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ORIGINAL ARTICLE

Preoperative Digital Three-Dimensional Planning for Rhinoplasty

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Abstract
Background This report describes preoperative digital planning for rhinoplasty using a new three-dimensional (3D) radiologic viewer that allows both patients and surgeons to visualize on a common monitor the 3D real aspect of the nose in its inner and outer sides.
Methods In the period 2002 to 2008, 210 patients underwent rhinoplasty procedures in the authors' clinic. The patients were randomly divided into three groups according to the type of preoperative planning used: photos only, a simulated result by Adobe Photoshop, or the 3D radiologic viewer. The parameters evaluated included the number of patients that underwent surgery after the first consultation, the number of patients who asked for a re-intervention, patient satisfaction (according to a test given to the patients 12 months postoperatively), the surgical time required for a functional intervention, and the improvement in nasal function by postoperative rhinomanometry and subjective evaluation.
Results Computer-aided technologies led to a higher number of patients deciding to undergo a rhinoplasty. Simulation of the postoperative results was not as useful in the postoperative period due to the higher number of reintervention requests.
Conclusion The patients undergoing rhinoplasties preferred new technologies in the preoperative period. The advantages of using the 3D radiologic viewer included improved preoperative planning, reduction in intraoperative stress, a higher number of patients undergoing surgery, reduction in postoperative surgical corrections, reduction in surgical time for the functional intervention, a higher rate of improvement in nasal function, a higher percentage of postoperative satisfaction, and reduced costs.

Keywords Preoperative digital planning · Rhinoplasty · Three-dimensional planning

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Communication with the patient is the basis of preoperative analysis and planning for plastic and reconstructive surgery. Each patient should understand his or her condition and the surgical goals. The patient also should be informed about the possible outcome and the risks of the suggested treatment. In rhinoplasty, many methods have been used over recent decades for preoperative analysis [6, 7, 11, 18, 19], planning [2, 5], and communication with the patient. Drawings on costly photographs [9, 10, 25] (since Jacques Joseph [12]) enlarged and littered with lines and angles, look-through techniques, radiographs, facial casts, and cephalometric measurements all may be used to visualize the patient's wishes and demonstrate the surgical possibilities [1].

As early as 1986, not long after the introduction of the personal computer, surgeons began incorporating digitized photography techniques [8] into their practice. With the help of photo-editing software (i.e., Adobe Photoshop), every surgeon currently may become an artist and alter the patient's nasal profile according to his or her wishes and make it appear as a realistic postoperative result [4, 15–17, 20–23]. In addition, some attempts have been made to plan rhinoplasties and other facial surgeries using surface scanners [13, 14, 24]. These systems create a textured surface model and allow for simulation of the surgery by deforming the scanned surface. However, because the information is limited to the external facial surface, no insight into the internal structures is provided.

Over the past 7 years, the authors have been using, with growing enthusiasm, a new advanced computer technology in the preoperative planning of functional and aesthetic rhinoplasty. This technology consists of a three-dimensional (3D) radiologic viewer (Alma3D; Alma IT Systems, Barcelona, Spain) that allows 3D reconstructions using digital computed tomography (CT) images in standard digital imaging and communications in medicine (DICOM). These images can clarify anatomic preoperative visualizations and the needed surgical corrections onto a common screen that both the patient and surgeon can appreciate (Fig. 1). Strictly speaking, this new technology offers an enhancement of the usual 2D images, not 3D views, because the images appear on a common digital monitor. Some refer to it as 2½D. To underscore this slight difference, quotation marks are used for expressions of “3D” in this report.

The following analysis aims to add further knowledge and experience to preoperative digital planning for rhinoplasty with the use of a new technology, including its effect on improvement of communication with the patient.

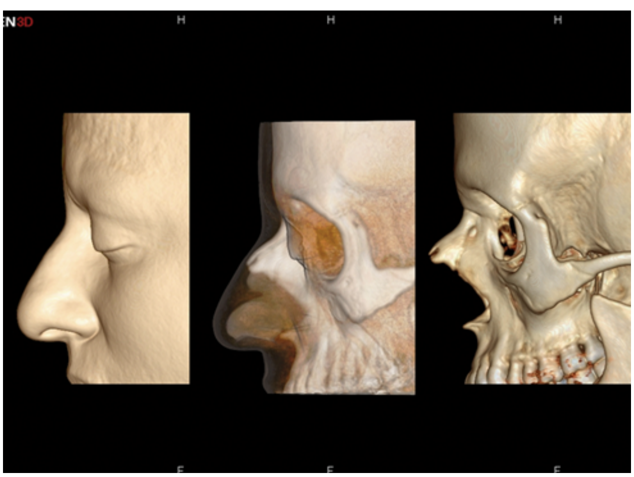


Fig. 1 The surgeon and the patient can view all the structures involved in a nasal deformity. The figure in the middle clearly shows the nasal bones, the nasal spine, the soft tissues, and the nasal vestibular air cavity with introflection of the triangular cartilages

Materials and Methods

In 2002, we began using the “3D” radiologic viewer (Alma3D, version 1.0 and updated versions 2.1 and 3.1) to create computer imaging “3D” reconstructions. Between March 2002 and January 2008, 231 patients came to our clinic requesting a rhinoplasty. Of these 231 patients, 210 underwent the intervention.

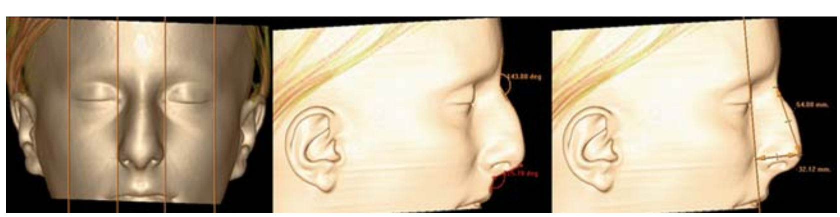
During the first consultation, the patients were randomly divided into three surgery groups, each consisting of 70 patients. All the patients who experienced a functional respiratory problem were investigated by pre- and postoperative rhinomanometry. Each patient came to our office twice before the operation.

The patients in group 1 underwent surgery after evaluation with only a clinical examination. During the first visit, procedures and results were discussed using patient photos, with simple lines and schemes marked by a pencil. The patients in group 2 were shown a postoperative simulated result by Adobe Photoshop during the first visit. The group 3 patients, during the first visit, were shown facial anatomic “3D” reconstructions of other patients. A facial CT scan was requested for these patients. During the second visit, the individual inner and outer anatomy was evaluated, a digital preoperative plan was made (Fig. 2), crucial structures for modification were identified, and all the procedures were discussed with the patients as well as the possible functional and aesthetic results.

The “3D” radiologic viewer used in this study is a module for reconstruction and advanced “3D” visualization that allows reconstruction of virtual 3D models for the study of images in standard DICOM format (CT). It permits segmentation of the visualized model for isolation and analysis of different tissues and has advanced tools for taking linear and surface measurements.

The computer “3D” reconstructions in this study were performed with different views and following different planes in the office with the patient interacting (Fig. 3). The patient’s wishes and expectations were correlated with the individual anatomy, the surgical possibilities, and the surgeon’s professional advice. For computer visual

Fig. 2 Evaluation of “3D” digital reconstruction and anthropometric parameters



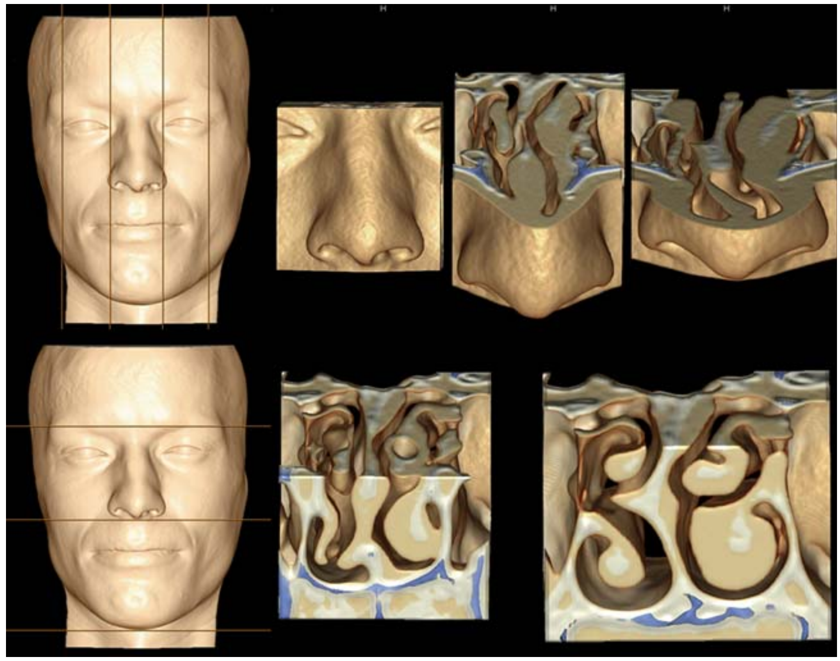


Fig. 3 Evaluation of the aesthetic facial proportions and views at the inner aspect of the air cavities. Septal deviation and consequent turbinate hypertrophy are clearly demonstrated. The "3D" reconstructions and the possibility of isolating and magnifying all the structures of interest gives information preoperatively on the real anatomic situation of the patient

communication, an IBM compatible personal computer with a standard flat screen monitor was used.

For all the groups, we evaluated the number of patients who decided to undergo surgery, the number of patients who requested a reintervention, and the patients' satisfaction (determined by a test given to the patients 12 months postoperatively) (Table 1). The results of this study are shown in the Table 2. Furthermore, for all the patients in each group undergoing aesthetic and functional surgery, we also evaluated surgical time, improvement in nasal function proved by a postoperative rhinomanometry, and improvement in nasal function determined by subjective evaluation (Table 3).

Table 1 Postoperative patient satisfaction

Patient test	No	Something	A lot	Wholy
How did your surgeon explain to you procedures, possible results, and complications of the rhinoplasty?				
Do you appreciate the way procedures, possible results, and complications of your operation were explained to you?				
Did you understand the procedures, possible results, and complications of the rhinoplasty before the operation?				
Are you satisfied with the postoperative result?				
Do you think that the postoperative result was similar to what was explained preoperatively?				

Table 2 Study results: Number of patients undergoing surgery and requesting reoperation

	G1[a] *n* (%)	G2[b] *n* (%)	G3[c] *n* (%)
Patients (*n*)	86	75	70
Patients who underwent surgery after the first consultation[d]	70 (81.4)	70 (93.3)	70 (100)
Patients requesting a reoperation[e]	7 (10)	8 (11.4)	1 (1.4)

[a] Group 1: aesthetic surgery with the aid of photos

[b] Group 2: aesthetic surgery with the aid of simulated postoperative results

[c] Group 3: aesthetic surgery with the aid of the "3D" radiologic viewer

[d] p Values for pairwise comparisons: G1/G2 (0.025), G2/G3 (0.028), G1/G3 (0.000)

[e] p Values for pairwise comparisons: G1/G2 (0.785), G2/G3 (0.016), G1/G3 (0.029)

The 210 patients (124 women and 86 men) in this study ranged in age from 17 to 60 years (mean, 26 years). They were followed up 1 to 5 years postoperatively (mean, 3 years). We obtained informed consent from each patient to use his or her images.

The day before surgery, the author revised the facial "3D" reconstructions for each patient in group 3. The following parameters were visualized and studied: anthropometric measures (including facial thirds, facial fifths, nasal length, nasal projection, nasal width, alar base, and columella), the nasolabial angle (with the nasal spine), the nasofrontal angle (evaluating the amount of soft tissues and nasal-frontal bones), osteotomy lines (marked on the bones at the right level, viewed at the angular artery, and

Table 3 Nasal function results

	G1[a] *n* (%)	G2[b] *n* (%)	G3[c] *n* (%)
Patients (*n*)	38	43	40
Surgical time (min)	94.7	87.3	57.8
Patients improving nasal function (rhinomanometry)[d]	34 (89.4)	36 (83.7)	40 (100)
Patients improving nasal function (subjective evaluation)[e]	34 (89.4)	38 (88.3)	39 (97.5)

[a] Group 1: functional and aesthetic surgery

[b] Group 2: functional and aesthetic surgery

[c] Group 3: functional and aesthetic surgery

[d] *p* Values for pairwise comparisons: G1/G2 (0.451), G2/G3 (0.008), G1/G3 (0.035)

[e] *p* Values for pairwise comparisons: G1/G2 (0.875), G2/G3 (0.109), G1/G3 (0.148)

transferred to the skin), and the nasal cavity (valvular area, septum, and cornet malformations). For the patients in groups 1 and 2, anthropometric measures were studied on common digital photos.

Results

The senior author, who has 25 years of experience with rhinoplasty, performed the operations for all the patients in this study. The results for the groups are presented in Tables 2 and 3, and the results for the patient satisfaction test are shown in Table 4.

The use of the "3D" viewer during the first consultation had a positive influence on the number of patients who decided to undergo surgery compared with the use of photographs. This difference between the use of the "3D" viewer and the use of both photographs (group 1 vs group 3, $p = 0.000$) and simulated results (group 2 vs group 3, $p = 0.028$), as determined by chi-square testing, was statistically significant [3]. Statistically significant differences also were found between the use of photographs and the use of simulated results (group 1 vs group 2, $p = 0.025$).

Important differences were found in the number of patients who requested a surgical correction of the result obtained. Significantly fewer patients requested such correction in the "3D" viewer group than in the simulation group (group 2 vs group 3, $p = 0.016$) or the photograph group (group 1 vs group 3, $p = 0.029$). No statistically significant difference was found between the use of photographs and the use of simulations.

Both the "3D" radiologic viewer results (group 3) and the simulated postoperative results by Adobe Photoshop (group 2) were judged positively by the patients as aids for explaining procedures, possible results, and complications. However, postoperative satisfaction was higher in group 3. The "3D" radiologic viewer was judged to be more effective in helping the patient to understand the procedures, possible results, and complications of rhinoplasty before the operation (Table 4).

Table 4 Patient understanding of procedures, results, and complications[a]

Patient test	No *n* (%)	Something *n* (%)	A lot *n* (%)	Wholy *n* (%)
Do you appreciate the way the procedures, possible results, and complications of your operation were explained to you?	G1 2 (2.8) G2 G3	G1 49 (70) G2 2 (2.8) G3	G1 19 (27.1) G2 3 (4.2) G3 2 (2.8)	G1 G2 65 (92.8) G3 68 (97.1)
Did you understand the procedures, possible results, and complications of rhinoplasty before the operation?	G1 5 (7.1) G2 G3	G1 19 (27.1) G2 17(24.2) G3 1 (1.4)	G1 45 (64.2) G2 48 (68.5) G3 4 (5.7)	G1 1 (1.4) G2 5 (7.1) G3 65 (92.8)
Are you satisfied with the postoperative result?	G1 8 (11.4) G2 11 (15.7) G3 2 (2.8)	G1 5 (7.1) G2 13 (18.5) G3 1 (1.4)	G1 51 (72.8) G2 36 (51.4) G3 3 (4.2)	G1 6 (8.5) G2 10 (14.2) G3 64 (91.4)
Do you think that postoperative result was similar to what was explained preoperatively?	G1 14 (20) G2 12 (17.1) G3 3 (4.2)	G1 6 (8.5) G2 34 (48.5) G3 4 (5.7)	G1 48 (68.5) G2 22 (31.4) G3 1 (1.4)	G1 2 (2.8) G2 2 (2.8) G3 62 (88.5)

[a] Group 1 (G1) (70 patients), G2 (70 patients), G3 (70 patients)

The mean surgical time for the patients in group 3, who were studied by the "3D" radiologic viewer and treated with aesthetic and functional surgery was 77.8 min. This was shorter than the surgical times the patients in groups 1 and 2 who underwent functional and aesthetic surgery. The difference in surgical time for a cosmetic procedure only among all the groups was not statistically significant (data not shown in this report).

The patients in group 3, studied preoperatively by the "3D" radiologic viewer, improved their nasal function more than the patients of groups 1 and 2, who were not studied by the "3D" viewer. This was evidenced by the use of rhinomanometry (group 1 vs group 3, $p = 0.035$; group 2 vs group 3, $p = 0.008$), although no significant differences were found in the patients' subjective evaluations of their improvement in nasal function.

Discussion

In nasal surgery, it is very important to use every instrument that helps to improve communication with patients [15–17, 20–23] and surgical preoperative planning [2, 5–11]. Patients and surgeons should agree on achievable goals before the surgical procedure.

In this study, we compared three different procedures used to manage patients requesting rhinoplasty, from the time they entered the clinic to the evaluation of their postoperative result. As shown in Tables 2 and 3, the patients preferred the aid of computer imaging during the preoperative consultations rather than simple photos and schemes. They had become aware of computer imaging and frequently asked for it when making an appointment by telephone. Although the simulation (morphing) of a possible postoperative result by common imaging software proved to be very effective during the preoperative period in impressing patients and convincing them to undergo surgery, in the postoperative period, the results were not similarly positive. A relevant percentage of the patients (11.4%) asked for a reoperation due to their dissatisfaction with the obtained postoperative result compared with the simulation.

In contrast, the results obtained with the aid of the "3D" radiologic viewer have proved it to be a sophisticated instrument for communicating with the patient during consultation. It has become a marketing tool that should not be underestimated. Imaging in front of the patients that offers them the possibility of accurately studying their own anatomy and planning their own surgical procedure is very impressive and helpful. With this imaging, patients better understand the anatomy, the procedures, and the possible results. We think that the "3D" radiologic viewer increases the patients' trust in our operations.

During this study, use of the sophisticated "3D" facial reconstructions in functional procedures improved both our surgical times and patients' nasal function (according to tests by postoperative rhinomanometry and subjective evaluation), probably because of more accurate preoperative planning and better understanding of the structures to be modified. The "3D" viewer allowed us preoperatively to study the following clearly:

1. The nasal dorsum (including any deviation, characteristics of the nasal bones, relative height of the nasal bridge, width of the dorsum and bony base, and transition into the nasal tip)
2. The nasal tip (including tip shape, definition or lack of definition of the tip, presence of surface defects, relationship of the columella to the alar rims, and nasal base width)
3. Profile characteristics (including position of the radix, slope of the dorsum, dorsal irregularities, presence or absence and location of a supratip break, amount of tip projection, nasal length, columellar/labial angle, columellar/lobular angle, nostril height and shape, prominence of the columella, length and relative position of crura, and nasal spine)
4. Basal characteristics (including nostril size, symmetry, nasal width, columellar width, alar position and symmetry, and tip definition)
5. Inner characteristics (including nasal valve morphology, septal deviations, cornet malformations, and sinus pathologies).

In addition, full facial views to determine the relative size of the nose and its relationship with other facial features are possible. By determining preoperatively which structures need modification, stress can be reduced for the surgeon, who can now go directly, with confidence, to change an already "known" nasal subunit, both functionally and aesthetically, without wasting time.

The data are stored on a CD, which can be used and managed easily with a standard computer and reviewed as often as necessary. The procedure is simple and speedy, requiring only 15 min.

The main disadvantage of the "3D" viewer is the radiation experienced by the patient. The need for a CT scan in planning a rhinoplasty may not be approved by all surgeons. The authors think that CT scanning without the "3D" radiologic viewer could not be justified currently except for osteocartilaginous deformities of the pyramid, wide septal perforations (to size and design the prosthesis), cornet malformations (concha bullosa), complications followed by dorsal transplants or implants, and congenital malformative syndromes (Figs. 4 and 5). However, in our personal experience, the advantages of using the "3D" radiologic viewer in the management of patients requesting

Fig. 4 A 17-year-old girl who experienced a rare inherited fragile bone syndrome called “osteogenesis imperfecta.” She came to the authors’ office asking for a rhinoplasty, and a computed tomography scan was prescribed. The “3D” reconstructions yielded much useful information preoperatively. The hypoplasia of the maxillary bones and the whole neurofacial skeleton, the abnormal dental distribution, and the generalized thinning of the bones are evident

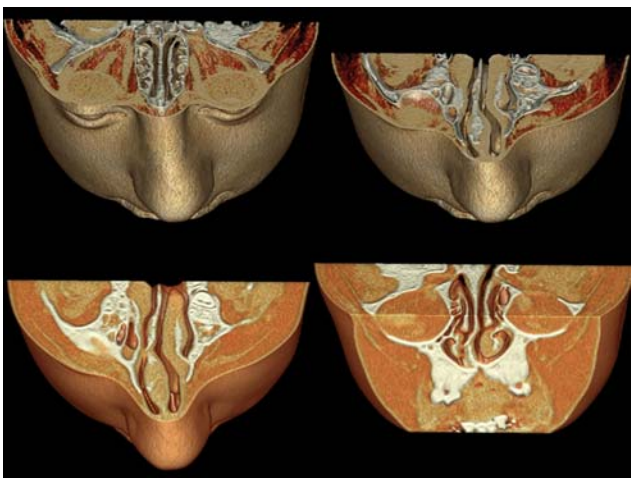


Fig. 5 The same patient as in Fig. 4. The inner “3D” views clearly demonstrate the facial skeletal alterations such as maxillary hypoplasia, absence of the maxillary sinus, septal deviation, left inferior turbinate hypertrophy, and thinning and asymmetry of the palatal bones

rhinoplasty are sufficiently significant for a preoperative CT to be requested. These advantages include improved preoperative planning, reduction of intraoperative stress, a greater number of patients with improved nasal function, reduction in surgical time for functional procedures, a greater number of patients undergoing surgery, reduction in postoperative surgical corrections, a higher percentage of postoperative satisfaction, and reduction of costs,.

Conclusions

Preoperative digital “3D” facial radiologic reconstructions not only educate and promote communication between the patient and the surgeon but also turn the patient into an active participant in the surgical process. The patient gains important knowledge, realistic expectations, and relief of anxiety. Computer digital views should currently be seen as a very interesting marketing ploy and an important component of preoperative planning for cosmetic and reconstructive rhinoplasty. The software is easy to handle, even for nonexperts.

From an academic standpoint, 3D computer imaging facilitates the training of residents and makes education easier and more efficient. The authors wholeheartedly recommend incorporating computer imaging into the preoperative consultation for patients who desire a rhinoplasty.

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