OPEN
PRS GLOBAL OPEN
ORIGINAL ARTICLE
Cosmetic

Comparing Postoperative Taping vs Customized 3D Splints for Managing Nasal Edema after Rhinoplasty

Anmol Patel, MD*
Alexandra N. Townsend, BS*
Alexandra R. Gordon, MS*
Jillian S. Schreiber, MD*
Oren M. Tepper, MD*†
John Layke, DO‡

Background: Significant swelling after rhinoplasty can temporarily obscure results and lead to distress for patients and surgeons. We recently developed three dimensional (3D)-printed nasal splints that aim to protect the nose and limit edema by applying gentle compression. This prospective, randomized study compares postoperative nasal edema in patients being treated with traditional taping versus 3D-printed splints.

Methods: Patients undergoing primary rhinoplasty (2019–2020) were randomized into two groups: taping versus 3D-printed splinting. For 12 weeks, patients either applied steri-strips to the dorsum and tip, or used 3D-printed splints, which were based on nasal simulations. The percentage change in volume (cm^3) was calculated for the total nose, dorsum, and nasal tip at various time points.

Results: Nasal taping (n = 34) demonstrated a volume reduction of 4.8%, 9.9%, 10.0%, 10.3%, and 10.6% (compared with baseline) at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year, respectively. In contrast, the resolution of swelling with 3D splints (n = 36) was 5.0%, 8.6%, 11.0%, 14.9%, and 15.1% at the same time points. Inter-group comparison showed that 3D splints led to significantly less edema of the total nose at 6 months and 1 year ($P \leq 0.05$), as well as consistent reductions in the tip and dorsum, specifically (1 year, $P \leq 0.1$, 0.01, respectively).

Conclusions: 3D-printed splints after rhinoplasty leads to a significant reduction of edema, most noticeable at 6 months and 1 year. This study suggests that customized 3D-printed splints offer an effective clinical alternative to traditional taping to reduce postoperative edema after rhinoplasty. *(Plast Reconstr Surg Glob Open 2023; 11:e5285; doi: 10.1097/GOX.0000000000005285; Published online 21 September 2023.)*

INTRODUCTION

Postoperative edema is inevitable in all cases of rhinoplasty and has been shown to be long-standing, lasting up to 1 year or more. Unfortunately, this can be a significant contributor to patient dissatisfaction due to the delayed visualization of the final aesthetic result.[1–4] Despite the clinical significance of postoperative edema, there is currently no standard management of this phenomenon in rhinoplasty. Methods that have been used include pharmacologic approaches (such as corticosteroids, NSAIDs, and herbal supplements) or manual techniques (such as head elevation, nasal packing, use of drainage tubes, and nasal taping).[5–8]

Recent developments in 3D printing technology may present a unique opportunity for entirely new approaches to manage edema. For instance, Erdogan et al recently described the use of custom printed 3D splints to improve short-term effects on periorbital edema postrhinoplasty compared with thermoplastic splints.[9] In this study, the authors show a significant reduction in periorbital edema and ecchymosis, using 3D custom external nasal splints compared with traditional thermoplastic splints in the perioperative and early postoperative periods. Since 2017, our group has been applying a similar concept using 3D-printed splints to accelerate postoperative edema resolution and improve nasal contour. The purpose of this study was to determine the potential utility of these

*From the *Montefiore 3D Printing and Innovation Laboratory, Division of Plastic and Reconstructive Surgery, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, N.Y.; †Tribeca Plastic Surgery Collective, New York, N.Y.; and ‡Beverly Hills Plastic Surgery Group, Beverly Hills, Calif.*

Drs. Patel and Townsend contributed equally to this work.

Received for publication June 2, 2023; accepted July 12, 2023.

Presented at Plastic Surgery The Meeting 2021.

DOI: 10.1097/GOX.0000000000005285

Disclosure statements are at the end of this article, following the correspondence information.

Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

customized splints to positively impact swelling. A randomized controlled study was conducted comparing traditional nasal taping methods and 3D-printed splints on long-term postoperative edema.

METHODS

Patient Selection and Treatment

A randomized prospective study was conducted on patients undergoing primary rhinoplasty performed by one of the senior authors (J.L. or O.T.) during 2019 and 2020. At the time of the initial visit, all patients had 3D photographs taken and a 3D simulation as part of their consultation (Vectra Software; Canfield, Parsippany, N.J.). Patients who were scheduled for surgery were then randomized by a mobile application (Randomizer for Clinical Trial, Medsharing, Paris, France), to receive either nasal taping or 3D-printed splints for postoperative management. If patients were randomized to the 3D-printed splint treatment group, a set of custom 3D splints were ordered based on their simulation (MirrorMe3D, New York, N.Y.). The average cost of the custom set of 3D-printed splints is roughly $350. The 3D-printed splint material is composed of a biocompatible polymer with a custom coating for a clear finish. This set consisted of three splints in decreasing size.

Surgical technique included supraperichondrial dissection at the nasal tip and subperiosteal dissection at the dorsum. Low-to-low lateral osteotomies were performed if needed. Of note, in our study, there were no hemostatic agents used. At the time of surgery, a traditional thermoplastic splint was placed at the conclusion of the case. At the first follow-up appointment at 1 week, the thermoplastic splint was removed, and the randomized treatment protocol was initiated for the subsequent 12 weeks. Each treatment group was instructed to wear the nasal tape or 3D-printed splint nocturnally and, if they were able to tolerate it, throughout the day. Patients were taught how to apply the steri-strips, and taping was performed daily by the patient by applying steri-strips over the dorsum and wrapping around the nasal tip (Fig. 1). For the 3D splint group, patients were instructed to begin with splint number one and then move to the subsequent nasal splint in 1 week, or when the existing splint felt loose (ie, falls of with routine movement; Fig. 2).

Inclusion criteria for this study included a preoperative 3D photograph, a 3D simulation of the intended rhinoplasty result, and postoperative photographs taken at 1 week (used as the reference baseline), 2 weeks, 6 weeks, 3 months, 6 months, and 1 year. This study was approved by the Albert Einstein College of Medicine institutional review board (no. 2020-12422), and all patients signed informed consent.

Takeaways

Question: Does the use of customized 3D-printed splints hasten the resolution of postoperative nasal edema after rhinoplasty when compared with traditional nasal taping?

Findings: A randomized controlled trial was performed with two groups (taping and 3D-printed splints). The intervention was applied for 12 weeks. 3D-printed splinting resulted in statistically more significant volume reduction after rhinoplasty when compared with traditional nasal taping, at time points 6 and 12 months.

Meaning: Customized 3D-printed splints offer an effective alternative to traditional taping, to reduce postoperative edema after rhinoplasty.

Fig. 1. Nasal taping. Representation of nasal taping using steri-strips along the dorsum and nasal tip.

STANDARDIZED 3D ANALYSIS

3D images were analyzed using the Vectra (VAM) software to quantify changes to the nasal soft tissue over time. Postoperative images were registered to the baseline image by manually selecting facial regions unaltered by surgery (forehead and temples), followed by software alignment of the selected identical surfaces. The nose was defined as a 3D object vertically bound from the inferior border of the glabella to the base of the columella and horizontally bound from the alar-cheek groove and the border of the nasal sidewalls. Standardized nasal landmarks (inferior border of glabella, border of nasal sidewalls, alar-cheek groove, columella) were placed on the nose for all baseline and postoperative images (Fig. 3). The nose was also subdivided between the nasal tip and dorsum for further analysis. [**See figure, Supplemental Digital Content 1,** which displays color map for postoperative reduction in edema. A color map was created to measure the reduction in postoperative

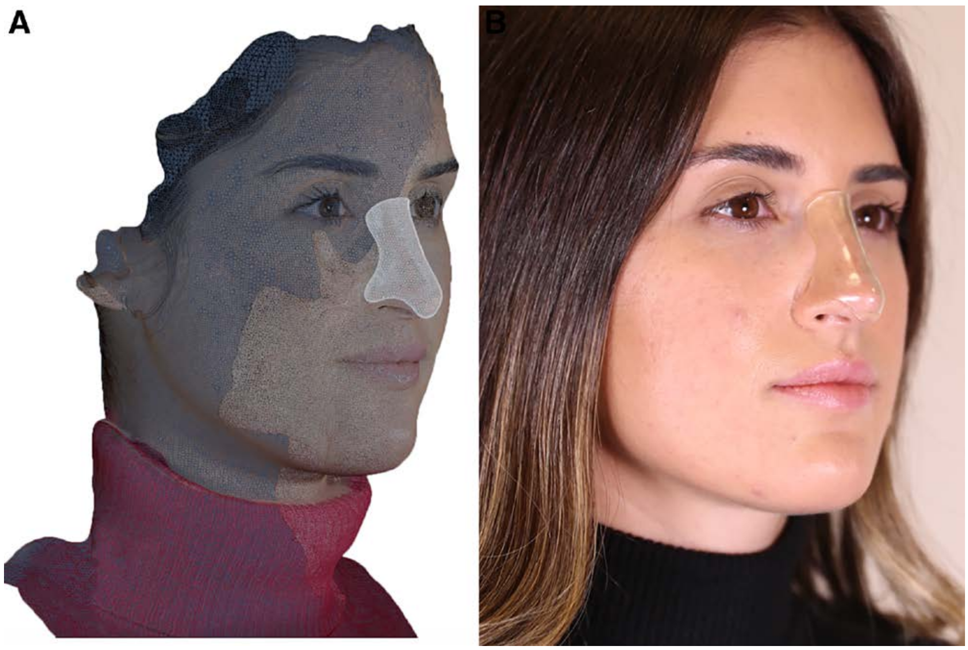

Fig. 2. A virtual overlay and 3D-printed representation of the 3D-printed splint, respectively. A, A 3D wire mesh image with virtual nasal splint overlay created using data generated through 3D image capture. B, A customized 3D-printed splint placed on top of the nose.

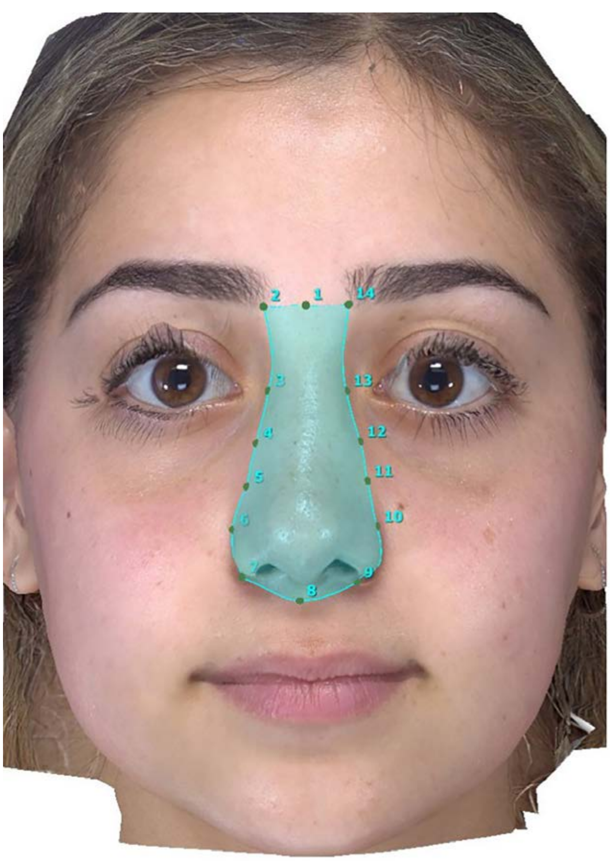

Fig. 3. 3D registration of the nose. Standardized landmarks were placed on the patient's baseline image (1-week postoperative). These exact landmarks were then projected onto the subsequent time points (6-week time point shown).

edema by registering the 1-year postoperative image of the nose onto the patient's baseline image in the (A) taping and (B) 3D-printed splint group. Blue color represents no volume change, whereas red color represents increased volume reduction. http://links.lww.com/PRSGO/C777.]

3D VOLUME

Nasal 3D volume measurements (cm^3) were made by calculating the volume of a closed surface with a plane behind the nose for selections of the total nose, dorsum, and nasal tip. Changes in edema were measured by subtracting volumetric measurements from baseline (1 week postoperative) at subsequent time point intervals. The distribution of edema was calculated as a percentage of total nasal volume in the dorsum and the nasal tip. Further delineation of edema distribution was achieved by creating topographic color maps and mesh overlays at each interval, compared with baseline, to visualize changes in volume and nasal contour (Fig. 4).

STATISTICAL ANALYSIS

All volume and surface area measurements were assessed twice to ensure intra-rater reliability. Pearson chi-square test was used to determine statistically significant goodness of fit and independence for the two postoperative management groups. A two-tailed paired samples *t* test was used to ascertain differences within groups of means and standard error. Statistical significance was determined by a *P* value of less than 0.05. Microsoft Excel (Microsoft Corp., Redmond, Wash.) and SPSS Statistics for Windows, version 27.0 (IBM Corp, Armonk, N.Y.) were used to calculate averages, percentages, SDs, and *P* values.

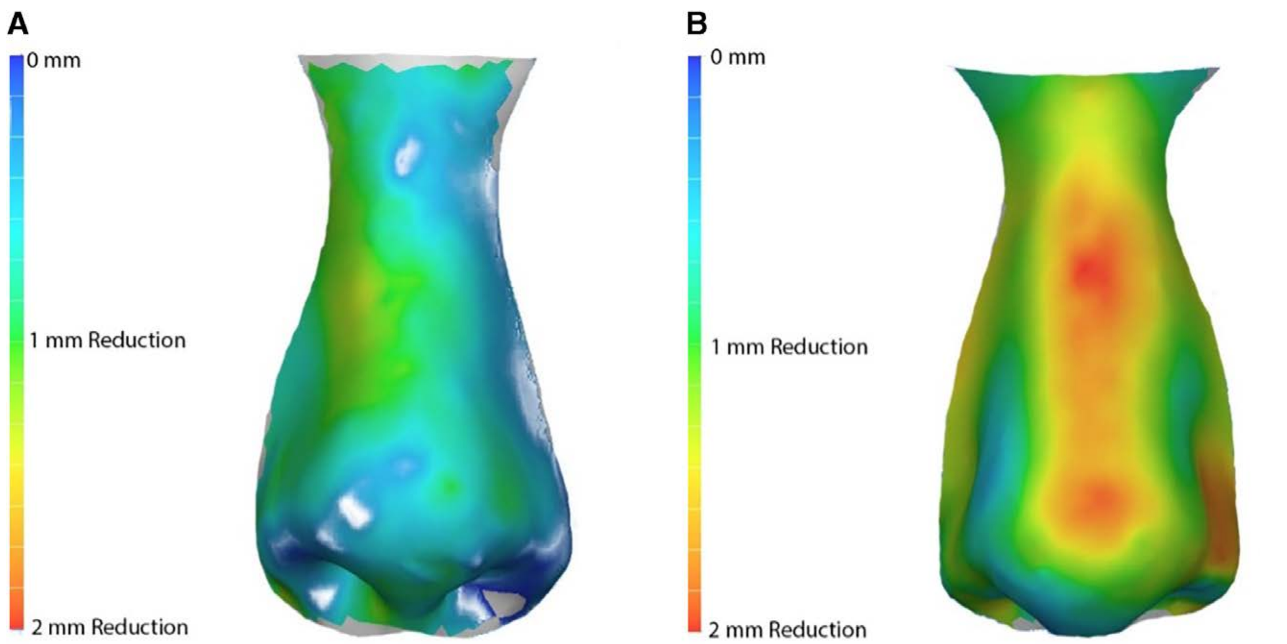

Fig. 4. A color map demonstrating the difference in preoperative and postoperative edema subdivided by nasal region. The total nose was aligned along an x, y, and z axis, with (A) the z axis pointing anteriorly, parallel to the nasal tip point, and the *y*-axis pointing superiorly with the horizontal xz plane aligned at the level of the superior alar crease. The nasal tip and dorsum were delineated by the z plane (B) (nasal tip selected in blue).

Comparisons with a *P* value less than 0.05 were considered statistically significant. Based on an alpha of 0.05, power analysis estimates that significant differences will be detected between groups with a sample size of 36 people in each group with a power exceeding 80%.

RESULTS

Study Demographics

A total of 70 patients met the inclusion criteria for the study, standard nasal taping (n = 34) versus 3D-printed splints (n = 36). The breakdown of patient demographics is shown in Table 1, with no significant differences noted between groups. The postoperative images are displayed for the taping group (Fig. 5) and 3D-printed splint group (Fig. 6) at 1 week and 1 year postoperative.

Table 1. Study Demographics

	Taping	3D Splint
No. patients	34	36
Age (avg years)	28.9 (±10.0)	33.6 (±10.6)
Gender		
Male	7	7
Female	27	29
Technique		
Closed rhinoplasty	2	1
Open rhinoplasty	32	35
Grafts		
Septal extension graft	20	36
Spreader graft	8	11
Auto-spreader flaps	5	1
Columellar strut graft	2	1
Alar construct graft	1	0

TOTAL NASAL EDEMA REDUCTION

Nasal taping led to a total volume reduction of 4.8%, 9.9%, 10.0%, 10.3%, and 10.6% total volume at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year, respectively, compared with baseline. In contrast, 3D-printed splints led to a total volume reduction of 5.0%, 8.6%, 11.0%, 14.9%, and 15.1% at identical time points. Comparison between treatment groups demonstrated that 3D-printed splints led to a significantly greater reduction in total nasal volume at the 6 month and 1 year time points ($P \leq 0.05$).

When looking at the rate of reduction of edema within each group, we noted the rate of reduction to be significant between 2 and 6 weeks in the taping group (Fig. 7). In comparison, the 3D-printed splint group demonstrated a more prolonged effect, with significant reduction between 2 to 6 weeks, and 6 weeks to 3 months ($P \leq 0.05$).

DISTRIBUTION OF VOLUME REDUCTION (DORSUM VERSUS NASAL TIP)

To better understand the resolution of edema according to region, we further analyzed the progression of 3D volumes in the dorsum versus nasal tip. When subdividing by region, we found a variable and statistically insignificant reduction in postoperative edema in the taping group for both the dorsum and nasal tip at the 1-year time point compared with baseline ($P \leq 0.05$). [**See graphs, Supplemental Digital Content 2,** which display the linear regression for fractional volume change. The fractional volume change

Fig. 5. Postoperative images at 1 week and 1 year postoperative in taping group. The (A) frontal and (B) lateral view at 1 week postoperative in the taping group. The (C) frontal and (D) lateral view at 1 year postoperative.

over 1-year was measured at the (A) dorsum and (B) nasal tip and a best fit line was created to illustrate the trend of postoperative reduction of nasal edema. **http://links.lww.com/PRSGO/C778**.] In contrast, in the 3D-printed splint group, both the dorsum and nasal tip demonstrated significant and consistent reductions in edema over the 1-year period compared with baseline ($P \leq 0.01$, 0.01 respectively). In the 3D-printed splint group, there was a significant reduction in the dorsal volume between 3 months and 6 months ($P \leq 0.05$). In the 3D-printed splint group, there was a significant reduction in nasal tip volume between 3 months and 1 year ($P \leq 0.05$).

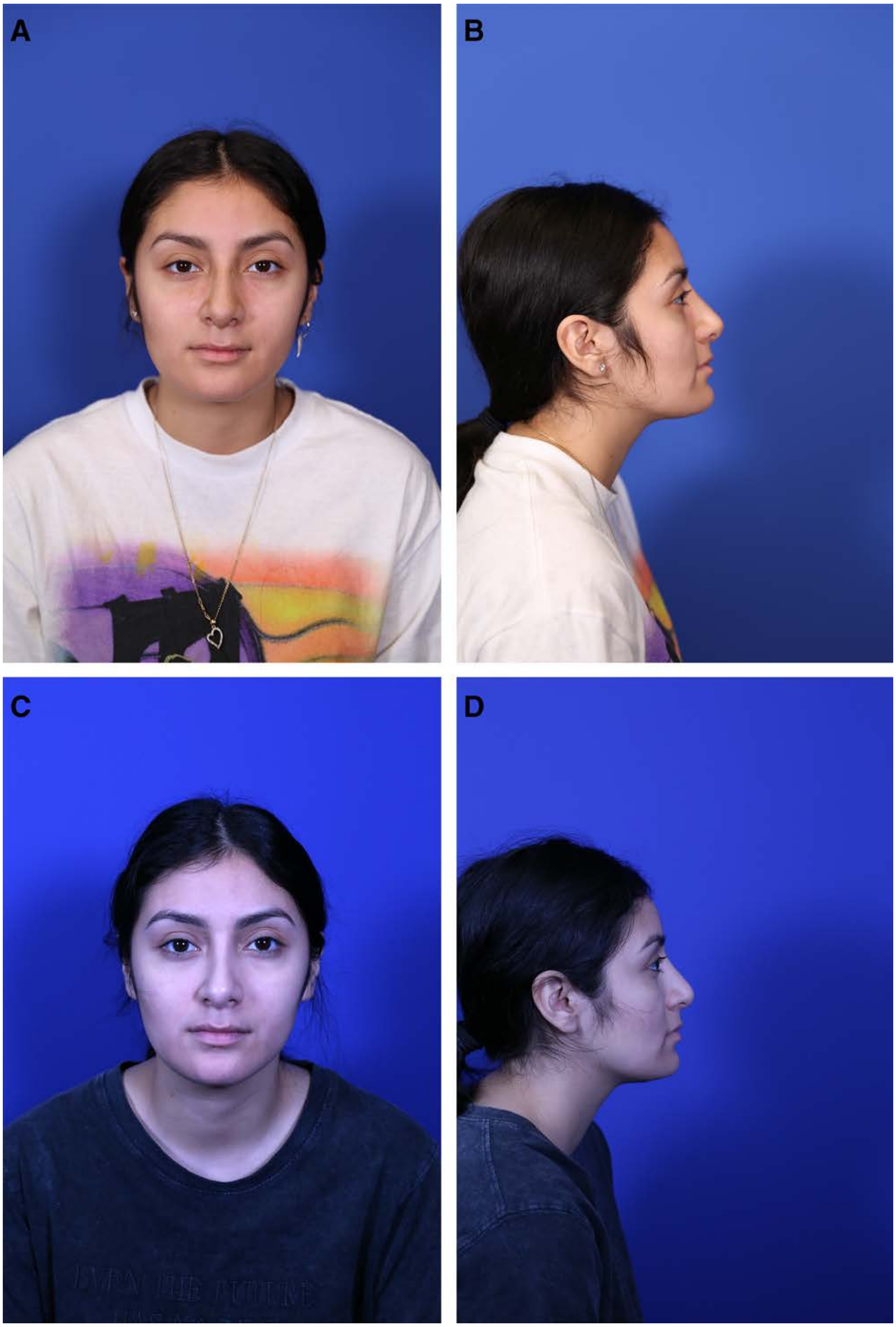

Fig. 6. Postoperative images at 1 week and 1 year postoperative in 3D-printed splint group. The (A) frontal and (B) lateral view at 1 week postoperative. The (C) frontal and (D) lateral view at 1 year postoperative.

DISCUSSION

Postoperative edema after rhinoplasty is inevitable and long-lasting, and leads to delayed aesthetic results and potential patient dissatisfaction. Because residual postoperative edema can linger for up to 1 year or even longer, many surgeons have used various methods to minimize edema, including pharmaceutical and manual approaches, with little to no data supporting one approach over another.[3,4] Of these methods, nasal taping is likely the most common method used by rhinoplasty surgeons today.[6–8] Our group sought to determine the efficacy of a novel approach using 3D-printing, which may provide a more personalized approach and more effective means of controlling postoperative edema.

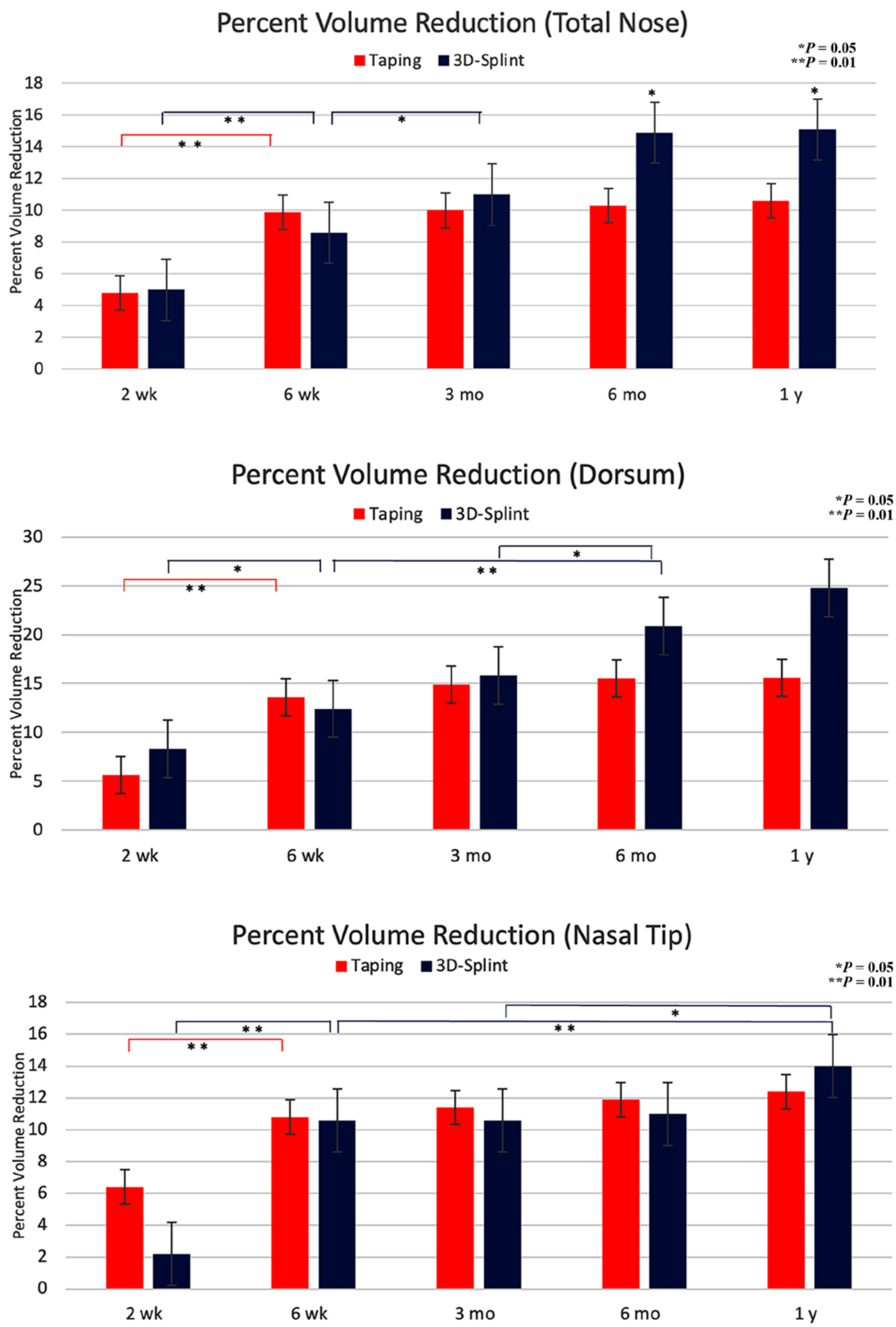

Fig. 7. Percentage volume reduction over time. The percentage nasal volume reduction was measured over time and compared within each treatment group and between groups across time points at the (A) total nose, (B) dorsum, and (C) nasal tip.

There are a number of key findings in this study that support the notion that 3D splints indeed offer advantages over taping. When analyzing both treatment protocol groups at 6 months and 1 year, the two groups exhibited a significant difference in total nasal volume reduction. However it should be noted that at the 1 year time point, the 3D-printed splint group had a greater reduction in total nasal edema compared with the taping group. These results suggest that using 3D-printed splints provides a greater reduction in postoperative edema across the total nose compared with traditional nasal taping. Within this study, we assessed each group for a significant difference in volume reduction between chosen time points. Interestingly, the efficacy of taping was only significant between 2 and 6 weeks in all regions of the nose (total nose, dorsum, and nasal tip). The 3D-printed splint exhibited similar findings as well as additional volume reduction between 6 weeks and 3 months in the total nose. This suggests an accelerated short-term resolution of edema that 3D-printed splints provide over traditional nasal taping. Acknowledging that the majority of postoperative edema after rhinoplasty typically resolves within the first 3 months, the study results are notable and suggestive of 3D-printed splints offering a hastened short-term recovery.[4]

Previously our group reported on postoperative edema resolution, and its effect on the nasal contour, and demonstrated the total amount of postoperative edema to be relatively greater in the dorsum versus the nasal tip.[5] Additionally, our prior study revealed that although dorsal edema is greater than that of the nasal tip, the dorsal volume exhibited faster resolution of edema. The results of this study support this notion by demonstrating postoperative edema resolving more quickly in the dorsum when compared with the nasal tip in the 3D-printed splint group. This has an important clinical implication, as swelling in the nasal tip may be more noticeable due to the complexity of the surface anatomy.[5] This underscores the positive effect of 3D-printed splints compared with nasal taping on nasal tip postoperative edema, as the taping group did not demonstrate significant volume reduction after the 6 week time point.

Although some rhinoplasty surgeons are skeptical of the utility of any postoperative physical measures, such as nasal taping or splinting, on the reduction of edema, the senior author feels that he has used nasal taping for years as he believes that taping does hasten the recovery and accelerate edema resolution. Because standard taping is standard in his practice, the senior author felt no treatment would be inappropriate. The addition of a control group would have been helpful to more clearly delineate the real difference in reduction of postoperative edema between the taping and 3D splinting group. However, although there is no direct control comparison group, this is a study that provides comparative data between the taping and 3D splinting groups. The comparative data showed that swelling does plateau at approximately 12 months and, therefore, there is no strong reason to believe that there would be no significant difference at a lengthened follow-up time comparing the study groups.

One of the reasons that we feel the 3D splinting group experienced greater reduction in postoperative edema when compared with the taping group is the ease of use of the nasal splint. The 3D-printed splint is easy to apply by simply laying it onto the nose, compared with nasal taping, which requires untaping and retaping the nose each day, accurately and consistently. We speculate that not just the customized nasal compression that the 3D splint provided, but also the ease of use of the 3D splint may have led to it yielding more significant volume reduction compared with the nasal taping. This may have resulted in increased compliance due to the less detailed nature of application and the fact that patients found the splint to be somewhat protective. It would be interesting and add value to follow up both treatment groups longer to assess volume reduction after a longer follow-up period. However, lack of follow-up after 1 year makes this metric difficult to attain. Of note, there were no occurrences of contact dermatitis, pressure injury, or any other complications experienced by patients using the 3D-printed splints.

The customized 3D-printed splints were formulated from the simulated rhinoplasty result that was created preoperatively. An ideal scenario would be the production of 3D-printed splints based on the final operative result. However, 3D images taken at the end of surgery are obscured by significant edema, especially when open technique is used. So, to obtain a splint that could be applied after 1 week and match the intended result, we relied on the simulated result to guide the 3D-printed splint mold. The intraoperative guides that are ordered alongside the 3D-printed splints match the nasal profile well. Therefore, the authors feel confident that the profile is well matched at the midline when compared with the simulated result. In comparison, there is likely more variability than paramedian regions which account for bony width and tip width, which are less objectively matched in the operating room. In the randomized controlled trial, there were no instances in which the 3D printed splints did not fit the actual result. However, in the senior author's practice, there have been scenarios in which we were not pleased with the match and reordered the splints. The average time period as to when patients switched to the next, smaller 3D-printed splint, based on patient feedback, was at weeks 2–3.

Although the cost of 3D technology equipment has significantly decreased over recent years, the financial investment still exists, creating a barrier to use. In order for a practice to implement the use of 3D imaging and customized nasal splints, they require a camera that has the capability to capture 3D images. The clinic can then simulate the ideal rhinoplasty result through an accompanying software imaging system and send these files to an outside 3D printing company, where the 3D splints can be made.

Important factors to consider when discussing postoperative edema and results are skin quality and thickness and the surgical maneuvers applied. Optimal skin quality and thin to medium-thickness skin allows for the skin envelope to contract around the underlying cartilaginous structures. Therefore, patients with these skin qualities may have demonstrated more significant volume reduction compared with patients with thicker skin. Unfortunately, the skin quality of the patients in our study was not recorded which limits our ability to assess this factor. Additionally, techniques that may work to control dead space and reduce edema were not used; so it is difficult to assess the impact of these.

One important limitation of this study is the uncertainty surrounding patient compliance, because we have little evidence to confirm their stated adherence to the full regiment of taping or splinting. Given that both treatments were at home, we had no way of ensuring consistent use or proper use of the nasal taping or 3D-printed splints. To our knowledge, all patients adhered to their treatment protocol. Although this does introduce a potentially confounding variable, it is notable that this limitation exists for both study arms. At follow-up appointments, we confirmed patient compliance and adequate technique within each arm of the study.

The promise of 3D-printed splints may suggest a more personalized, in-office approach for the management of postoperative edema after rhinoplasty. The growth, increasing accessibility, and decreasing cost of 3D imaging and printing may allow for the capture of the 3D image and printing of the customized 3D-printed splint in the office. This concept is not all that futuristic, as it mimics the in-office practices of 3D technology in dentistry today. This eliminates the reliance on third party companies for 3D materials, decreases turn around time, and allows the surgeon to address asymmetries that exist in the postoperative period. Additionally, patients expressed that they felt more protected with the 3D-printed splint when compared with the support that traditional nasal taping provided.

CONCLUSIONS

Postoperative edema management is variable among plastic surgeons, ranging from homeopathic to allopathic interventions, physical compression, or no intervention at all. This study compared traditional taping methods with customized 3D-printed splints used in the postoperative period for 3 months. Our findings show that 3D-printed splints offer long-term benefits with greater reduction of edema at 6 months and 1-year postoperative. This study suggests the use of 3D-printed splints as a more personalized approach for postoperative rhinoplasty edema management to generate optimal long-term patient outcomes.

Oren M. Tepper, MD
497 Greenwich St
New York, NY
E-mail: Orenteppermd@yahoo.com
Instagram: @drorentepper

DISCLOSURES

Oren Tepper is a shareholder of MirrorMe3D. Oren Tepper and John Layke have a patent (# US-2022-0047409-A1). All the other authors have no financial interest to declare in relation to the content of this article.

PATIENT CONSENT

The patients provided written consent for the use of their images.

REFERENCES

1. Pavri S, Zhu VZ, Steinbacher DM. Postoperative edema resolution following rhinoplasty: a three-dimensional morphometric assessment. *Plast Reconstr Surg.* 2016;138:973e–979e.
2. Gordon AR, Schreiber JE, Patel A, et al. Defining spatial and temporal resolution of edema following rhinoplasty: a three-dimensional topographical analysis. *Plast Reconstr Surg.* 2022;150:928e–930e.
3. Gökçe Kütük S, Arıkan OK. Evaluation of the effects of open and closed rhinoplasty on the psychosocial stress level and quality of life of rhinoplasty patients. *J Plast Reconstr Aesthet Surg.* 1347;72:1347–1354.
4. Erol OO. Long-term results and refinement of the Turkish delight technique for primary and secondary rhinoplasty: 25 years of experience. *Plast Reconstr Surg.* 2016;137:423–437.
5. Gordon AR, Schreiber JE, Patel A, et al. Defining spatial and temporal resolution of edema following rhinoplasty: a three-dimensional topographical analysis. *Plast Reconstr Surg.* 2022;150:928e–930e.
6. Ong AA, Farhood Z, Kyle AR, et al. Interventions to decrease postoperative edema and ecchymosis after rhinoplasty: a systematic review of the literature. *Plast Reconstr Surg.* 2016;137:1448–1462.
7. Dixon TK, Caughlin BP, Munaretto N, et al. Three-dimensional evaluation of unilateral cleft rhinoplasty results. *Facial Plast Surg.* 2013;29:106–115.
8. Ozucer B, Yildirim YS, Veyseller B, et al. Effect of postrhinoplasty taping on postoperative edema and nasal draping: a randomized clinical trial. *JAMA Facial Plast Surg.* 2016;18:157–163.
9. Erdogan MM, Simsek T, Ugur L, et al. The Effect of 3D-printed custom external nasal splint on edema and ecchymosis after rhinoplasty. *J Oral Maxillofac Surg.* 2021;79:1549.e1–1549.e7.