Osseous Transformation with Facial Feminization Surgery: Improved Anatomical Accuracy with Virtual Planning

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Background: Facial feminization surgery entails a series of surgical procedures that help the transwoman pass as their affirmed gender. Although virtual surgical planning, with intraoperative cutting guides, and custom plates have been shown to be helpful for craniomaxillofacial reconstruction, they have not yet been studied for facial feminization surgery. The authors used cadaveric analysis for morphologic typing and to demonstrate the utility of virtual surgical planning in facial feminization surgery procedures.

Methods: Male cadaveric heads underwent morphologic typing analysis of the frontal brow, lateral brow, mandibular angle, and chin regions ($n = 50$). Subsequently, the cadavers were split into two groups: (1) virtual surgical planning intraoperative cutting guides and (2) no preoperative planning. Both groups underwent (1) anterior frontal sinus wall setback, (2) lateral supraorbital recontouring, (3) mandibular angle reduction, and (4) osseous genioplasty narrowing. Efficiency (measured as operative time), safety (determined by dural or nerve injury), and accuracy (scored with three-dimensional computed tomographic preoperative plan versus postoperative result) were compared between groups, with significance being $p < 0.05$.

Results: For frontal brow and lateral lower face, morphologic type 3 (severe) predominated; for lateral brow and chin, type 2 (moderate) predominated. For frontal sinus wall setback, virtual surgical planning improved efficiency (19 minutes versus 44 minutes; $p < 0.05$), safety (100 percent versus 88 percent; $p < 0.05$; less intracranial entry), and accuracy (97 percent versus 79 percent; $p < 0.05$) compared with no preoperative planning. For mandibular angle reduction, virtual surgical planning improved safety (100 percent versus 88 percent; $p < 0.05$; less inferior alveolar nerve injury) and accuracy (95 percent versus 58 percent; $p < 0.05$).

Conclusions: Preoperative planning for facial feminization surgery is helpful to determine morphologic typing. Virtual surgical planning with the use of cutting guides/custom plates improved efficiency, safety, and accuracy when performing four key craniofacial techniques for facial feminization. (*Plast. Reconstr. Surg.* 144: 1159, 2019.)

Transgender individuals experience a mismatch between their gender identity and their phenotypic primary and secondary sexual characteristics. The prevalence of gender dysphoria, as estimated by the Williams Institute at the University of California, Los Angeles, is 0.6 percent.[1] One of the greatest challenges to transgender individuals is acceptance in society. For presenting in public as a member of the opposite gender, facial features are of paramount

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importance. Facial feminization surgery involves a series of surgical procedures aimed at feminizing the transwoman's face, with the goal of easing her psychosocial burden. Facial feminization surgery is associated with improved mental health and quality of life.[2,3]

There are numerous bony and soft-tissue differences between the male and female face. Osseous differences between the male and female face almost universally include the forehead, lateral supraorbital region, lateral jawline, and chin.[4–6] On frontal view, the female face is softer, more rounded or oval-shaped, with a more pointed chin, whereas the male face is more square and angulated, with a strong jawline and chin (Fig. 1). On lateral view, men traditionally have bossed foreheads, whereas women have more gently sloped or flat foreheads. Procedures to offer transformation from a male to a female face include anterior frontal sinus setback or recontouring, supraorbital reduction, mandibular angle reduction, and osseous genioplasty.[4–6] Other skeletal procedures sometimes offered include the following: orthognathic (jaw) surgery and/or zygomatic width reduction. In addition, soft-tissue procedures may be performed simultaneously, or in a staged fashion, and include forehead shortening/brow lift, septorhinoplasty, upper lip shortening, fat grafting, and/or laryngochondroplasty ("trach shave").

Over the past 10 years, craniomaxillofacial reconstruction has used virtual surgical planning with computer-aided design (CAD) and computer-aided manufacturing (CAM) for intraoperative cutting guides to enhance efficiency, accuracy, predictability, and reproducibility of osseous procedures.[7,8] In orthognathic and mandibular reconstruction, virtual surgical planning and CAD/CAM have been shown to decrease the risk of nerve injury.[9,10] It has also been shown to enhance accuracy of frontal sinus reconstruction.[11] Virtual surgical planning has not been well studied in facial feminization surgery, despite the need for multiple craniofacial techniques to modify the facial skeletal. We used cadaveric analysis to determine male face morphologic types for anatomical regions that need to be altered in facial feminization surgery: (1) frontal brow, (2) lateral brow, (3) mandibular angle, and (4) chin. In addition, we studied cadaveric operative techniques to evaluate virtual surgical planning and CAD/CAM manufacturing preoperative planning for efficiency, safety, and accuracy in the four main osseous procedures of facial feminization surgery: (1) anterior frontal sinus wall setback, (2) lateral supraorbital recontouring, (3) mandibular angle reduction, and (4) osseous genioplasty.

METHODS

Male cadaveric heads underwent computed tomographic imaging and craniofacial operative procedures for osseous facial feminization (n = 50). Imaging was used to assess male anatomical morphology of four facial regions that are known to need modification for facial feminization: (1) frontal brow, (2) lateral brow, (3) mandibular angle, and (4) chin. Imaging was also used postoperatively to assess the accuracy of the procedures. In addition, 10 female three-dimensional computed tomographic scans were used as references. Abnormal skulls were excluded from this study (e.g., skulls with significant facial asymmetry, trauma, or congenital deformities).

Morphologic types were designated for each of the four anatomical regions based on previous experience. The number of cadaver heads with each morphologic type was recorded independently by three separate senior plastic surgeons (Tables 1 through 4). Frontal brow morphology was separated into type 1, mild bossing only, small or no frontal sinus, and thick anterior wall; type 2, moderate bossing, normal frontal sinus, and flatness in midforehead; and type 3, significant masculine bossing and large projection. Although type 4 has been previously described, we did not see this type in our cadaveric skulls.[12] Lateral brow morphology was separated into type 1, no or minimal overhang of supraorbital bar; type 2, moderate overhang of lateral supraorbital bar; and type 3, significant overhang of lateral supraorbital bar extending down the lateral orbital wall. Mandibular angle morphology was separated into type 1, mild lower face width/angular projection; type 2, moderate lower face width/angular projection; and type 3, significant angular projection with acute mandibular angle. Chin morphology was separated into type 1, mild chin width; type 2, moderate chin width; and type 3, significant chin width and increased lower face height.

Operative techniques are tailored to the morphologic types for each region. For the frontal brow procedures, type 1 (mild bossing, no sinus/thick anterior wall) underwent recontouring with a side-cutting burr; type 2 (moderate bossing, normal frontal sinus) underwent limited burring, and midforehead hydroxyapatite or fat grafting; and type 3 (significant bossing) underwent anterior frontal sinus wall setback with resorbable plate (Resorb x; KLS Martin, Jacksonville, Fla.)

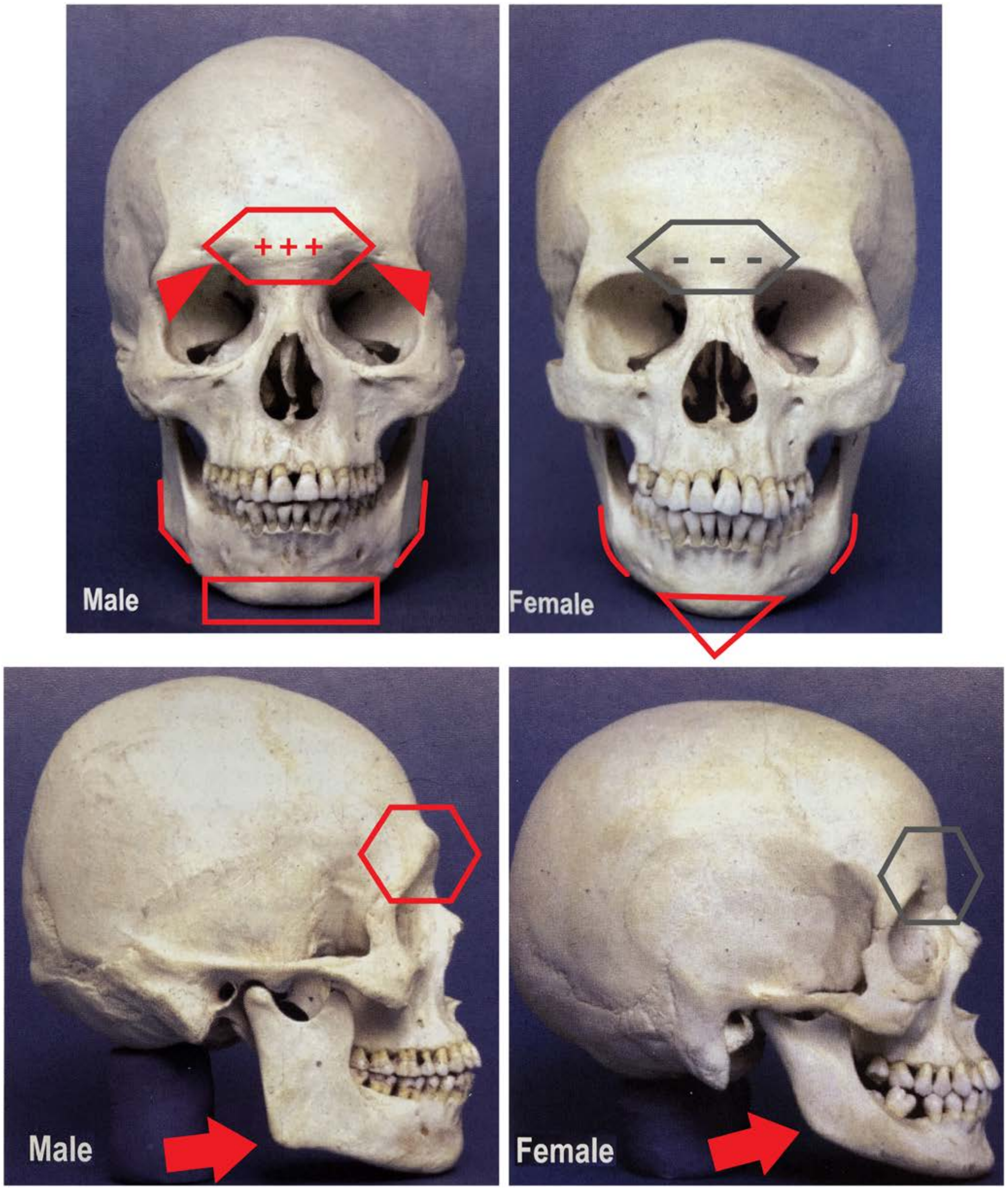

Fig. 1. Morphologic gender skull differences as originally described by Doug Ousterhaut. (*Above*, *left*) Male skull (frontal view) demonstrating bossed forehead, low supralateral brow, wide lower face, and wide chin. (*Above*, *right*) Female skull (frontal view) demonstrating flat forehead, contoured supralateral brow, narrow lower face, and pointy chin. (*Below*, *left*) Male skull (lateral view) demonstrating bossed forehead, supralateral brow hooding, acute mandibular angle, and large chin. (*Below*, *right*) Female skull (lateral view) demonstrating recessed forehead, low supralateral brow, soft curved mandibular angle, and small chin.

or wire fixation and peripheral burring (Fig. 2). For lateral brow procedures, type 1 (no overhang) underwent no procedure; type 2 (moderate overhang) underwent side-cutting burr recontouring; and type 3 (significant overhang) underwent ostectomy with reciprocating saw. For mandibular angle procedures, type 1 (mild lower face width) underwent partial masseter resection (and would undergo serial botulinum toxin type A injections every 6 months); type 2 (moderate lower face width) underwent limited mandibular angle burring and partial masseter resection; and type 3 (significant lower face width, acute angle) underwent mandibular angle resection (Fig. 3). For chin procedures, type 1 (mild chin width) underwent lateral chin burring; type 2 (moderate chin width) underwent osseous genioplasty narrowing/advancement; and type 3 (significant chin width, increased lower face height) underwent osseous genioplasty narrowing, shortening, and advancement (Fig. 4). For the comparative study, the male cadaver skulls were separated into two

Table 1. Frontal Brow (Forehead/Frontal Sinus) Types and Indicated Corrective Techniques*

Frontal Brow Type	Defining Features	Techniques for Transformation	Prevalence (%)
1	Mild bossing, no or minimum frontal sinus, thick anterior wall	Burring	3/50 (6)
2	Moderate bossing, midforehead flattening	Burring plus fat filling	4/50 (8)
3	Significant bossing, large projection	Anterior frontal sinus wall setback	43/50 (86)

*Type 3 requiring an anterior frontal sinus wall setback is the most common.

equal groups: group 1, virtual surgical planning and CAD/CAM preparation before performing the operative techniques; and group 2, no preoperative planning. Because type 1 cases required no surgery or minor procedures, types 2 and 3 were added so that the comparative groups each had 25 specimens. The specimens were separated randomly into groups and age was recorded. For group 1, virtual surgical planning and CAD/CAM had cutting guides and custom plates made (KLS Martin, Jacksonville, Fla.). Cutting guides were made for frontal brow, lateral brow, mandibular angle, and chin. Movements were based on existing three-dimensional computed tomographic scan morphology and desired change for each region. Custom plates were made for the frontal brow and osseous genioplasty. Surgery was performed on fresh cadavers with soft tissues attached to mimic in vivo procedures.

Group 1 (virtual surgical planning and CAD/CAM) was compared to group 2 (no preoperative planning) for efficiency, safety, and accuracy. Efficiency was based on operative time per region; we did not include preoperative planning time. Safety was based on inadvertent entry into the cranial space or dural injury (for the forehead and lateral supraorbital regions) and sensory nerve injury (for mandibular angle and chin regions). Accuracy was based on volumetric analysis comparing the preoperative to the postoperative three-dimensional computed tomographic scans for each region. Measurements were calculated as percentage accuracy, as follows: *Absolute value of expected volumetric change* minus *Actual volumetric change* times 100 divided by *Expected volumetric change* times 100, divided by *Expected volumetric change* or *Percentage accuracy* = (EVC – AVC) × 100/EVC. Expected volumetric change is the volume reduction change from preoperative three-dimensional computed tomographic scan to virtual surgical planning result. Actual volumetric change is that volume reduction change from preoperative three-dimensional computed tomographic scan to the actual postoperative result. We compared the percentage accuracy per region of group 1 (virtual surgical planning) to group 2 (no preoperative planning).

For statistical analysis, group 1 (virtual surgical planning) was compared to group 2 (no preoperative planning) using a t test to identify significant differences between the two groups. All data were analyzed using JMP Pro 12 statistical software (SAS Institute, Inc., Cary, N.C.). A cutoff of $p < 0.05$ was considered statistically significant for all values.

RESULTS

For morphologic types, 93 percent were recorded identically by the three independent reviewers for all regions. The remaining 7 percent with discrepancies among reviewers were reviewed and reclassified. Mean cadaveric age was 54.3 ± 4 years.

Forehead brow morphology in a large majority of specimens was type 3, with significant masculine bossing and large projection (86 percent). Type 2 (moderate bossing) and type 1 (mild bossing) made up only 8 and 6 percent, respectively (Table 1). The forehead brow type 3 cases required an anterior frontal sinus wall setback. The mean amount of setback was 6.2 ± 2 mm from maximal projection. For group 1 (virtual surgical planning) cadavers, cutting guides were designed within the exact border of the frontal sinus, and the location of the septum was marked. A surgical drill was used to precisely cut the anterior frontal sinus wall out, a reciprocating saw was used to horizontally cut the bone removed, and custom plates were used for fixation in a posterior position (Fig. 2). Of note, 88 percent of cases had a septum present requiring an osteotomy to take off the anterior frontal sinus wall in one piece. Group 2 (no preoperative planning) had a window made in the anterior frontal sinus wall, bone was removed as multiple individual pieces, and wire and miniplate fixation of bone with degree of setback was determined on the table. Group 1 (virtual surgical planning) resulted in improved efficiency with decreased operative time compared to group 2 (no preoperative planning) (19 ± 3 minutes versus 44 ± 5 minutes; $p < 0.05$). Although operative times were consistent throughout group 1 (virtual surgical planning) cases, for group 2 (no preoperative planning) cases, there was a learning curve, with slower times for the initial one-third of cases (58 minutes) and faster times

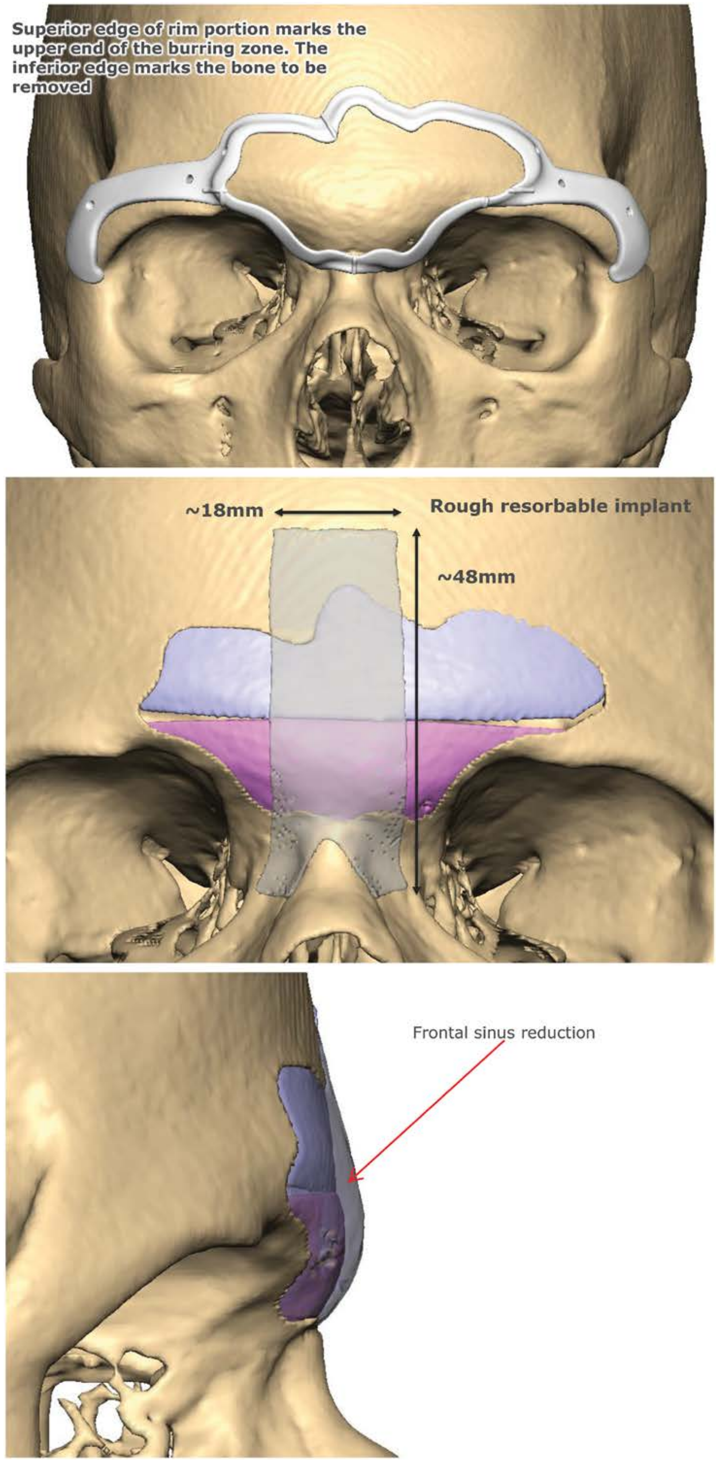

Fig. 2. Virtual surgical planning for the brow region. (*Above*) Cutting guide for frontal brow (central) for osteotomy of the anterior frontal sinus wall and cutting guides for the lateral brow (lateral) for ostectomy of the lateral supraorbital bar. (*Center*) Custom resorbable plate fixation after anterior frontal sinus wall horizontal sectioning (for contouring from convex to flattened) and setback; borders are contoured with a burr (*arrow*). (*Below*) Right lateral side view of brow demonstrates frontal sinus wall setback. *Gray outline* shows original convex contour and *colored bones* show new flat contour.

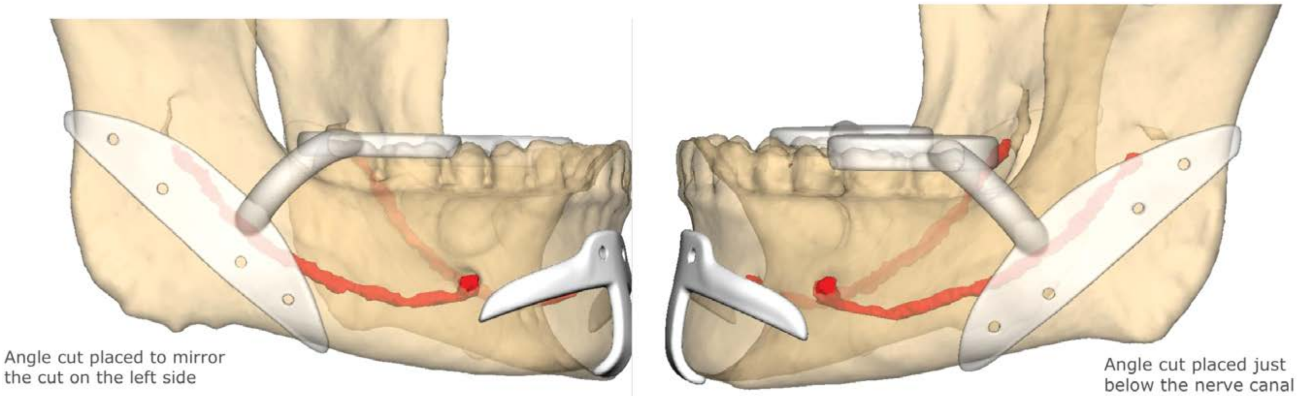

Fig. 3. Virtual surgical planning for mandibular angle reduction. Occlusal bite registration of second/third molars is used for cutting guide positioning; ostectomy is planned symmetrically at least 5 mm below the inferior alveolar nerve.

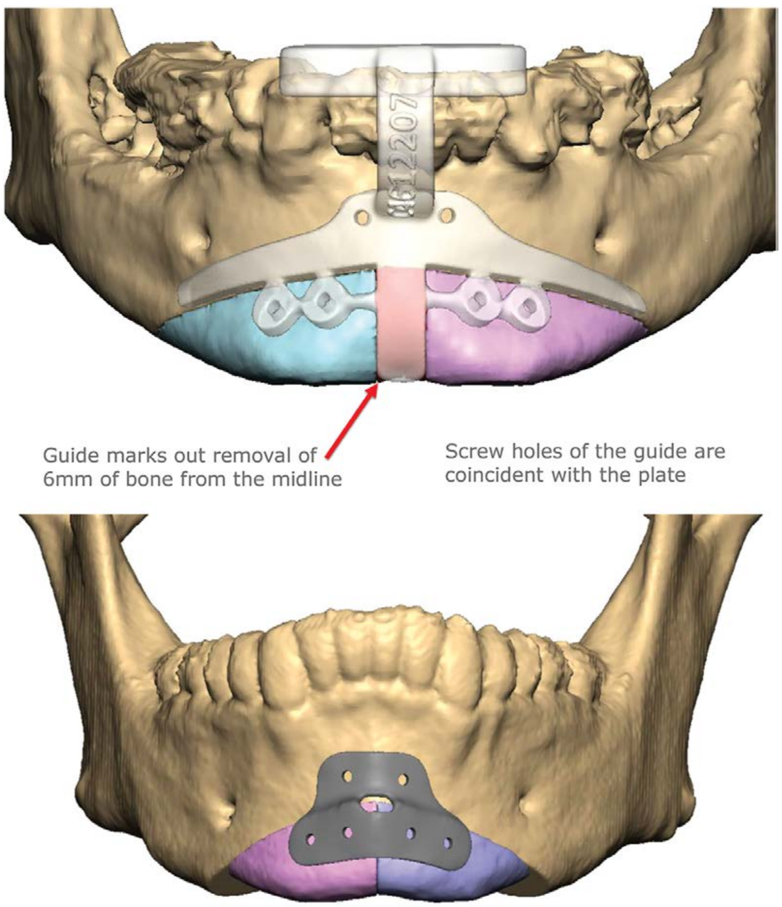

Fig. 4. Virtual surgical planning for osseous genioplasty narrowing. (*Above*) Cutting guide for osteotomy 6 mm below the mental foramen with central bone resection. (*Below*) Custom plate fixation after chin narrowing and advancement (although chin movement may vary). Bone bur contouring is often performed at the lateral aspect of the osteotomy to smooth the edges.

for the last one-third of cases (37 minutes). There also was improved safety with group 1 (virtual surgical planning) cases, with no complications, compared to group 2 (no preoperative planning), with four inadvertent intracranial entries (safety, 100 percent versus 88 percent; $p < 0.05$) (Table 5). Finally, group 1 (virtual surgical planning) had improved accuracy compared with group 2 (no preoperative planning) (97 ± 4 percent versus 79 ± 3 percent; $p < 0.05$).

Lateral brow morphology in a majority of cases was type 2 with moderate supraorbital overhang (66 percent) (Table 2). Type 3 (significant supraorbital overhang) and type 1 (no supraorbital overhang) made up only 18 percent and 16 percent, respectively. Type 2 cases required lateral brow burring, with a cutting guide used for group 1 (virtual surgical planning) cases. When comparing group 1 to group 2 cases, there was similar efficiency (18 ± 2 minutes versus 20 ± 3 minutes), similar safety (100 percent versus 96 percent), and similar accuracy (94 ± 4 percent versus 88 ± 5 percent) (Table 5).

Mandibular angle morphology had a majority of cases with type 3 or with significant lower face width (66 percent) (Table 3). Type 2 (moderate lower face width) and type 1 (mild lower face width) made up 24 percent and 10 percent, respectively. Type 3 cases required mandibular angle resection; for group 1 (virtual surgical planning) cases, a cutting guide based on occlusal reference was used to protect the nerve and gain symmetry (Fig. 3). When comparing group 1 cases to group 2 (no preoperative planning) cases, there was similar efficiency (18 ± 2 minutes versus 20 ± 3 minutes; $p < 0.05$); however, group 1 was superior with regard to safety (100 percent versus 88 percent; $p < 0.05$) (less inferior alveolar nerve injury) and accuracy (95 ± 4 percent versus 58 ± 2 percent; $p < 0.05$) (Table 6).

Chin morphology had the most cases with type 2 or with moderate chin width (74 percent). Type 3 (significant chin width and lower face height) and type 1 (mild chin width) made up 20 percent and 6 percent, respectively (Table 4). Type 2 cases required osseous genioplasty narrowing; for group 1 (virtual surgical planning), a cutting guide based on occlusal reference was used, with the amount of central narrowing marked for resection (Fig. 4). When comparing group 1 cases to group 2 cases (no preoperative planning), there was similar efficiency (18 ± 2 minutes versus 24 ± 3 minutes), similar safety (100 percent versus 92 percent), and similar accuracy (95 ± 4 percent versus 88 ± 5 percent) (Table 6).

DISCUSSION

Facial features are extremely important for a transgender person trying to present in public as a member of the desired gender. As such, transgender individuals seeking confirmation surgery often seek facial feminization surgery even before top (breast) or bottom (genitalia) surgery. Douglas Ousterhout studied differences between the male and female face and the male and female facial skeleton.[12] Using knowledge of facial differences between the sexes, effective transformational facial feminization surgery procedures were devised.[4,5,13]

On systematic anatomical analysis, phenotypic difference between the male and female face become apparent. The male upper third face begins with an M-shaped hairline and has a more prominent, longer, sloping forehead. The central brow above the nasal radix is bossed from the underlying frontal sinus. The male lateral brow arch tends to be flat or only slightly arched. By contrast, the female hairline is set lower and resembles an upside-down V shape, and the forehead has a milder slope.[14] The female central brow is flat and blends into the nasal radix. The female lateral brow is arched or peaking vertically at the lateral limbus. In the midface, the male nose is longer, wider, with a more prominent dorsal hump; the female nose has a lower radix;

Table 2. Lateral Brow (Supraorbital Rim) Types and Indicated Corrective Techniques*

Lateral Brow Type	Defining Features	Techniques for Transformation	Prevalence (%)
1	No or minimal supraorbital overhang	No surgery	8/50 (16)
2	Moderate supraorbital overhang	Burring	33/50 (66)
3	Significant overhang; extending down lateral orbital wall	Ostectomy	9/50 (18)

*Type 2 requiring burring of the overhanging bone is the most common.

Table 3. Mandibular Angle (Lower Face Width) Types and Indicated Corrective Techniques*

Lower Face Width Type	Defining Features	Techniques for Transformation	Prevalence (%)
1	Mild lower face width	Masseter resection serial botulinum toxin type A	5/50 (10)
2	Moderate lower face width	Angle burring, masseter resection	12/50 (24)
3	Significant lower face width/acute angle	Mandibular angle resection	33/50 (66)

*Type 3 requiring mandibular angle resection is the most common.

Table 4. Chin Types and Indicated Corrective Techniques*

Chin Type	Defining Features	Techniques for Transformation	Prevalence (%)
1	Mild chin width	Burring	3/50 (6)
2	Moderate chin width	Osseous genioplasty narrowing	23/50 (46)
3	Significant width, increased lower face height	Osseous genioplasty narrowing; vertical shortening	10/50 (22)

*Type 2 requiring osseous genioplasty narrowing and advancement is the most common.

Table 5. Comparative Outcomes of Facial Feminization Surgery with Virtual Surgical Planning versus No Preoperative Planning for Forehead and Lateral Brow*

Regions for Transformation	Forehead			Lateral Brow		
	Efficiency (min)†	Safety†	Accuracy†	Efficiency (min)	Safety	Accuracy
VSP	19 ± 3	25/25 (100%)	97± 4%	18 ± 2	25/25 (100%)	94 ± 4%
No preoperative planning	44 ± 5	21/25 (88%)	79 ± 3%	20 ± 3	24/25 (96%)	88 ± 5%

VSP, virtual surgical planning; EVC, expected volumetric change; AVC, actual volumetric change.
*Facial feminization surgery with VSP was more accurate and efficient in the forehead region. Efficiency = procedure time (min); safety = avoidance of inadvertent intracranial injury or sensory nerve injury; accuracy = absolute value of (EVC – AVC) × 100/EVC.
†$p < 0.05$.

Table 6. Comparative Outcomes of Facial Feminization Surgery with Virtual Surgical Planning versus No Preoperative Planning for Lower Face Width and Chin:

Regions for Transformation	Lower Face Width			Chin		
	Efficiency (min)	Safety*	Accuracy*	Efficiency (min)	Safety	Accuracy
VSP	34 ± 3	25/25 (100)	95± 4%	18 ± 2	25/25 (100%)	95 ± 4%
No preoperative planning	37 ± 3	22/25 (88)	58 ± 2%	24 ± 3	23/25 (92%)	88 ± 5%

VSP, virtual surgical planning; EVC, expected volumetric change; AVC, actual volumetric change.
*Facial feminization surgery with VSP was more accurate and efficient in the lower face width (mandibular angle region). Efficiency = procedure time (min); safety = avoidance of inadvertent intracranial injury or sensory nerve injury; accuracy = absolute value of (EVC – AVC) × 100/EVC.
†$p < 0.05$.

narrower, smoother dorsum and supratip break; and greater tip rotation. The male lip is longer than the female lip. In the lower third of the face, the male jaw is square, angulated, and appears wider because of lateral ridging/lipping of the mandibular angle and a bulkier masseter. By contrast, the female lower face is triangular. The male face has a wider, longer, and often more protruding chin, whereas the female chin is shorter and more narrow.[15] Previous studies suggest that the male chin may be as much as 20 percent longer than the female chin.[16]

Despite these general descriptive differences, our anatomical cadaveric study showed variation and gradation of masculine features. These variations were separated into morphologic types. Preoperative skeletal analysis with the use of computed tomographic imaging allowed for regional morphologic typing. In our cadaveric study, we found that for each of the four regions, there was one morphologic type that predominated. For the frontal brow and lateral lower face width regions, type 3 predominated, and for the lateral brow and chin regions, type 2 predominated. Thus, in the majority of cadavers, the brow, lateral supraorbital, mandibular angle, and mental regions were significantly "masculine" enough to warrant modification of the craniofacial skeleton. Both type 2 and type 3 required craniofacial osteotomy techniques.

Traditionally, the amount of recontouring and reduction of bony prominences performed was based on artistic insight and experience. However, with that traditional approach, underresection, overresection, or unequal (side-to-side) resection are possible. In our study, the traditional approach (i.e., no–preoperative planning group) was less accurate compared with the virtual surgical planning group in facial feminization surgery that used surgical cutting guides. For all four regions operated on, there was less accuracy without the use of virtual surgical planning when the virtual plan was compared to the actual three-dimensional computed tomographic outcome. This was particularly true for the frontal brow region with an anterior frontal sinus wall setback and for the lower facial width region with mandibular angle reduction. Most importantly, the virtual surgical planning group demonstrated improved *safety* with regard to reduced intracranial injury (with the frontal sinus osteotomy) and decreased nerve injury (with the mandibular angle osteotomies). As surgeon experience increases, the likelihood of these safety mishaps are less likely, but with virtual surgical planning, they can be minimized altogether. Also, the virtual surgical planning group had greater efficiency with decreased operative times compared with the no–preoperative planning group. This benefit of efficiency using virtual surgical planning likely decreases with increasing experience. Also, additional time is spent by the surgeon for preoperative virtual surgical planning.

For the frontal brow region, the anterior frontal sinus wall setback had the greatest decrease in comparable operative time (group 1, 19 minutes; group 2, 44 minutes). This is likely attributable to greater surgeon confidence and control of the resection margin while using the cutting guides for anterior sinus wall removal. In addition, the frontal sinus wall was taken in one piece, sectioned horizontally, and fixed with a custom plate, and the borders were contoured to create a flat forehead (Fig. 2). This expedited technique was faster than the no–preoperative planning group, with piecemeal removal of the anterior sinus wall followed by wiring of the individual bony segments. Virtual surgical planning for the frontal brow minimized the need for intraoperative revisions and adjustments. These decreased operative times with virtual surgical planning were seen from the very first virtual surgical planning cases. With no preoperative planning, there is a learning curve with long operative times for the first several cases and then a slow decrease in operative times as one gains experience. For the lateral brow region, the virtual surgical planning group showed only small improvements with efficiency, safety, and accuracy that were not significant compared with the no–preoperative planning group.

Injury to the inferior alveolar nerve is a considerable concern during mandibular angle resection.[17,18] In our study, the virtual surgical planning group had fewer inferior alveolar nerve injuries and better side-to-side symmetry following resection. Although injury to molar tooth roots has been reported in mandibular angle reduction, we did not see that in any cases.[19] The authors feel that for type 2 and 3 morphology (90 percent), an angle resection with simultaneous limited masseteric reduction is superior to rasping.[19] For the chin, the virtual surgical planning group showed only small improvements with efficiency, safety, and accuracy that were not significant compared to the no–preoperative planning group. Interestingly, the time necessary to place the cutting guides did not adversely affect the operative time despite this being an added step.

A theoretical advantage to using virtual surgical planning (not studied here) is the positive aspect of involving the facial feminization surgery patient with treatment decisions preoperatively. Candidates for these procedures are very involved with their health care decision-making. Preoperative information given in the right way to these patients may reduce perioperative anxiety and improve overall patient experience.[20,21] We also recognize that it will not be valuable to involve some patients in planning cutting guides, as they will have a poor understanding of how surgical technique translates into clinical outcomes.

This cadaveric study allowed us to standardize the methodology for facial feminization surgery and control for many variables; however, there were limitations. This study did not represent a true operative environment with considerations for bleeding and anesthesia. There is a need for in vivo intraoperative reproducibility. Perioperative concerns including surgical-site infections, reaction to foreign body, and bone healing could also not be assessed. Most importantly, before one could suggest superiority of one method over another, a comparative study on patient-reported outcome measures and clinical safety would be necessary. This is warranted to help validate these new techniques for this patient population that is willing to accept significant social, psychological, and medical risk to achieve their health goals. One limitation of using virtual surgical planning is that the result is only as good as the preoperative plan at the time of virtual planning. This study does not attempt to comment on the skill of the planner as it pertains to the final result. Previous reports document that forehead surgery may be safely performed in experienced hands.[22] Finally, age of patients requesting facial feminization surgery may be younger than the mean 54.3 years of our cadaveric group.

In summary, this cadaveric study demonstrated improvement in efficiency (time), safety (less injury), and accuracy (ability to replicate surgical plan) with the use of virtual surgical planning for regional facial feminization surgery techniques of the forehead, lateral lower face, and chin. Use of virtual surgical planning in dealing with the heterogeneity of facial features and the difficult nature of craniofacial contouring procedures improves a plastic surgeon's chance of achieving ideal results for the facial feminization surgery patient. Otherwise, without virtual surgical planning, only the expert with immense experience, precise technical skill, and immense visuospatial perception will be able to achieve aesthetically satisfying results with low complications. In addition, the transwoman undergoing gender confirmation surgery of the face, should be involved in the preoperative planning. Virtual surgical planning allows for transwomen to have a role in creating the final appearance of femininity.

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