis of the mandibular incisor teeth and a true vertical line through B point. Pogonion should lie 4 mm anterior to the vertical line and the lower incisor tip 4 mm posterior to the line.

**ANTHROPOMETRIC STUDIES**

Contemporary facial analysis must include reference to Leslie Farkas, MD, the pioneer of craniofacial anthropometry. Dr. Farkas spent most of his academic life, from the late 1960s to late 1980s, evaluating facial form among a number of ethnic groups. He developed various facial anatomic data points that often coincide with known cephalometric points but include numerous other points as well. Using these data points he developed normative data that surgeons and others could refer to when assessing patients and contemplating surgery. His Caucasian series is amongst the largest, with approximately 2500 individuals.[44,45] Multiple analyses were constructed to assess facial features and provide comparisons between the sexes and various ethnic groups.

These studies revealed that average anatomic distances in males were always greater than in females. The bi-gonial distance showed the greatest discrepancy between the sexes. Finally, in regard to the chin itself, men's chins projected more than women's and the overall projection on average was generally less than what we would consider "normal" by subjective data such as the QUAC.[42]

**CHIN CLASSIFICATION**

Medical and scientific fields are replete with various classification systems utilized to ease documentation and communication amongst peers and colleagues. Guyuron, et al. have put forth a system to convey abnormalities with the chin. While this represents a thorough classification system it is not readily adopted in the literature nor in discussions with colleagues, but it can serve as a useful means of documentation. The system is outlined in Table 2.[46]

**SURGICAL TECHNIQUE FOR OSSEOUS GENIOPLASTY**

In my experience and opinion the osseous genioplasty is a procedure most often done in conjunction with orthognathic surgery. It tends to be a balancing procedure to improve overall facial harmony as well as bony and associated soft tissue relation-

**TABLE 2: CHIN CLASSIFICATION[46]**

| CLASS | |
|---|---|
| I | Macrogenia: horizontal, vertical, combined |
| II | Microgenia: horizontal, vertical, combined |
| III | Combined: horizontal macro/ vertical microgenia, horizontal microgenia/vertical macrogenia |
| IV | Asymmetric: a) short, b) normal, c) long anterior facial height |
| V | Witch's Chin: soft tissue ptosis |
| VI | Pseudomacrogenia: normal bony volume with excess soft tissue volume |
| VII | Pseudomicrogenia: normal bone volume with retrogenia secondary to excessive maxillary growth and clockwise rotation of mandible |
| VIII | Iatrogenic malposition |

ships. It is also utilized as an adjunct for patients with severe obstructive sleep apnea to advance the attached genial tubercles and associated musculature to assist with airway enlargement. Advancement procedures are performed most often, but vertical reduction or augmentation as well as horizontal reduction is also possible.

The surgery is best performed in the operating room under general anesthesia. Local anesthesia is utilized to assist with hemostasis, but the injected volume should be kept to a minimum so as not to distort the soft tissues. The osseous genioplasty is approached via an intraoral incision made in a number of ways, including scalpel, electrocautery, radiowaves or laser. The incision should be kept more toward the labial surface instead of at the vestibular depth or toward the dentition. Care is needed initially with the lateral aspects of the incision so that the terminal branches of the mental nerves are not transected. Frequently, retraction of the mucosa can allow the nerves to be visualized just deep to the surface, aiding in their avoidance. The mentalis muscles are then transected and a full thickness subperiosteal flap is elevated to completely expose the anterior mandible. The mental nerves and foramina are identified and exposed bilaterally.

Once appropriate exposure has been made, the midline and para-midline areas are marked. I frequently do this initially with a pencil then go over the lines with the Piezosurgical saw, sagittal saw or other marking device to leave a lasting reference for the procedure. Careful measurements are made to mark out the desired location for the osteotomy. Marking this line, in a fashion similar to that above, aids in the actual procedure. Importantly, the osteotomy must stay a minimum of 4.5 mm below the mental foramen and ideally should be closer to 6 mm below so as to not injure the mental nerves.[28] Figures 10 and 11 (on page 15) highlight these surgical aspects of exposure, marking, nerve identification and fixation.

The actual osteotomy is completed with oscillating, reciprocating, sagittal or Piezosurgical devices. Variations in the angulation of the osteotomy are possible and are adjusted based on the desired result of the procedure. A steep oblique osteotomy should generally be avoided because it contributes to fairly significant notching and palpable defects at the inferior border of the mandible following healing (Fig. 12 on page 16). Vertical reduction can be accomplished by removing a wedge of bone correlating to the change desired. Vertical enhancement is done by augmenting the chin with some type of interpositional graft material using a variety of common grafting techniques. I prefer the use of interpositional coralline hydroxyapatite blocks as shown in the case series in figures 13-16.

Utilize copious amounts of irrigation to cool the bone and assist with visualization during the osteotomy procedure. Strive to keep the saw in a single plane to assist with symmetry and enable a uniform platform for repositioning. Once the osteotomized segment is downfractured carefully inspect the lingual pedicle and floor of mouth soft tissues. Any bleeding must be controlled before progressing.

Then position the inferior border segment to the desired location and secure it in place. In most cases, appropriate symmetry

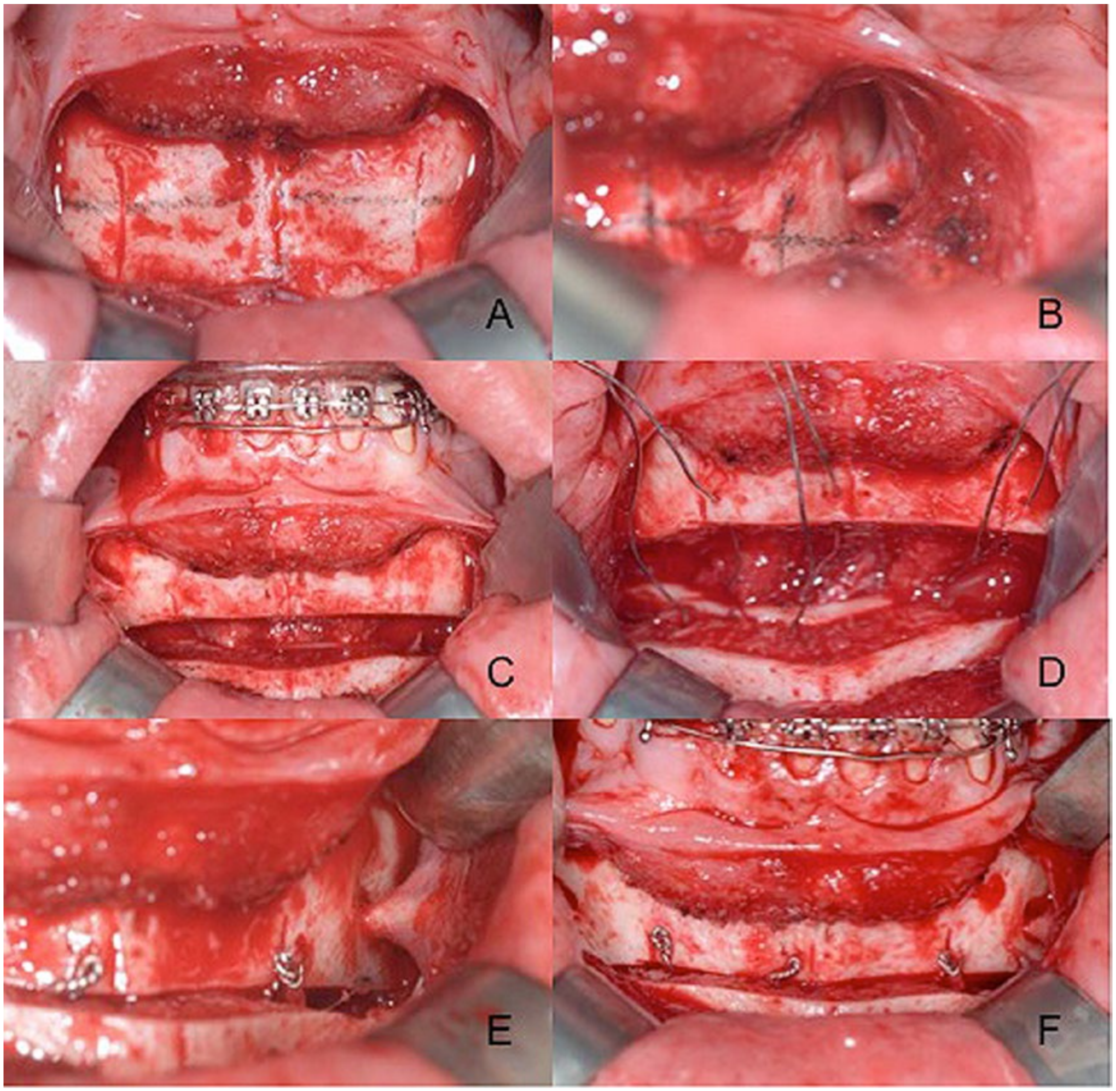



Figure 10: **A.,B.** Surgical exposure of the chin showing vertical reference lines and position of mental nerve; **C.,D.** Osteotomy is completed and secured with wire fixation; **E.,F.** Completed osteotomy and fixation.

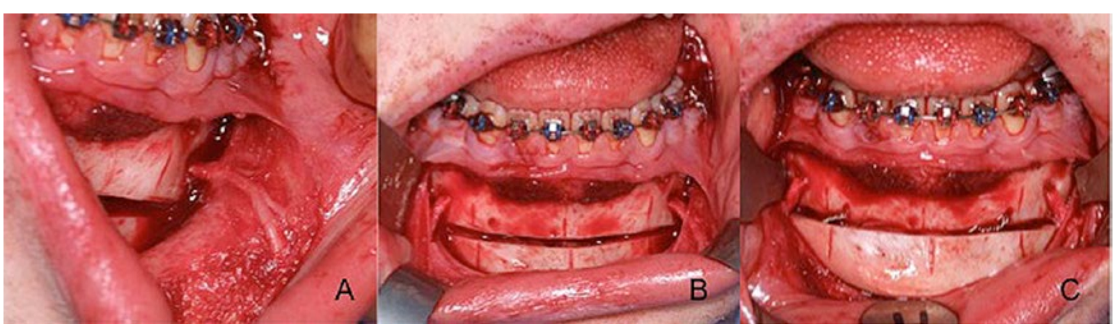



Figure 11: **A.** Osteotomy of the chin depicting terminal extension of mental nerve and it's superficial position submucosally; B., C. Completed osteotomy and fixation with mild asymmetry correction.

can be maintained by utilizing the reference lines placed at the time of the surgery, but cases of pre-existing asymmetry or cases combined with other procedures can be more difficult. The advent of virtual surgical planning has greatly enhanced management of such cases. Procurement of a CBCT or medical grade CT scan with the addition of associated patient fiducial markers for orientation purposes allows comprehensive evaluation and planning in patients undergoing orthognathic surgery and associated genioplasty.[47-49]

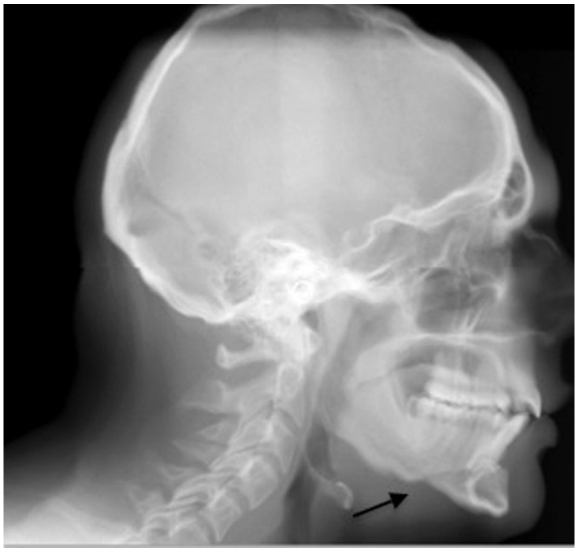


Figure 12: A steep oblique osteotomy should generally be avoided as it contributes to fairly significant notching and palpable defects at the inferior border of the mandible following healing (arrow).

Virtual surgical planning can also be utilized to generate patient specific custom positioning devices to assist with the osteotomy and subsequent repositioning of the inferior border segment to the planned location. (See also *Selected Readings in Oral and Maxillofacial Surgery* Vol. 17, #6; Vol. 19, #5; Vol. 20, #2) The devices are referenced


Figure 13: **A.** Preoperative lateral view of patient with class II malocclusion and vertical chin deficiency; **B.** Postoperative lateral and **C.** frontal views following BSSO advancement of mandible and advancement plus vertical lengthening of chin with placement of inter-positional coralline hydroxyapatite . Note significant improvement in chin projection and volume as well as improved cervicomental angle and softened labiomental sulcus.

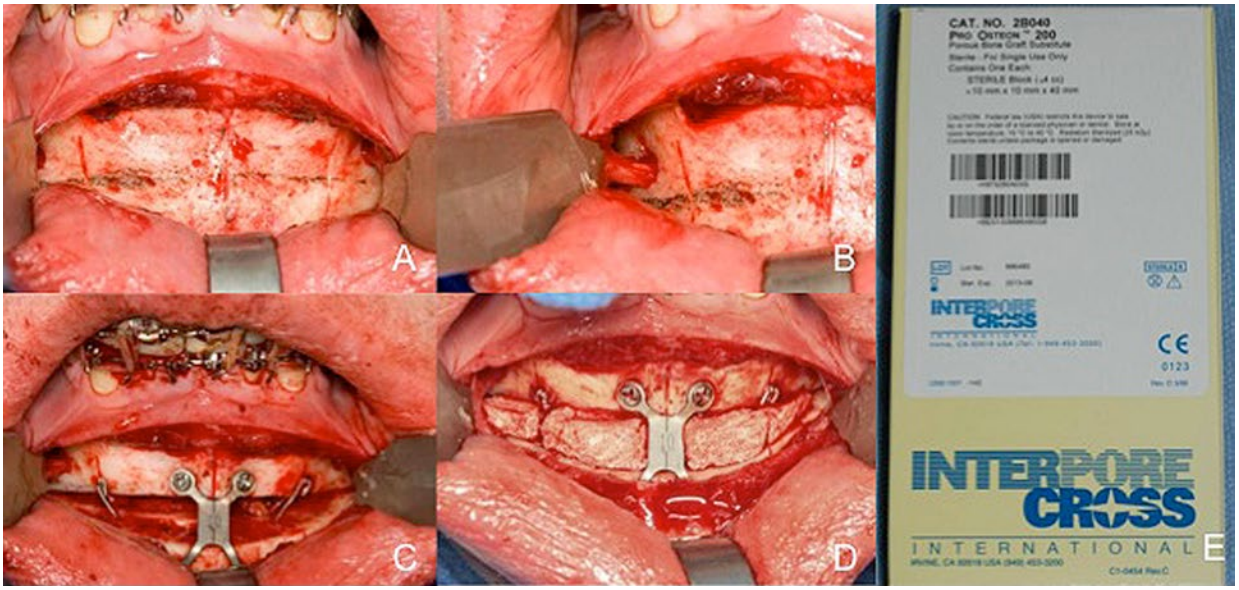



Figure 14: **A., B.** Intraoperative view of patient in Fig. 13 depicting access and nerve position; **C., D.** Completed osteotomy with advancement, downgraft and fixation as well as placement of the hydroxyapatite material; This material handles well but is brittle so careful manipulation is paramount. Wedging the material into position works well. An example of this type of material is depicted in image **E**.

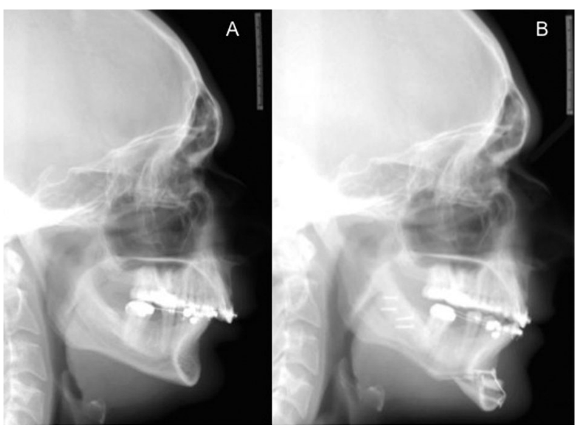



Figure 15: **A.** Pre- and **B.** postoperative lateral cephalometric views depicting the change in mandibular and chin position. Note the significant improvement in vertical enhancement of the chin and the presence of the interpositional graft

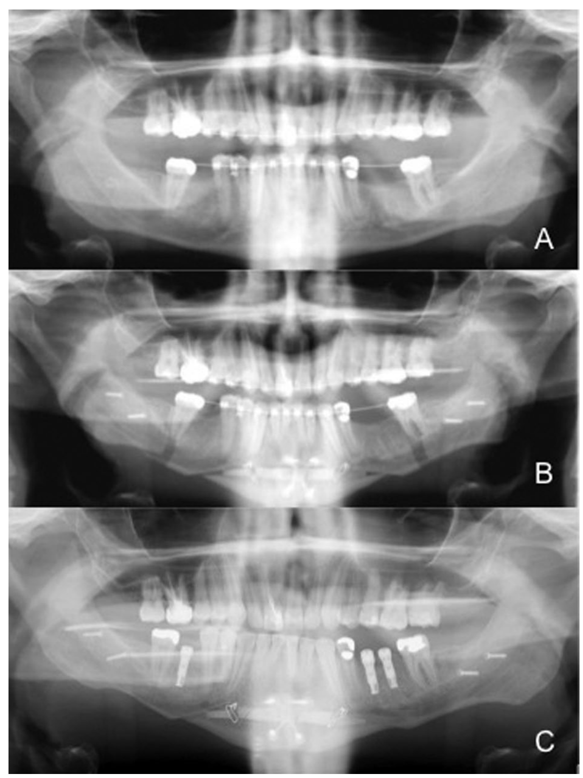



Figure 16: **A.** Pre-operative, **B.** Immediate postoperative and **C.** one-year postoperative panoramic radiographs depicting mandibular and chin advancement and augmentation. Note osseous healing of chin and associated graft.

off the patient's dentition or final occlusion. Positioning screw holes are marked with the initial device and then used later with the repositioning component, allowing exact repositioning in three dimensions based on the pre-surgical planning. An example of this technique is shown in Figures 17-20 (on pp. 18-20). This method has been shown in a multicenter study to be more accurate than "free-handing" the position of the inferior chin segment.[50]

Choice of fixation is surgeon dependent and can include wires, lag screws or bone plates and screws. Personally, even though it is an older method, I prefer to use wire osteosynthesis for routine cases, using a central and two paramedian wires. This affords much better fixation of the "wings" of the inferior segment and avoids palpable hardware in the midline following osseous remodeling (Fig.10). Additionally, expense is minimal in contrast to standard titanium hardware. The mentalis muscle is then repaired primarily

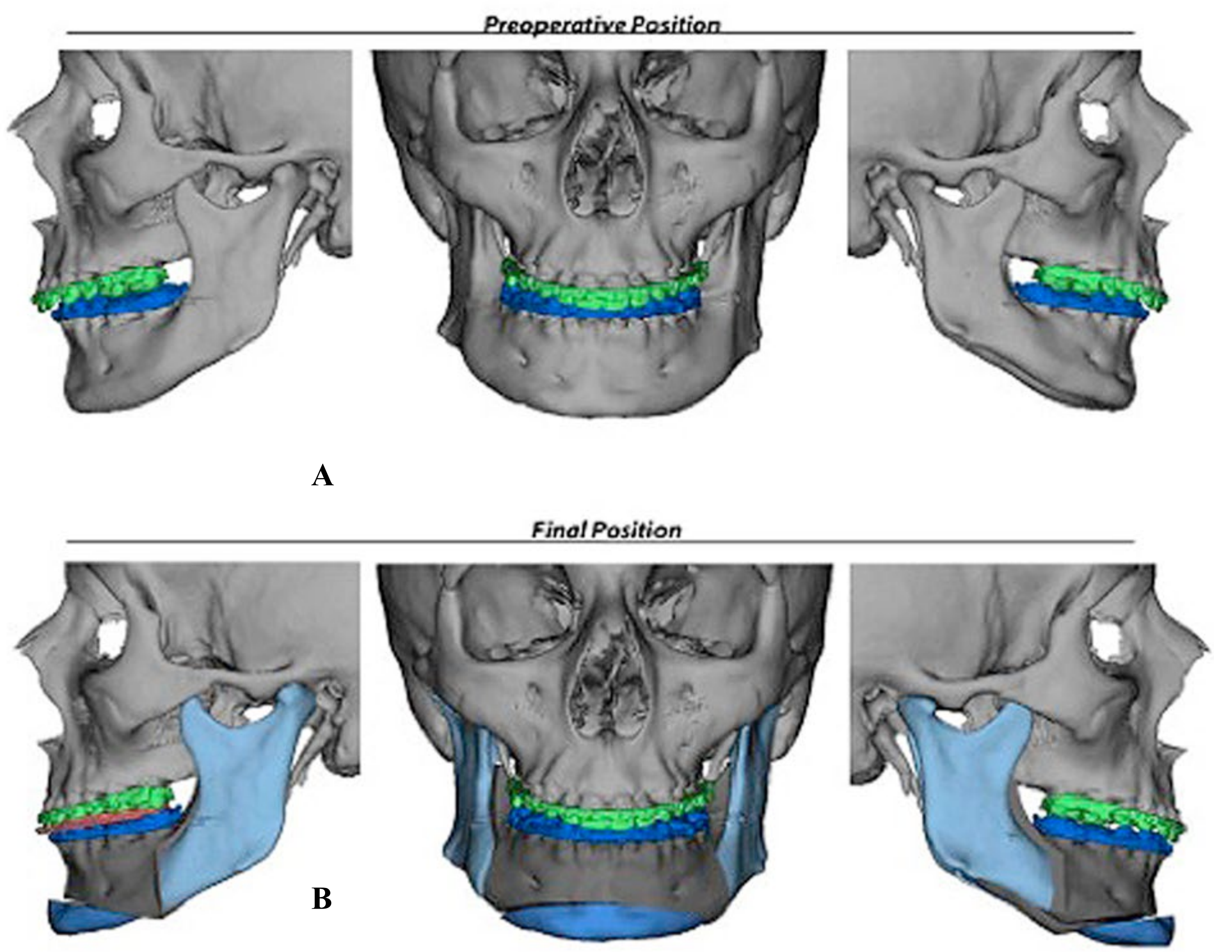



Figure 17: **A.** Preoperative position and **B.** postoperative projection using virtual surgical planning techniques

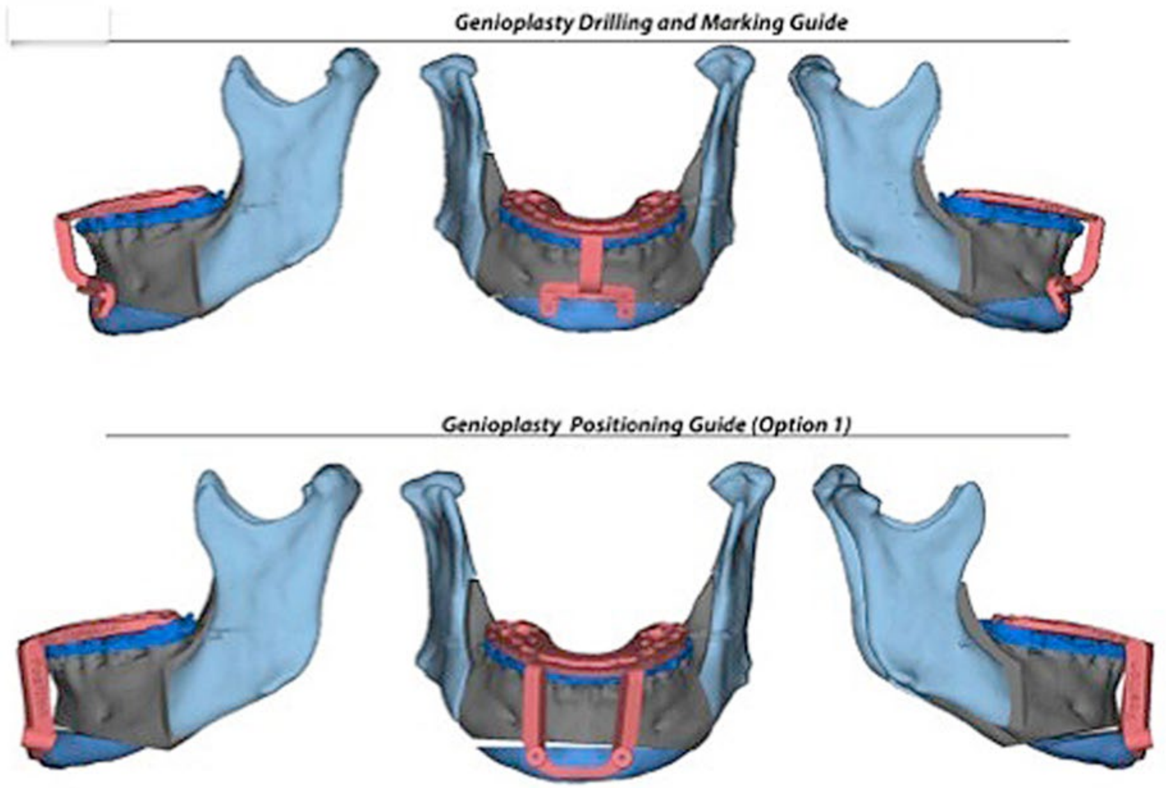



Figure 18: Virtually generated drilling, marking and positioning guides. The guides are referenced off of the final occlusal splint in this case. The marking guide (superior image) allows for duplication of the virtually planned osteotomy. Protection of the nerve is preplanned into the guide as the nerve position can easily be determined from the DICOM images. The positioning guide (inferior image) then positions the inferior segment in place three dimensionally based on desired outcomes.

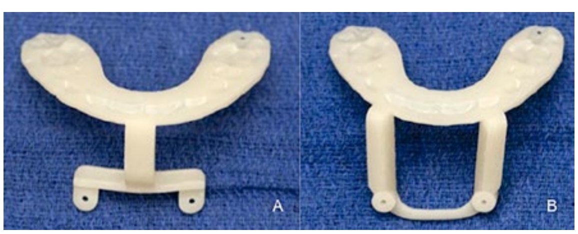



Figure 19: Virtually planned and printed three dimensional chin marking (A) and positioning guides (B).

and the mucosa closed in a watertight fashion. Supportive tape and or dressings are employed as desired. The important advantages and disadvantages of osseous genioplasty as well as a summary of the surgical technique can be found in Tables 3 (on p. 20) and Table 4 (on p. 21).

## CHIN IMPLANTS FOR AUGMENTATION GENIOPLASTY

In addition to osseous genioplasty a number of options are available to utilize

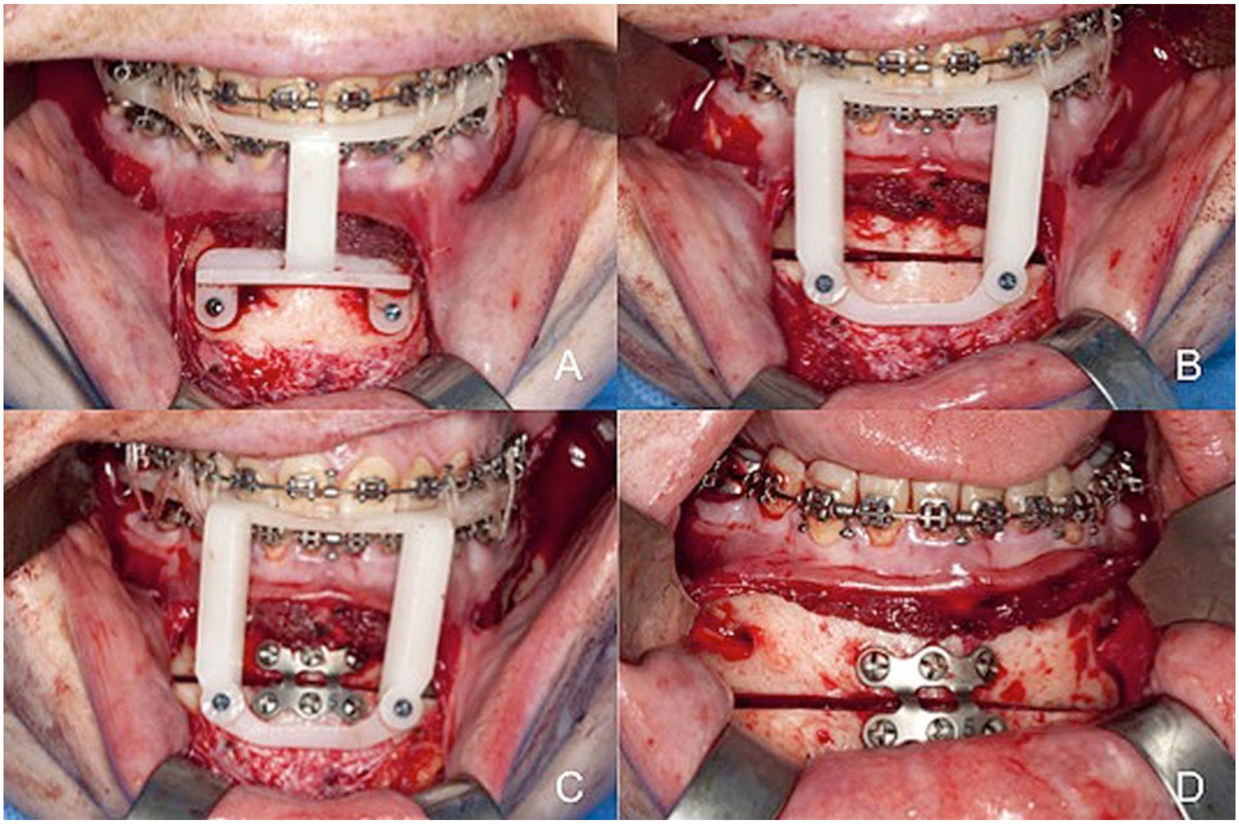



Figure 20: Intraoperative views depicting use of the **A.** virtually planned chin marking and **B.** positioning guides as well as **C., D.** fixation of the inferior chin segment.

| TABLE 3: ADVANTAGES & DISADVANTAGES OF CHIN OSTEOTOMY | |
|---|---|
| ADVANTAGES | DISADVANTAGES |
| Very versatile procedure | Requires osteotomy, adding risk from surgery and anesthesia |
| Corrects vertical problems | Significant surgical armamentarium |
| Corrects AP excess and asymmetry | Significant microdroplet blood aerosol |
| Stable over time | Vascular injury risk |
| Increases submental length and cervicomental angle | Airway emarrassment risk |
| Advances genial-tongue-hyoid position, of benefit in sleep apnea | Not easily reversible |
| | Increased expense for anesthesia, OR time and fixation materials when compared to implants. |

| TABLE 4: SURGICAL TECHNIQUE FOR SLIDING OSSEOUS GENIOPLASTY |
|---|
| General anesthesia |
| Intra-oral incision positioned more toward the lip than the alveolus or vestibule |
| Indentification of mental nerves |
| Mark midline and para-midline areas |
| Utilize sagittal or reciprocating saw for osteotomy, maintaining a single plane |
| Verify hemostasis at lingual aspect |
| Reposition inferior segment to desired location and align reference lines |
| Secure fixation with wires, screws or plates |
| Repair mentalis muscle primarily |
| Mucosal closure |

alloplastic implants in order to achieve specific patient and surgeon demands. Several characteristics of ideal alloplastic implants should be considered when selecting one for facial augmentation of the chin or other areas of the face. (Table 5).

The most common materials in use today for facial augmentation are solid silicone, porous polyethylene and PTFE (polytetrafluoroethylene). Once again, each of these materials has unique characteristics that may merit its use for certain applications. Surgeons frequently favor one material over another due to personal preference, handling characteristics, ease of use, ease of removal if necessary, and cost among other variables. There are a number of styles and choices available when selecting various implants for chin augmentation. This offers a great deal of flexibility in assisting patients with their specific clinical concerns. Surgeons should be well versed in these options in order to help patients make informed decisions.

| TABLE 5: CHARACTERISTICS OF IDEAL ALLOPLASTIC IMPLANTS |
|---|
| Anatomical configuration that conforms well to bony contours |
| Shape that imitates desired outcome |
| Easily implantable and non-palpable |
| Margins blend to bony surfaces |
| Easily removed |
| Malleable, confortable and inert |
| Easily modifiable by surgeon |

There are a number of advantages to using an implant over the traditional osseous genioplasty. (Table 6 on p. 22) Certainly from a surgeon's perspective implant placement is an easier procedure than osseous genioplasty. As noted, placement can be performed in a venue other than the operating room. In the setting of cost conscious consumers and surgeons this offers a significant benefit amongst the other inherent benefits with this technique (Fig. 21 on p. 22).

Facial implants and chin implants in particular are commonly used for augmentation procedures.[36,51] While these offer numerous advantages and have a high overall suc-

| TABLE 6: ADVANTAGES AND DISADVANTAGES OF CHIN IMPLANTS | |
|---|---|
| ADVANTAGES | DISADVANTAGES |
| Quick procedure | Capsular contracture |
| Requires minimal instrumentation | Infection |
| Less dissection than osteotomy | Bone resorption |
| No risk to floor of mouth vasculature | Dislodgement/malposition |
| "Easily" reversible procedure | Explantation/soft tissue chin pad issues |
| Wide selection of implant options | Vertical changes are difficult |
| Customizable | Lower lip retraction |
| Can be done under local anesthesia, sedation or general anesthesia in office setting or in the OR | Inventory expenses/storage |
| Easily added to compliment other procedures such as facelift or neck-lift | |

Figure 21: **A., B.** Preoperative and **B., D.** postoperative views following mandibular advancement (BSSO) and genioplasty using virtual chin marking and positioning guides.

cess rate surgeons must also be cognizant of inherent disadvantages with the use of such implants. These are summarized in Table 6.

One certainly expects there to be osseous remodeling with traditional bony genioplasty. It comes as no surprise then that some bony resorption should be anticipated with placement of chin implants. This is discussed further in the section on complications. Resorption tends to be minimal in general. Proper implant selection, placement and fixation all act to minimize this issue. Malpositioned implants are more of a concern clinically and have inherent esthetic compromises as well. (Figures 22-24 on pp. 23, 24).

The surgical placement of chin implants differs from osseous genioplasty in several ways. The surgeon must, of course, be as familiar with the local anatomy, as one would be when performing an osseous genioplasty. Additionally, one should know the characteristics of the implant to be implanted so


Figure 22: **A., B.** Preoperative and **C., D.** six-month postoperative views of a 20-year-old male who underwent placement of a solid silicone chin implant under IV sedation and local anesthesia in the office setting. Note improved esthetic appearance of the chin and lower facial third plus competence of the lips.

that proper insertion can be achieved. Surgical access can be from either an intraoral or extraoral approach. The method chosen frequently is a function of surgeon experience, training, comfort level, patient desire and or history of prior local surgery as well as consideration of any other surgical procedures taking place simultaneously. If a patient were to be undergoing removal of impacted wisdom teeth concurrently with chin implant placement then likely an intraoral placement route would be employed. A patient undergoing face and neck lift would already have exposure of the submental area and thus the extraoral approach would be advised for chin implant placement. The steps involved in placement of a chin implant are outlined in Table 7 on P. 24.


Figure 23: **A., B.** Preoperative and **C., D.** six-month postoperative views of a 19-year-old female who desired improvement to her chin projection. She underwent removal of impacted third molars and placement of a medium solid silicone extended anatomical chin implant via an intraoral approach under IV and local anesthesia in the office setting. Note improvement in cervicomental angle, chin projection and decreased lower lip pout or eversion.

Once basic access has been obtained the surgeon needs to be cognizant of the "pocket" that is developed. Solid silicone and PTFE implants are much more flexible than porous polyethylene implants. A smaller pocket size is advisable with the former two implants whereas with the less flexible implants wider exposure is necessary. The porous polyethylene implants are often (continued on p. 25)

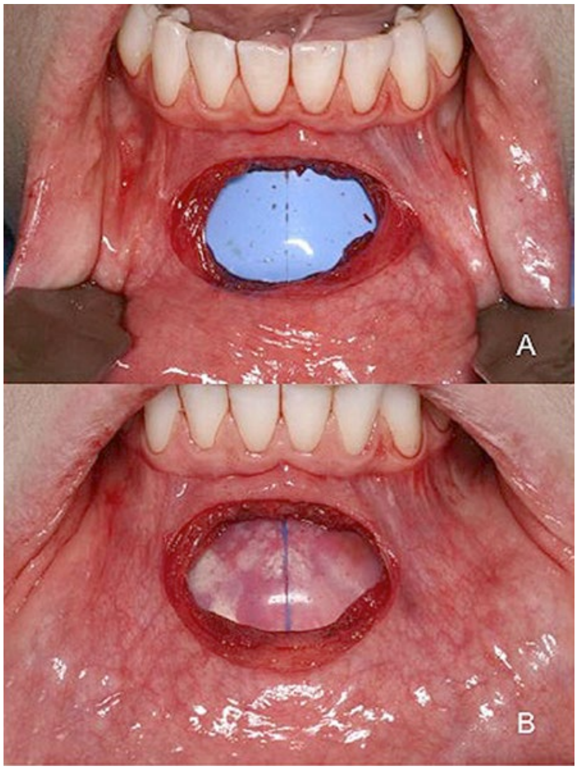
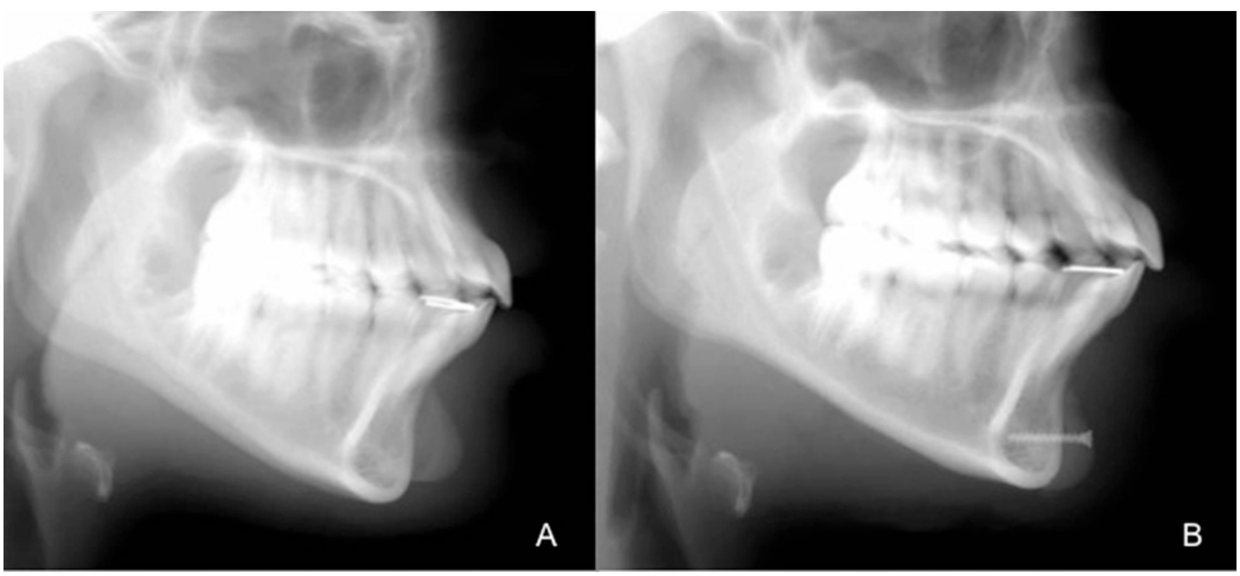



Figure 24: (Above) **A.** Access and intraoral placement of solid silicone chin implant sizer and **B.** actual implant. Note the embedded midline reference line within the implant for accurate positioning.

| TABLE 7: SURGICAL TECHNIQUE FOR IMPLANT PLACEMENT |
|---|
| Local, sedation or general anesthesia |
| Intraoral vs. extraoral access |
| Identify mental nerves |
| Symmetric positioning of implant |
| Fixation of implant |
| Repair of mentalis muscle |
| Support dressing |

Figure 25: (Below) Lateral cephalometric images depicting a malpositioned chin implant that was initially secured with suture fixation to the periostium. **A.** The patient presented two weeks postoperatively complaining the chin appearance had changed. She had no other symptoms. It turns out that she slept mostly on her front side with the face down. **B.** She underwent a brief IV anesthetic for implant repositioning and screw fixation. No additional problems were encountered. Image **B** shows excellent position of the implant with the screw fixation.



sectioned to allow insertion of the segments more easily and then reconnected *in situ*.

Most contemporary style implants are more anatomical in design than their original counterparts. The "tails" of chin implants generally extend posteriorly to the first molar area and feather out in size from anterior to posterior. This design assists with making the implants less perceptible and also avoids the look of a "stuck-on" or button style implant at the chin prominence.

Care should be taken once again to ensure the mental nerves are not impinged upon with placement of chin implants. To ensure the implant remains in the desired position fixation of some sort is advised. Screw fixation affords the best insurance against migration. This coupled with an appropriate pocket size should result in the desired outcome (Fig. 25 on p. 24).

One should have a good idea preoperatively of the size of the implant to be placed. Reusable sizers are available for most implant styles, and as one performs these procedures more frequently experience and insight are gained that is beneficial in determining the appropriate size implant to utilize (Fig. 26).

The complication rate is generally low for these implants. This includes the risk for infection as well, regardless of the route of insertion. The benefit of local antibiotic irrigation or impregnation of the implant with antibiotic solution under vacuum pressure is controversial. Yaremchuk discusses this in his ***Atlas of Facial Implants*** and notes no difference in outcomes when antibiotics are utilized versus when they are not utilized.[42]

Once the implant is securely positioned the re-approximation of the mentalis muscles, soft tissue closure and support tape or dressing is completed in a fashion similar to that of a traditional genioplasty.

**Custom Chin Implant Fabrication**

One of the unique aspects about alloplastic implants is their handling characteristics. This coupled with modern technology

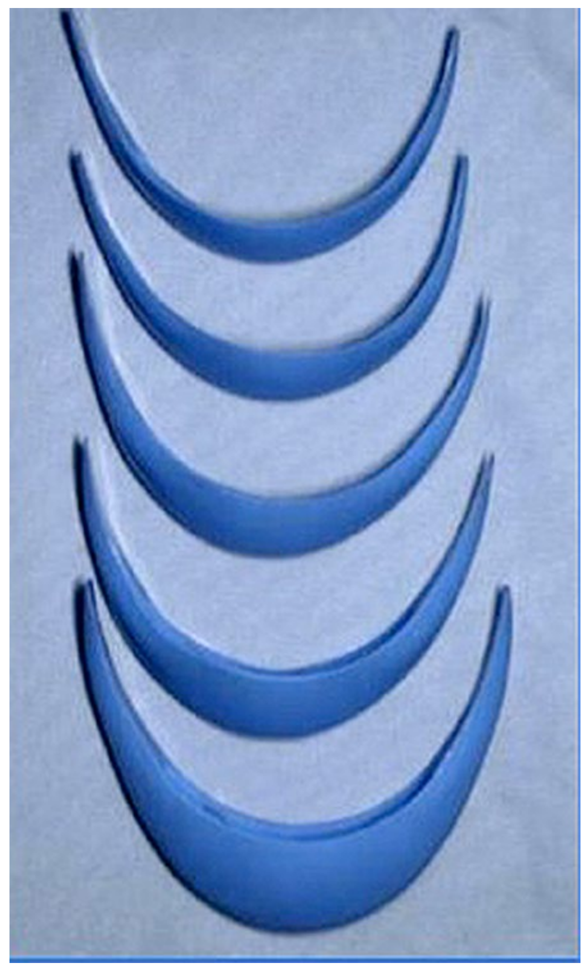


Figure 26: Example of solid silicone chin implant sizers ranging from extra small to extra large. The implants at the extreme ends of the spectrum are rarely used.

allows the surgeon to offer patients customized implants. Clearly this is not something that would be utilized for most routine cases but becomes extremely valuable as an option when patients present with marked asymmetries, multiple prior failed procedures or other unusual scenarios where either traditional genioplasty or use of a "stock" implant would not correct the problem.

Once it has been determined that a patient-specific implant will be utilized then the patient undergoes a manufacturer's recommended CT or CBCT scanning protocol to fabricate the patient-specific implant. These are fairly routine now in contemporary practice and most in-office CBCT scanners can accommodate these protocols. It can be tremendously beneficial to the patient and surgeon alike to involve the patient in the actual design process. This is paramount in revision esthetic cases where the patient is dissatisfied with prior results.

The CT/CBCT DICOM data can be used to either "print" a stereolithographic model for implant fabrication or alternatively this can be done digitally (Fig. 27).(See also *Selected Readings in Oral and Maxillofacial Surgery*, Vol. 13, #1) One advantage of the model is that it allows a "hands on" approach that can be important to the patient so they can realize the exact way the implant will benefit their unique circumstance. I always have the patient review the model or final digital plan and have them "sign off" on the design before committing the plan to the manufacturer for fabrication. Both solid silicone and porous polyethylene implants can be fabricated using this process. Once the implant is fabricated then placement proceeds in the fashion previously described.

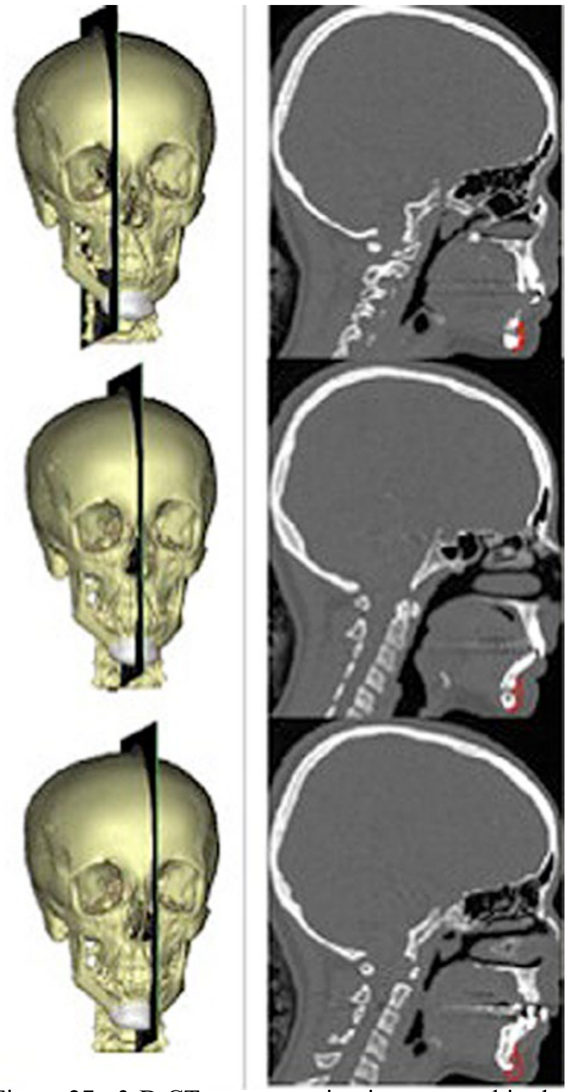


Figure 27: 3-D CT reconstruction images used in the digital design and fabrication of a custom chin implant (red outline).

An example of the merits of this technique is highlighted in Figures 28-33 (on pp. 27-31). This patient presented for evaluation and management of his chin with the primary complaint that he was dissatisfied with it's appearance after having undergone two prior osseous genioplasty procedures. There was obvious asymmetry on examination and certainly a revision genioplasty (continued on p.


Figure 28: Pre-operative **A.** frontal and **B.** lateral views of a patient status post two prior genioplasty procedures elsewhere presenting for consultation and management of his chin deformity. Note asymmetry of the inferior border on frontal view. Custom chin implant fabrication was the treatment of choice for correction of this problem.

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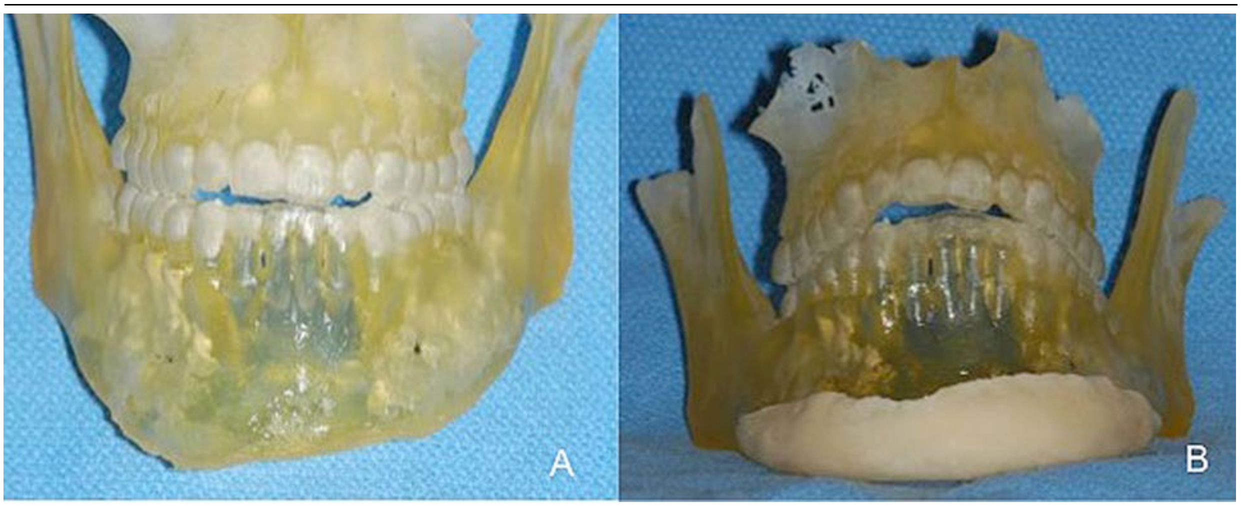


Figure 29: Stereolithographic model of patient in Fig. 28. Chin deformity and deficiency is obvious. **A.** These models are very helpful in illustrating the defects to patients and assisting with plans for correction . **B.** Initial fabrication of chin implant using sculpting clay on the model. The patient can “sign off” on the design and thus play a key role in treatment.


Figure 30: Multiple views depicting custom chin implant fabricated from porous polyethylene. The modeling clay version **A.** is then converted to the final version for eventual implantation **B., C., D**. The material is fairly rigid and thus sectioning of the implant is beneficial for insertion.

28) could have been entertained and was offered as a possible treatment option. Clearly interpositional bone grafting would have been necessary.

A discussion was also undertaken highlighting the merits of a custom implant in his situation. The primary advantage included his ability to see the implant pre-operatively and understand how this would address his esthetic concerns. Additional grafting procedures would not be required, minimizing morbidity to the patient. Predictable results could also be anticipated instead of free-handing the placement of the inferior border segment subsequent to a repeat osteotomy.

This particular implant was fabricated out of porous polyethylene. Due to it's size it was sectioned in half by the manufacturer for ease of insertion at the time of the procedure. Placement was via an intraoral access, and the implant was secured with two fixation screws in each half once final positioning had been obtained (Fig. 32 on P. 30). He also underwent simultaneous submental liposuction. Results of the surgery are shown in Fig. 33 (on p. 31). This technique offers another option for the surgeon and patient alike in managing difficult chin augmentation or asymmetry cases.

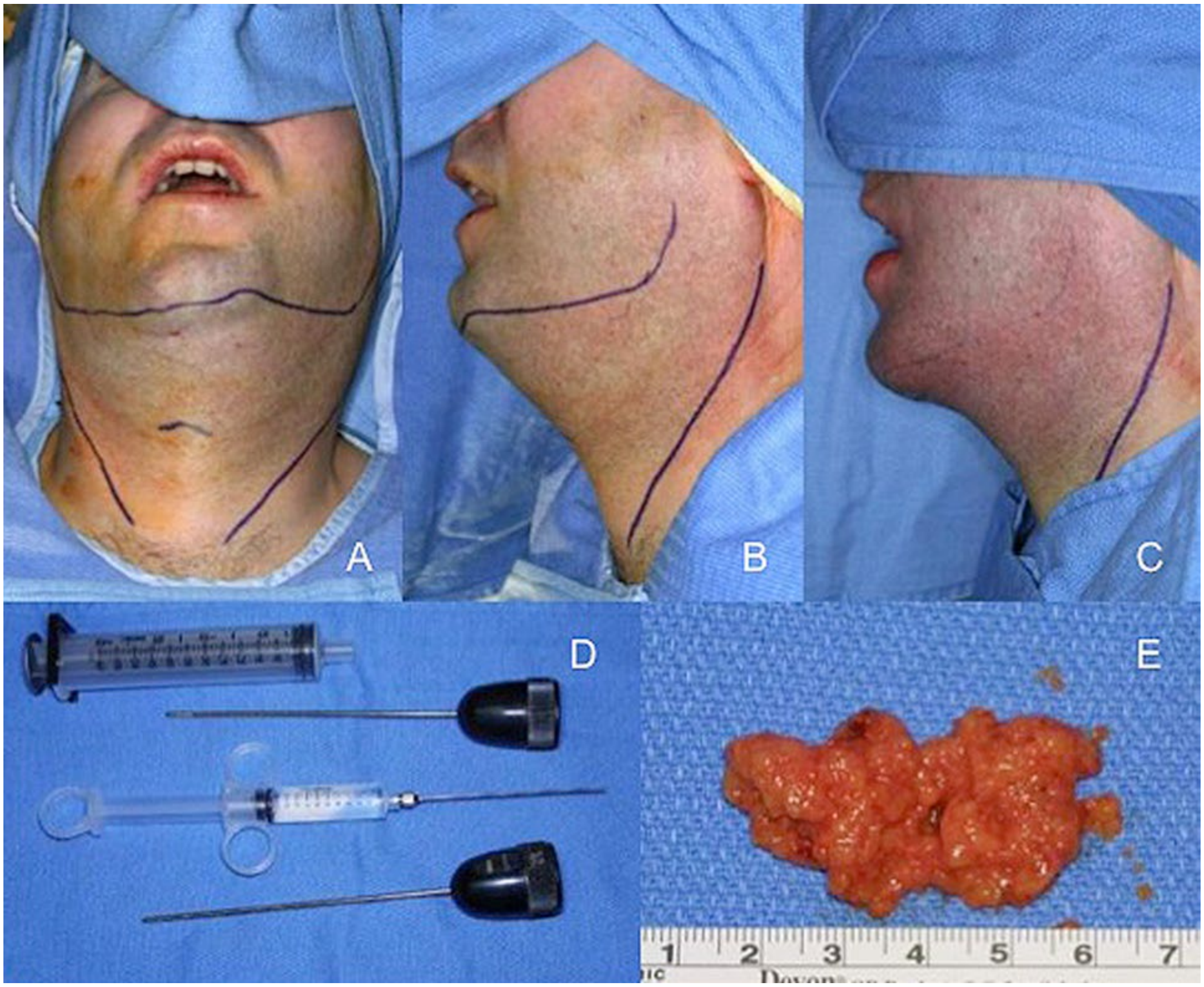

Figure 31: Intraoperative views of patient in Fig. 28 depicting **A.** pre-operative frontal, **B.** immediate post-operative chin implant insertion lateral and **C.** immediate post-operative lateral view subsequent to submental liposuction. **D., E.** Liposuction cannulas and fat removed.

## Genioplasty in Conjunction with Orthognathic Surgery or Sleep Apnea

Most osseous genioplasty procedures performed by oral and maxillofacial surgeons are done in conjunction with orthognathic surgery. This includes either isolated maxillary or mandibular procedures plus the chin surgery or concurrent double jaw surgery and the chin.

Evaluation and completion of the genioplasty in this setting proceeds as previously described but is done subsequent to the other jaw surgery. The genioplasty is often done as a balancing procedure to assist with facial harmony. Details of the other orthognathic procedures are beyond the scope of this chapter.

Overall patient satisfaction with these combined procedures is high, as described by

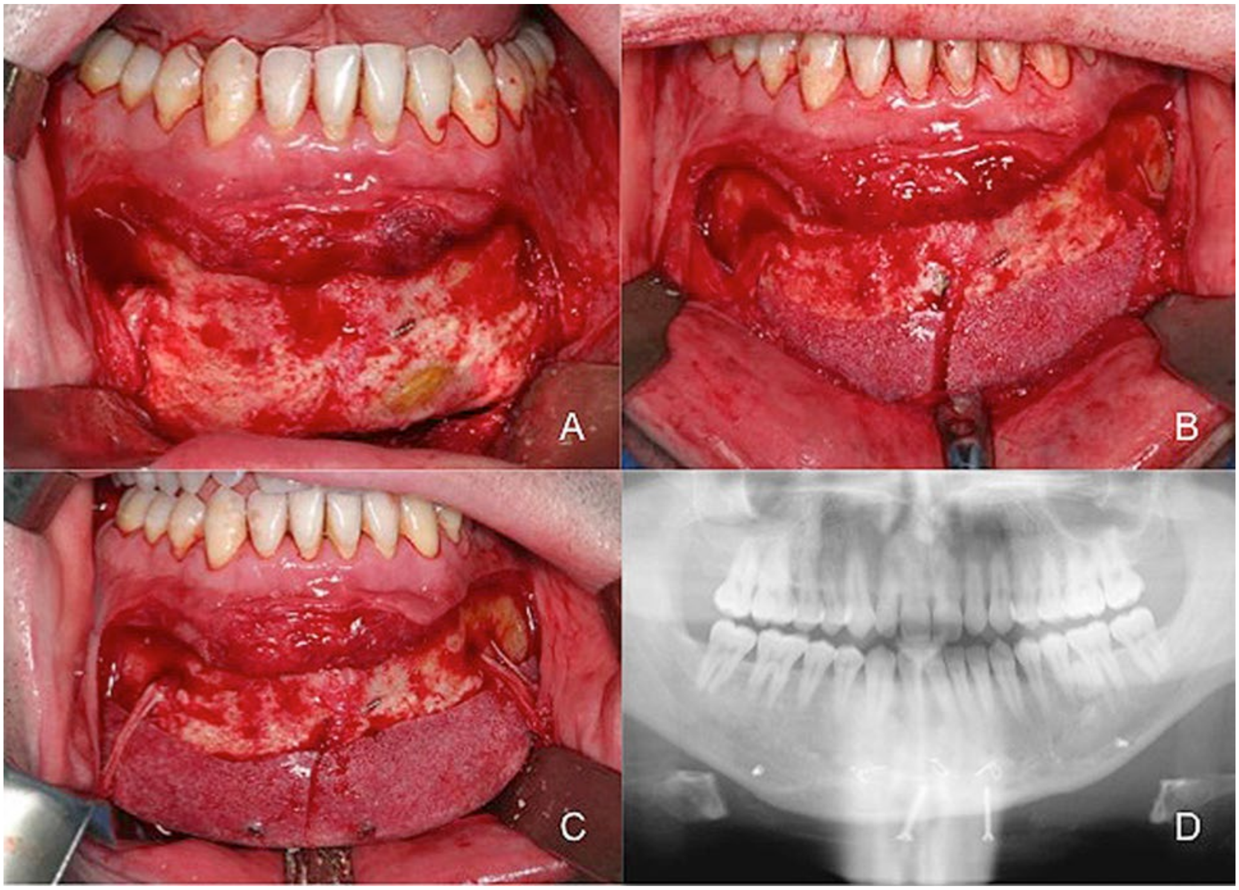


Figure 32: Intraoperative views showing **A.** intraoral access and exposure of mental nerves plus **B., C.** insertion of segmented custom chin implant and final fixation with central and lateral screws. **D.** Final panoramic radiograph noting the fixation screws retaining and securing the implant.

Chang, et al. and Gui, et al.[36,52] An example of this approach is seen in Figures 34-37 (on. pp. 31-33). This 19-year-old female underwent a three piece segmental Lefort I osteotomy, bilateral sagittal split ramus osteotomy and advancement genioplasty to correct her apertognathia, maxillary transverse hypoplasia, bilevel occlusal plane, mandibular hypoplasia and deficient chin projection. The comparison photographs highlight the significant differences that can be achieved with these combination procedures. Final one-year postoperative radiographs demonstrate excellent osseous healing in all areas and the absence of any "notching" at the inferior border of the mandible. Once again, the notching can be avoided by extending the osteotomy further posteriorly to the antegonial notch or molar area.[53]

Finally, genioplasty is frequently utilized in obstructive sleep apnea patients undergoing surgical procedures. The goal in this situation is to make the osteotomy above the genial tubercles so the tongue base and suprahyoid musculature can be advanced, thereby improving airflow and reducing apnea symptoms. The actual procedure does


Figure 33: **A., C.** Pre-operative and **B., D.** one-year post-operative views following insertion of a porous polyethylene custom chin implant and submental liposuction. Note improved appearance of chin contours in both views.

not vary much from what is described herein and overall has good success with 50% to 74% improvement in OSA using just this procedure.[54,55]

**SOFT TISSUE CHANGES WITH GENIOPLASTY**

Successful long term outcomes for genioplasty depend on predictable soft tissue and skeletal movements, as well as knowledge of soft tissue postoperative response to the new skeletal position. Despite a wealth of literature, understanding long-term soft tissue response is limited by studies with small samples sizes, short follow-up time and inclusion of other orthognathic procedures.[56-60]

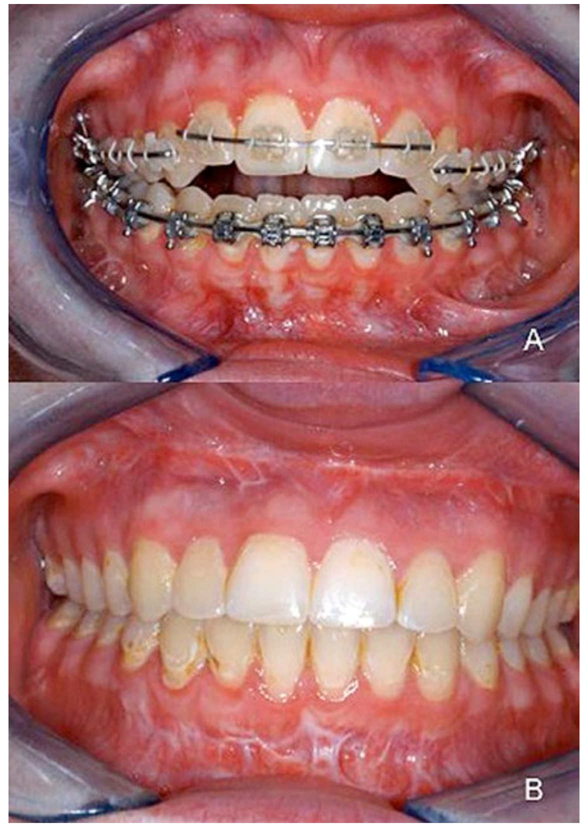


Figure 34: **A.** Pre-operative and **B.** post-operative occlusion views of a 19-year-old female who underwent a three piece segmental Lefort I osteotomy, BSSO and advancement genioplasty.

**Preoperative Assessment and Patient Presentation**

Genioplasty is considered to be very stable, but there are multiple factors affecting soft tissue outcomes. These include surgical technique, dissection approach, amount of skeletal movement, osseous remodel-

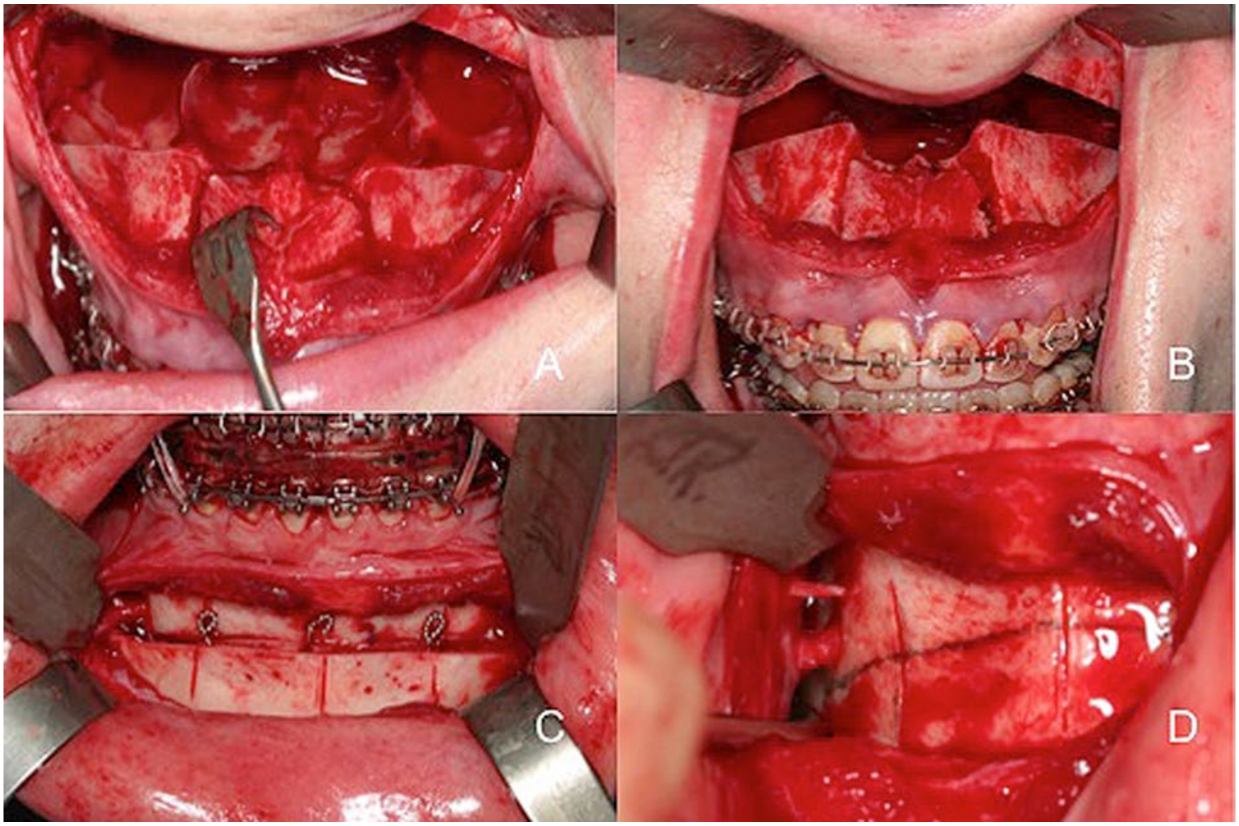


Figure 35: Intra-operative views of patient described in Fig. 34 depicting **A., B.** the segmental Lefort I and **C., D.** the genioplasty. Note the wire fixation to secure the osteotomy **C.** and the accessory nerve branch shown on the right side **D**.

ing and resorption, connective tissue attachments, individual patient variation and whether additional surgical procedures were completed.[59,60]

**Lip Competence and the Labiomental Fold**

Preoperative evaluation of lip competence and the labiomental fold is also valuable. A puckered appearance of the chin is created by the contraction of the mentalis muscle as it tries to raise the lower lip for lip closure. In this case, the lower lip is strained, producing an appearance commonly known as *peau du orange* or surface of an orange.

When a surgical approach to genioplasty is considered, the mentalis muscle is the only one with clinical significance because its anatomy highly influences the lower lip position and ultimately lip competence.[61] This is because the mentalis muscle provides most of the vertical lower lip support and it is the only lower lip elevator.[62] Sequelae of a nonfunctioning mentalis are lip incompetence and chin ptosis.[43] Isolation and precise reattachment of the mentalis muscle during genioplasty has been shown to significantly improve lower lip posture when compared to a control group of patients who did not undergo mentalis reattachment and experienced undesirable lower lip posture and increased tooth show.[63] In this study, precise reattachment of the mentalis muscle with genioplasty resulted in maintenance or increased lower lip length.

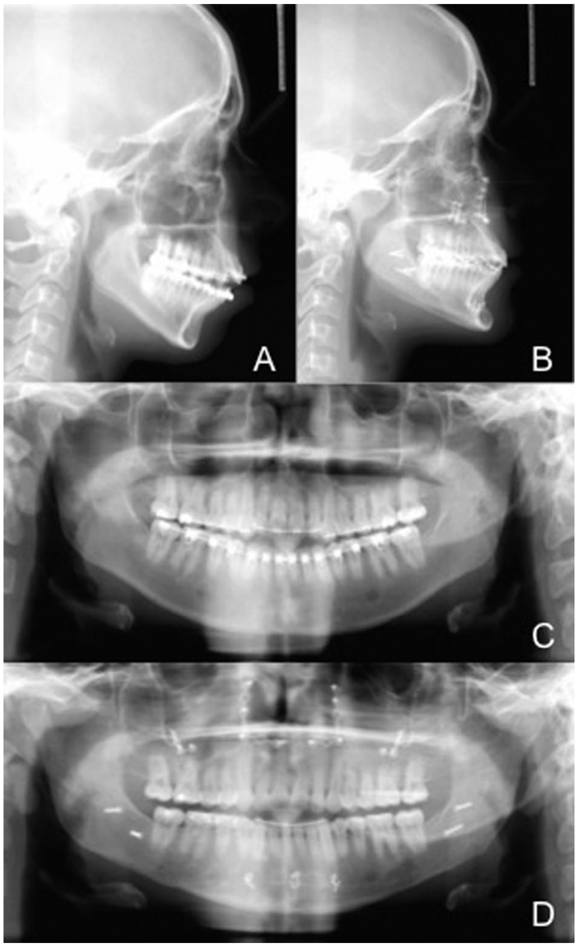


Figure 36: **A., C.** Pre-operative and **B., D.** one-year final post-operative lateral cephalometric and panoramic radiographs depicting orthognathic correction of the patient's malocclusion in addition to chin enhancement by means of sliding osteotomy. Note occlusal plane correction, closure of apertognathia and significant improvement to chin projection restoring facial balance.

Genioplasty has been shown to affect the depth and shape of the labiomental fold.[64] As a guide, the labiomental fold (the deepest point between lower lip and pogonion) should be no more than 4mm behind a line from the vermillion-cutaneous junction of the lower lip through pogonion.[65]

According to Rosen, preoperative soft tissue and labiomental fold abnormalities


Figure 37: **A., C.** Pre-operative **B., D.** and one-year final post-operative frontal and lateral views of patient depicted in Figs. 34-36. Note the idealized proportions achieved with orthognathic surgery and the significant improvement in chin position obtained with this type of correction.

were present in 88% of the patients seeking treatment, the majority of which had a Class II skeletal relationship.[64] In this patient population 40% of the cases had a deep and exaggerated labiomental fold, procumbent lips and a decreased lower facial height while 25% had a shallow labiomental fold, lip incompetence or strain and increased lower facial height .[64,66]

A deeper labiomental fold can be produced by a sagittal advancement of the mandible, vertical shortening of the chin or isolated sagittal advancement of the chin.[64,67]

Rosen suggests that the labiomental fold can be de-emphasized by concurrent advancement and vertical lengthening of the chin.[64,66]

These findings suggest that a visibly deficient chin is only one aspect of the patient presentation. Understanding lower lip position, labiomental fold depth and lower facial height is crucial to optimal outcomes after skeletal repositioning. The only component that genioplasty has no control of is lower lip position.[64] The position of the lower lip is influenced by teeth inclination, and position of the maxilla and mandible. Usually, the upper lip is slightly forward of the lower lip, with more of the lower lip vermilion border visible on the frontal view.

**Soft Tissue Changes with Advancement Genioplasty**

A commonly used method to evaluate soft tissue changes is by cephalometric tracing as shown by Park, et al.[43] Soft tissue changes associated with advancement genioplasty have a ratio of soft tissue to bony movement ranging from 0.6:1 to 1:1.60,[68,69] A study by Lines, et al. suggested that the lower lip advanced at a ratio of 0.66:1 to the lower incisor advancement.[90] In general, the average soft tissue response at pogonion for mandibular advancement is approximately equal to the skeletal advancement, but this becomes highly inconsistent when genioplasty is done concurrently with other orthognathic procedures.[70,71]

A recent study on advancement genioplasty by inferior osteotomy alone has shown soft tissue response almost equal to bony movement at 6 months, with minimal vertical changes, a decrease in soft tissue thickness and an increase in labiomental sulcus depth.[72] Shaughnessy, et al, also reported an increase in labiomental sulcus depth after a 3-year follow-up on advancement genioplasty by horizontal movement alone, but found great individual variability and minimal changes on the lips.[67] Literature review indicates that 90% to 100% of soft tissue response to bony movement can be expected with osteotomy advancement genioplasty, approximately 80% to 90% response with alloplasts and vertical augmentation graft, and slightly less (60% to 70%) with onlay bone grafts. (Table 7)

**Soft Tissue Changes with Setback/reduction Genioplasty**

With regards to setback/reduction genioplasty, studies have suggested a ratio of soft tissue to bony movement ranging from 0.27:1[73] to 0.58:1 [74] with most studies suggesting that the results are not highly predictable and have great variance. Reduction wedge genioplasty has been shown to have the most predictable soft tissue response followed by the horizontal sliding approach.[5] The least predictable method for soft tissue response seems to be the osteotomy at the inferior border.[5,59] Soft tissue changes in reduction genioplasty were relatively stable at one year in a skeletal Class III patient population who underwent simultaneous orthognathic surgery.[75]

It is obvious that it is difficult to assess soft tissue changes based on reduction genioplasty alone because reduction genioplasty is not often done as a stand alone procedure like advancement genioplasty. Cases of a protruded chin where mandibular prognathism is also present ultimately require orthognathic mandibular setback and chin reduction. Prediction of soft tissue response in reduction genioplasty alone has been shown to be difficult particularly because the same soft tissue pogonion position was found after reduction without any bone relapse.[57] This finding is attributed to postoperative soft tissue thickening.

Caution is recommended for reduction genioplasty in patients with minimal labiomental folds depth because this method further flattens the chin and eliminates the labiomental fold, resulting in poor esthetic outcomes.[76] A summary of the soft tissue responses to hard tissue movements is noted in Table 7.

**VERTICAL CHANGES OF THE CHIN FOLLOWING GENIOPLASTY**

Several studies have attempted to evaluate skeletal changes after advancement genioplasty.[43,59,77,78] The reported changes are due to bone remodeling, occurring mostly in the superior and anterior surface of the advanced bony segment, especially during the first six months, although small, significant vertical hard tissue changes attributed to continuous bone remodeling have been reported.[67]

Recently, minimal vertical changes have been reported with an inferior osteotomy approach to advancement genioplasty.[72] Cephalometric analysis of a group of patients undergoing advancement genioplasty with a horizontal osteotomy also reported minimal vertical changes at six months.[72]

When advancement genioplasty is combined with other orthognathic procedures, such as mandibular advancement, the contribution of the genioplasty itself to vertical changes becomes more difficult to establish. This is supported in a study from Ewing and Ross who demonstrated that without genioplasty, the vertical contribution of mandibular advancement is only 10%.[60]

For treatment of the vertically and sagittally deficient chin, Rosen reported complete vertical stability after 11 months of follow-up for eight patients.[79] His approach consisted of

**TABLE 7: SOFT TISSUE RESPONSE TO HARD TISSUE MOVEMENT[5]**

| PROCEDURE | SOFT TISSUE RESPONSE |
|---|---|
| Horizontal advancement | |
| Osteotomy | 90-100% horizontal |
| Alloplast | 80 - 90% horizontal |
| Only Bone Graft | 60 - 70% horizontal |
| Burr to reduce bony chin | 25 - 30%; creates a flat chin |
| Vertical augmentation graft | 80 - 90% of vertical augmentation |
| Reduction Genioplasty | |
| Wedge | 90% of vertical reduction |
| Osteotomy at inferior border | 25%; unpredictable results |

a horizontal sliding osteotomy with a vertical interpositional graft of coralline hydroxylapatite (HA). An example of this technique is shown in Figures 13-16. The HA material does not remodel nor alter it's original dimensions significantly after placement. This case illustrated in the figures has a retrognathic mandible and vertically deficient chin managed with BSSO mandibular advancement and horizontal and vertical advancement genioplasty. The HA grafts are best secured with bone plates for added strength and stability. Additionally, the HA is brittle and is not able to sustain compressive forces.

In a prospective study of high angle skeletal Class II malocclusion adolescents, patients in the early and late stages of puberty undergoing osseous genioplasty were evaluated.[80] Significant changes in the vertical dimension were noted immediately after surgery. The authors found a significant difference in growth direction for both groups at one-year follow-up suggesting that early genioplasty during puberty may help redirect the orthopedic growth in this patient population.[80]

Unpredictable and small changes in the vertical direction have been reported for setback genioplasty.[81] Attempts to establish a correlation in the vertical dimension between hard and soft tissue movements for this approach have not shown any promising results.[75] Despite this, Park, et al. noted a slight elongation of the soft tissues in the vertical dimension six months postoperatively for patients who underwent simultaneous BSSO and setback genioplasty. With this said, it is difficult to establish whether this is related to the genioplasty procedure alone because it may also be attributed to rotation from the BSSO. The effect of precise mentalis muscle re-attachment for an osseous genioplasty showed superior outcomes of soft tissue response on the vertical dimension in which the lower lip length was either maintained or increased thus providing either stable or improved lip competence.[63]

## COMPLICATIONS

Potential complications may be related to existing systemic conditions and associated co-morbidities such as diabetes mellitus, connective tissue disorders, nicotine dependency, history of hepatitis C, or a positive test for human immunodeficiency virus.[82] In these cases, a more conservative surgical approach is recommended to minimize possible difficulties with postoperative healing.

### Anesthesia

Complications with anesthesia are rarely reported and generally minimal in nature. As described earlier, osseous genioplasty alone or combined with orthognathic surgery is best performed under general anesthesia while alloplastic chin implants can be placed under a combination of local anesthesia, with or without sedation. Possible complications include aspiration, hypertension, hypotension, cardiac arrest, cardiac arrhythmia, bronchospasm, laryngospasm and other compromised airway conditions. Fortunately, all of these possibilities are rare, and careful screening preoperatively will alert the astute surgeon to issues requiring management prior to entering the operating room.

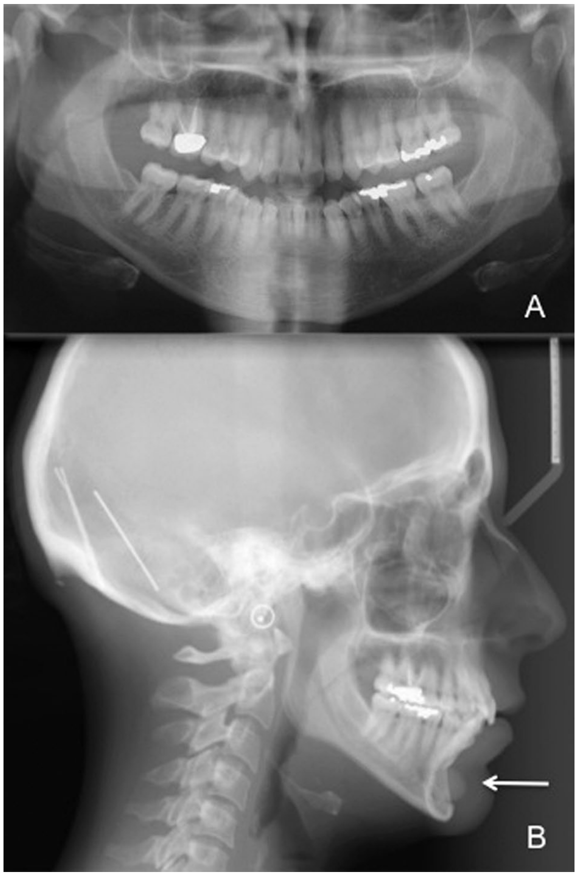


Figure 38: **A.** Panoramic and **B.** lateral cephalometric radiograph of a female patient with an older solid silicone "button" style chin implant. The patient was asymptomatic but the lateral view shows the implant to be malpositioned superiorly and bone resorption is also present (arrow). This is common when these implants are used and is likely secondary to lack of fixation and pressure from the mentalis muscles.

## Surgical Approach Issues

In cases where alloplastic chin implantation is planned, resorption of the underlying bone may occur (Figs. 38 -39). Robinson and Shuken have described a grading scale regarding the degree of resorption that occurs with alloplastic chin implants.[83] (Table 8) Extended anatomical implants, appropriate pocket size and stable fixation all act to minimize this potential problem.

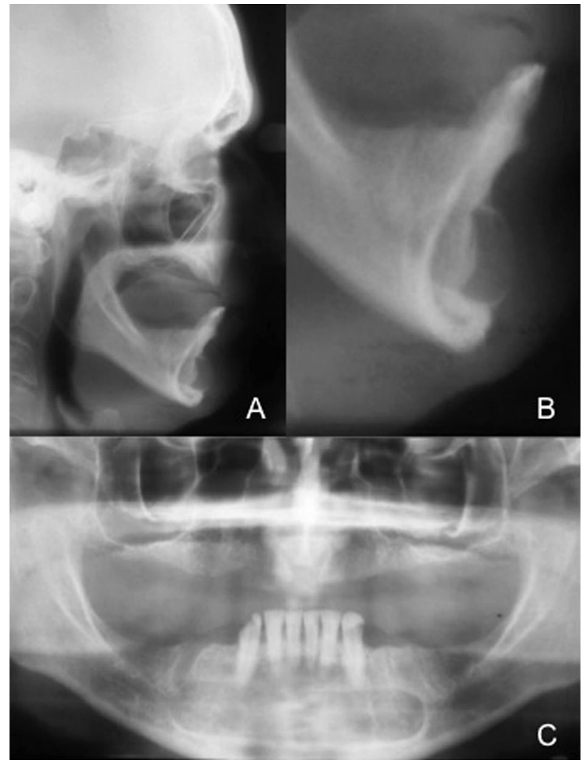


Figure 39: Older male patient presenting for mandibular dental implant consultation was found to have a solid silicone "button" style chin implant **C.** in place with significant bone resorption **A., B.** Dental implant placement for mandibular reconstruction is possible but would require removal of the implant for proper treatment. The patient elected to retain the chin implant.

Poor incision design can increase the risk for muscle damage, resulting in soft tissue ptosis and skin irregularity, or lower lip lag. Special attention is recommended for proper reattachment of the mentalis muscle to

| **TABLE 8: BONE RESORPTION WITH CHIN IMPLANTS[83]** | |
|---|---|
| Grade I | Cortical bone resorption only- No dimensional changes |
| Grade II | Up to 3 mm bone resorption |
| Grade III | 3-5 mm bone resorption |
| Grade IV | < 5 mm bone resorption |

avoid most if not all of the known or potential complications with lip ptosis or other irregularities.

Devitalization of teeth and mental nerve damage causing neurosensory loss are possible complications associated with horizontal and vertical osteotomies. Transient neurosensory loss can be anticipated with either osseous or alloplastic genioplasties. Careful attention must be paid to identify the mental nerves and avoid them with either approach. Clearly the mental nerves are at somewhat of a greater risk for injury with osteotomies but the outcome of persistant nerve paresthesia or other conditions is equally devastating to patients undergoing such elective procedures (Fig. 40). The osteotomy should stay several millimeters (4.5-6.0 mm) below the mental foramen. If a nerve transection should occur then direct primary neurorrhaphy should be performed with re-approximation of the epineurium using 7-0 or 8-0 monofilament sutures. A nerve guide tube can be utilized to assist with the repair and help to allow for improved outcomes. An example of this complication and repair is found in Figures 41-42.

**Postoperative Complications**

Wound dehiscence is a potential postoperative complication, mostly related to alloplastic implants.[84] Its management is difficult and may require implant removal. Figure 43 shows an example of such a case. This young female had undergone placement of a porous polyethylene implant elsewhere prior to her seeking consultation for management of the implant exposure. Clearly, in this case retention of the implant is contra-indicated as it

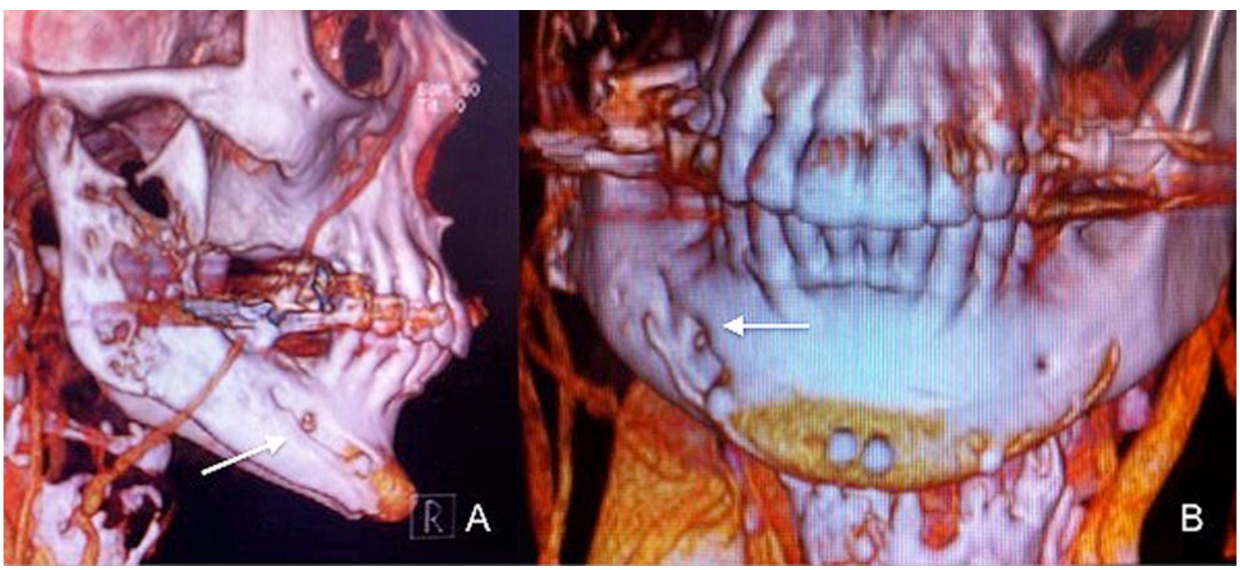


Figure 40: Sixty-six-year-old female patient presented with onset of right mental nerve paresthesia. She had a silicone chin implant placed several years prior to presentation. **A., B.** Bone resorption is evident on the right side. The implant is malpositioned superiorly on the right and lies directly over the mental foramen (arrow). While clearly the implant is not positioned properly it was not the etiology of the paresthesia. She had an infiltrating lymphoma of the right posterior mandible that caused the paresthesia.

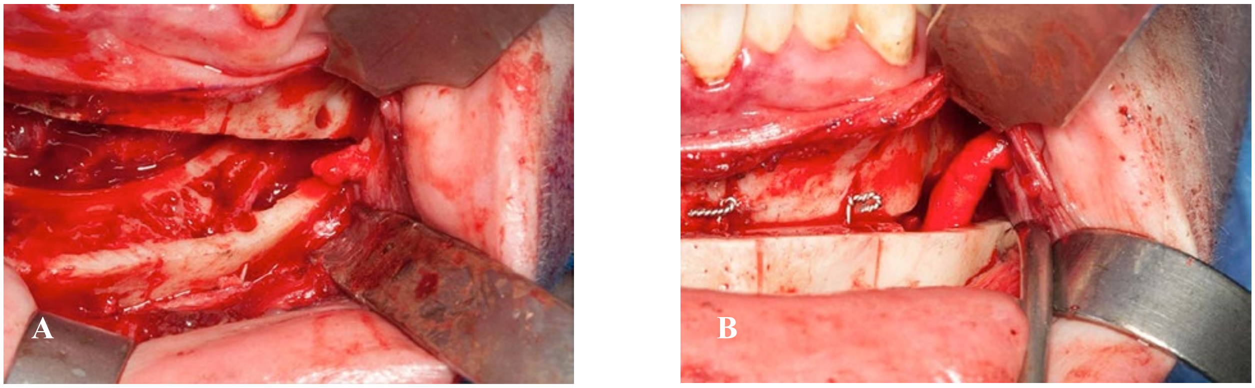


Figure 41: Complication of bilateral mental nerve transection during a genioplasty procedure. **A.** The left side is shown with the residual nerve visible in the inferior segment and the stump in the soft tissue. Note the proximity of the osteotomy to the foramen, thus the complication could be anticipated; **B.** Fixation and immediate repair of transected mental nerve. A collagen based nerve guide tube was utilized to stabilize the repair and provide a conduit for regeneration.

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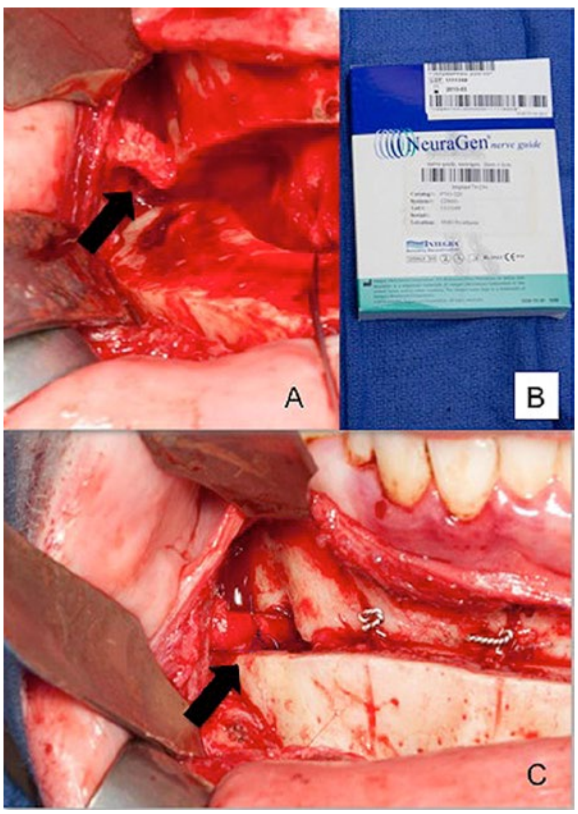


Figure 42: Patient described in Fig. 40. **A.** Transected right mental nerve and **C.** immediate repair are depicted (arrow) once again using the **B.** NeuraGen nerve guide tube.

would be nearly impossible to predictably cover the implant with soft tissue. Additionally, given the length of exposure in the oral cavity the implant had become seeded with bacteria and would be a source for infection.

Careful selection of patients for alloplastic implants is paramount. If the patient has a deficiency that is beyond the normal amount of correction managed by an implant and it is subsequently placed, the risk for soft tissue breakdown and exposure should be anticipated.

Wound dehiscence can also be associated with osseous genioplasties. Exposure of underlying hardware can become seeded with bacteria and will likely lead to its eventual removal. A mucosal dehiscence with underlying bone exposure was reported by Hoenig in 15 out of 494 patients undergoing genioplasty.[3]

Erosion of bone or tooth roots may be noticed with implants. This may require

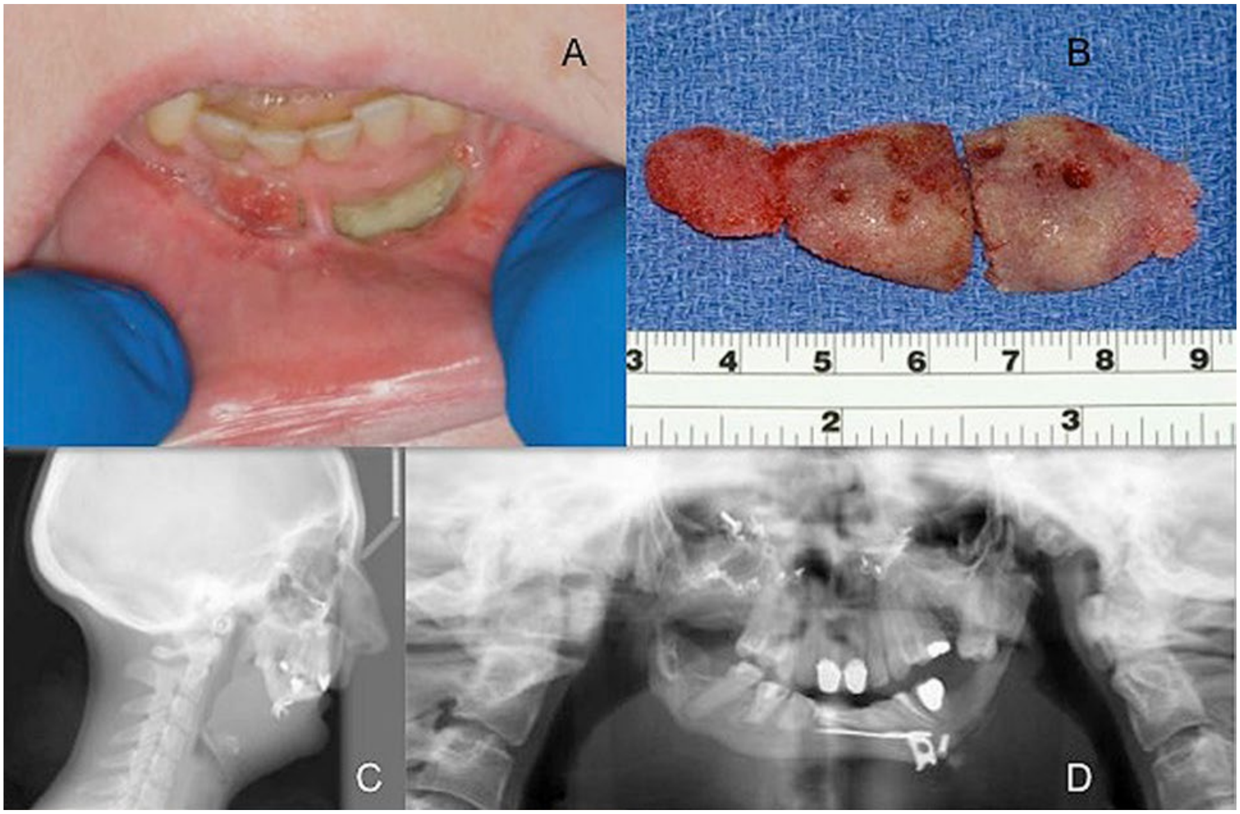


Figure 43: **A.** Intraoral presentation of an infected and exposed porous polyethylene chin implant. The patient had the implant placed elsewhere but presented for treatment options. **B.** Removal of the implant was advised. **C.** Lateral cephalometric and **D.** panoramic radiographs depict the patient at the time of presentation. Clearly one could anticipate this complication eventually given the patient's mandibular anatomy. In this author's opinion a chin implant is contraindicated in this patient and similar clinical scenarios.

implant removal depending on the magnitude of erosion present. Osseous genioplasty may also result in loss of tooth vitality. If there is no severe bony erosion, loss of tooth vitality can be managed with root canal therapy, but tooth extraction may be required if the adjacent bony structure is severely compromised. Rare complications such as the need for periodontal therapy,[85] defective ossification,[86] mandibular fracture after osteotomy[87] and respiratory mucocele formation[88] have also been reported.

Infection is a rarely reported complication with one study describing zero infections for alloplastic reactions,[36] and another study reporting need for removal of two out of eight implants placed.[89]

Transient lower lip numbness has been reported as a common complication, with 1 in 500 patients having persistent numbness at one year.[36] Complete recovery from lower lip numbness has been reported for patients with isolated genioplasty and approximately 15%

of patients reporting transient numbness at one-year follow-up.[3]

Soft tissue complications are mostly related to issues with improper mentalis muscle isolation and reattachment,[61] scarring, or the level of the osteotomy. Lip incompetence and ptosis or asymmetry may follow, and these have been shown to be difficult to correct because they require an additional surgery to suspend and reposition the lip.[61] Unless grossly severed and not reattached, the mentalis muscle recovers within weeks to several months.

When a horizontal osteotomy is required, it is crucial to place the osteotomy as far posteriorly as possible along the border of the mandible body to avoid a step-off deformity in the area of the labiomental groove. Failure to do so may result in both a visible and palpable defect along the inferior border of the mandible over time. (Figs. 44-46 on pp. 42-44)

Dissatisfaction with the esthetic outcomes from both the patient and surgeon are also factors to be considered. When alloplastic implants are incorrectly sized, this correction is quite simple because the size can simply be modified by either removing the implant and leaving the capsule or exchanging for a different size implant. Another factor to consider with alloplastic implants is healing of the fibrous capsule that can result in soft tissue thickening. If overall facial esthetic outcomes are unsatisfactory, then such thickening may require revision of the genioplasty or additional surgical procedures, including rhinoplasty or orthognathic repositioning of mandible or maxilla. For subtle soft tissue improvement of symmetry or volume, various facial fillers, Botox-A Cosmetic® injections or suction assisted lipectomy in the submental area have been suggested.[82]

Overall, a high degree of patient satisfaction has been reported with genioplasty with one study finding that 73.2% of patients deemed the outcomes to be excellent and 23.6% deemed the outcome good.[3] A summary of possible complications is listed in Table 9.

## CONCLUSION

The literature regarding the chin and genioplasty procedures reveals extensive historical documentation relating to facial evaluation. This emphasizes the importance of the chin and its role in facial esthetics, balance and harmony of the face. Weakness of the chin has been shown to affect perception of an individual's character.

Knowledge of local anatomy allows one to safely perform surgical procedures with predictable outcomes. Numerous options are available to modify the chin and can include

| **TABLE 9: COMPLICATIONS OF GENIOPLASTY** |
|---|
| Tooth devitalization |
| Neurosensory loss |
| Soft tissue chin ptosis |
| Dental root exposure |
| Asymmetry |
| Irregularities and step deformities |
| Lower lip lag |
| Over and under correction |
| Patient or surgeon dissatisfaction |


Figure 44: 17-year-old female with idiopathic condylar resorption and significant chin retraction. Correction of her chin required orthognathic correction of her deformity. **A., D.** Pre-op, **B., E.** 6-months after bilateral costochondral rib graft reconstruction of the mandible and counterclockwise mandibular repositioning with intentional creation of a large posterior open-bite deformity. **C., F.** Postoperative result following Lefort I advancement and posterior down-graft to close posterior open-bite plus advancement genioplasty. Note significant improvement in the lower facial third dimensions. This magnitude of correction is not typically possible with other surgical procedures.

fillers, implants, osteotomies or combinations of these methods. Evidence-based analysis of the literature supports the safety profile for genioplasty procedures.[51] Fortunately, complications are uncommon and generally easy to manage surgically.

While new materials may become available in the future, current materials have a long and successful track record when used in the appropriate clinical situation. The use of customized implants has a significant role in the multiply-operated or syndromic pa-

Figure 45: Postoperative radiographs from patient described in Fig. 44. Occlusal plane normalized and maximal advancement of the chin to improve facial balance

tient because they allow a method to correct unusual anatomical issues with one procedure and often with less morbidity. Advances in virtual surgical planning will continue to offer surgeons additional and predictable means to assist with correction of subtle or complex chin position issues.

Patients will continue to request enhancement of the chin and contemporary surgeons will rely upon history, anatomy, careful evaluation and surgical execution as well as technological advances to provide them with the results they deserve – results to improve their position in life's race.

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**Kevin L Rieck DDS, MD** is a consultant and Assistant Professor of Surgery in the Department of Surgery, Division of Oral and Maxillofacial Surgery at Mayo Clinic in Rochester MN. He completed specialty training in oral and maxillofacial surgery and his general surgery internship at Mayo Clinic Graduate School of Medicine. He is a graduate of Mayo Medical School. His dental education was at the University of Illinois Col-



Figure 46: **A.** One-year postoperative results from costochondral grafting to mandible and 6-month post-operative results from Lefort / Genioplasty procedure. **B.** Note stable occlusion without openbite deformity and significantly improved chin projection.

lege of Dentistry in Chicago. He also earned Bachelor's and Master's degrees in Biology from the University of Illinois Urbana-Champaign.

Dr. Rieck is a Diplomate of the American Board of Oral and Maxillofacial Surgery and a Fellow of the American Academy of Cosmetic Surgery, AAOMS and ACOMS. He has lectured nationally and internationally on a variety of topics. He was the Scientific Chair for the American College of Oral and Maxillofacial Surgeon's Annual Meeting in April 2013. His surgical interests include orthognathic surgery, cosmetic facial surgery, dental & craniofacial implants and associated hard tissue grafting procedures as well as lasers for facial surgical applications. He has published numerous scientific articles and book chapters.

Kevin is a fitness enthusiast and enjoys many outdoor activities with his family including biking, skiing, scuba diving and other water sports. Together they all share an interest in Martial Arts. He is currently a Third Degree Black Belt in Tae Kwon Do.

He dedicates this chapter to his family, Wendy, Heidi, Olivia and Connor for the time they sacrifice to allow him to pursue and complete these projects. He is also indebted to his residents for keeping him current and assisting in the care of their wonderful patients.

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5323 Harry Hines Blvd., M/C 9109
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PHONE: 214/648-3554 FAX: 214/648-2918
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