Analysis of Quality of Life With 3D-Printed Model vis-á-vis Conventional Procedure in Oral & Maxillofacial Surgery – An Empirical Study

Zainab Chaudhary¹, Mithilesh Kadanthode¹, Pankaj Sharma¹, Sujata Mohanty¹, Ragavi Vijayaragavan¹, PS Bhandari², Lalit Maini³, and Shekar Grover⁴

Abstract

Aims and Objectives: 3d-printed models (bio-models) have become a useful tool in the armamentarium of surgeons for improved surgical planning in the recent past. This study directs at reinforcing the incorporation of these bio-models as a handy tool in treatment planning, resident training, patient education and record maintenance. The aim of this empirical study was to compare the outcome in reconstructive maxillofacial surgery when planned using 3d-printed model and without 3d-printed model (conventional). The objectives were to assess and compare the intraoperative time taken during reconstruction, the immediate post-operative experience (pain, mouth opening and incidence of infection) and the quality of life using University of Washington (UW-QOL) questionnaire during follow up.

Methods: This retrospective comparative study was conducted in Department of Oral & Maxillofacial Surgery, from March 2018 to March 2020. It included 50 cases consisting variety of pathologic and traumatic maxillofacial defects and they were grouped into with 3d-printed model (Group A) and without 3d-printed model (Group B). The groups were further subclassified based on maxillary (MR) and mandibular reconstruction [vascularized flaps (VFFF), non-vascularised grafts (NVG), reconstruction plate alone (RP)]. We compared intra operative time taken along with immediate post-operative parameters (pain, mouth opening and presence of infection) and patient’s quality of life using UW-QOL questionnaire. These values were taken for comparison and statistical analysis was done by unpaired t-test.

Result: There was 14.75% (35.26 minutes) mean reduction in operative time (*P = .029) and reduction in mean visual analogue score (VAS) (*P = .003) with statistically significant difference. However, increase in immediate post-operative mouth opening was not found to be statistically significant difference (P = .471). The comparison of the social and functional domain of UW-QOL showed statistically significant P-value in saliva (*0.004) and mood (*0.002) with regard to NVG. In RP group, pain (*0.026), swallowing (*0.041) and taste (*0.008) was found to be statistically significant. In MR group, only pain (*0.037) showed statistically significant difference.

Conclusion: Use of 3d-printed model to guide and assist in surgical procedures have provided promising results. Based on this study, we found that there is decreased intraoperative time and post-operative pain score when 3d-printed model were used. The patient’s quality of life was also found to be better in terms of reduction in pain, salivary secretion and mood

¹Department of Oral and Maxillofacial Surgery, Maulana Azad Institute of Dental Sciences, New Delhi, India
²Department of Plastic Surgery, Lok Nayak Jai Prakash Narayan Hospital, New Delhi, India
³Department of Orthopaedics, Maulana Azad Medical College, New Delhi, India
⁴Department of Dental Public Health, Maulana Azad Institute of Dental Sciences, New Delhi, India

Corresponding author:
Zainab Chaudhary, Department of Oral and Maxillofacial Surgery, Maulana Azad Institute of Dental Sciences, MAMC Complex, Bahadur Shah Zafar Marg, New Delhi 110002, India.
Email: zainabgauri@yahoo.co.in

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elevation. With increased success rate, the authors are of the strong opinion that it is time to revisit the surgical protocol used for reconstruction and include 3d-printed model as a primary tool or technology across the board for all patients notwithstanding the comparative cost, as the results offset the financial aspect.

**Keywords**
3d-printed model, bio-models, maxillo-mandibular reconstruction, prebent plates, medical rapid prototyping, quality of life

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**Introduction**

Reconstruction of the face after trauma or surgical tumor extirpation is an integral part of Oral and Maxillofacial surgical procedures to provide desirable functional and aesthetic results. The main goal is to attain preoperative form and function with minimum operative and postoperative morbidities. The literature shows successful use of both vascularized and non-vascularized bone grafts for reconstruction of defects and deformities of midface and mandible with the ultimate aim of providing adequate bone for dental rehabilitation, more recently by insertion of osseointegrated dental implants.1,2

It is difficult to replicate the complex three-dimensional conformation of the face. Any deviation from structural alignment may likely lead to functional disturbances like malocclusion and temporomandibular joint disorders. Furthermore, cases involving extensive bony resection, TMJ involvement, insufficient teeth for dental guidance, severely distorted bony contour and dilemma of primary or secondary reconstruction have definitely added to the difficulties in the reconstructive task.

The advent of newer technologies and surgical techniques has enabled modern Oral & Maxillofacial Surgeons to effectively accomplish the goals of reconstruction. Most recently the use of 3-Dimensional (3D) bio-models to guide and assist in surgical procedures have provided promising results.

3d-printed model (Bio model) have been utilized for variety of different purposes since their introduction by Charles Hull in 1986.3 With advances in radiology and computer aided design and computer aided manufacturing (CAD-CAM) along with improved material and accuracy, 3d-printed model have become a useful tool in the armamentarium of surgeons by improving surgical planning and reducing the operating time.3,4

The treatment of head and neck pathology has profound and long-term effects on a patient’s overall health, appearance, speech, ability to breathe, communicate, eat, and swallow. Quality of life (QOL) is a measure that encompasses many of these variables and can be used as an outcome measure, along with such factors as mortality, morbidity, survival, and recurrence.5 Successful use of 3d-printed model in improving the predictability of treatment of maxillofacial defects secondary to traumatic or pathologic conditions has already been described in the literature.6-8

The aim of this article is to present 50 cases demonstrating the versatile use of 3d-printed model for maxillofacial reconstruction and to compare the performance of the pre-bent plates with conventional intra operatively adapted plates in terms of time taken for surgery, immediate postoperative pain, mouth opening and presence of infection along with analysis and comparison of quality of life (QOL) during follow up. With this study, we intend to further reinforce the incorporation of 3d-printed model as a handy tool in treatment planning, resident training, patient education and record maintenance.

**Patients & Study Design**

Our study design included 50 patients with racial origin from South Asia; treated in our department of oral and maxillofacial surgery from March 2018 to March 2020. Pathology and defects including either maxilla or mandible were included in the study. Initial investigations included plain radiographs and routine blood tests. The final diagnosis for all the pathologies was reached after histopathologic examination.

The patients were categorized into group A (with 3d-printed model) and group B (without the use of 3d-printed model). They were subgrouped according to maxillary (MR) and mandibular reconstruction [vascularized flaps (VFFF), non-vascularised grafts (NVG), reconstruction plate alone (RP)]. We compared the performance of these procedure in terms of time taken for surgery, immediate postoperative experience (pain, mouth opening and presence of infection) and QOL during follow up.

Time taken for surgery was the duration from incision to closure of surgical field and the pain was assessed using visual Analogue Scale (VAS) with ‘0’ being ‘No pain’ and ‘10’ being ‘Worst Pain’ during immediate post op period. We also noted immediate postoperative Mouth opening and incidence of Infection during the post op period. Infection at surgical site was identified based on Classification of Surgical Site Infections (SSI) criteria, summarized from the Centers for Disease Control and Prevention/National
Deep incisional SSI Infection must occur within 30 or 90 d after the operative procedure and involve deep soft tissues of the incision.

**Table 1. Classification of Surgical Site Infections, Summarized From the Control and Prevention/National Healthcare Safety Network Surveillance Definitions for Specific Types of Infections.**

| SSI                        | Criteria                                                                 |
|----------------------------|--------------------------------------------------------------------------|
| Superficial incisional SSI | Infection must occur within 30 d after any operative procedure and involve only the skin and subcutaneous tissue of incision. The patient must also have 1 of the following: 1. Purulent drainage from incision 2. Organisms identified from an aseptically obtained specimen 3. Superficial incision that is deliberately opened by a surgeon or other designee and culture or non-culture-based testing is not performed, and at least 1 of the following signs or symptoms: Pain or tenderness; localized swelling; erythema; or heat. 4. Diagnosis of a superficial incisional SSI by the surgeon or an attending physician or other designee |
| Deep incisional SSI        | Infection must occur within 30 or 90 d after the operative procedure and involve deep soft tissues of the incision (fascial and muscle layers). The patient must also have at least 1 of the following: 1. Purulent drainage from the deep incision. 2. A deep incision that spontaneously dehisces or is deliberately opened or aspirated by a surgeon, attending physician, or other designee, and the organism is identified by a culture or non-culture based microbiologic testing method. The patient must also have 1 of the following: Fever, localized pain, or tenderness. 3. An abscess or other evidence of infection involving the deep incision that is detected on gross anatomic or histopathologic examination or imaging test |

SSI = Surgical Site Infections
The surgical approach for the lesion was decided according to the size and location of the pathology or defect. The detailed characteristics of Diagnosis, Defects and Treatment of the patients in group A and group B are presented in Tables 2 and 3. The preplanned osteotomy margins were reproduced on the patient’s bone and whenever the lower border of mandible was not obliterated by the pathology, preadapted plates were placed on the bone and screw holes marked prior to resection. All pathologies underwent surgical resection and immediate reconstruction except for 3 cases which were reconstructed as secondary procedures. Vascularized free fibular flap (VFFF) was used for 2 patients in which 1 underwent double barrel technique (Figure 3A-D).

Anterior iliac crest graft (ICG) was used in 5 cases, Costochondral grafts (CCG) in 3 and Rib graft (RG) in 2, with later being the choice for younger patients. In 1 of the cases reconstructed with anterior iliac graft, 4 dental implants were placed immediately (Figure 4A-D).

Reconstruction plate (RP) without graft was used in 6 cases of which 2 were plate replacement due to failure. For maxillectomy cases, preadapted titanium mesh was used for reconstruction (Figure 5A-F). Plating was carried out after putting the patient on Intermaxillary fixation (IMF) and done keeping in view that at least 3 - 4 screws were placed on the sound bone adjacent to the continuity defect.

Combined - Combined Extraoral & Intraoral approach; H - Hemi-mandibulectomy including the condyle; C - Central mandibulectomy defect including bilateral canines; L - Lateral mandibulectomy defects excluding the condyle (Boyd’s HCL classification); Type II - Maxillectomy excluding the orbit; Type III- Maxillectomy involving the orbital adnexae with orbital retention; b - defect involving less than or equal to unilateral palate (Brown’s classification of maxillary defects); VFFF - Vascularized Free Fibular Flap; ICG - Anterior Iliac Crest Graft; CCG - Costochondral grafts; RG - Rib Graft

Combined - Combined Extraoral & Intraoral approach; H - Hemi-mandibulectomy including the condyle; C - Central mandibulectomy defect including bilateral canines; L - Lateral mandibulectomy defects excluding the condyle

Figure 1. (Patient No. 8, Table 2). (A) Virtual anatomic reconstruction 3D image of a mandible with pathology in relation to left ramus (marked red) generated from digital imaging and communications in medicine data; (B) Mirrored image denoted by blue colour replacing the pathology.

Figure 2. (Patient No. 9, Table 2). (A) Preadapted Titanium Reconstruction plate on 3d-printed model; (B) Occlusal view.
| #  | Age/Sex | Diagnosis                                      | Surgical approach | Type of defect | Reconstruction                  |
|----|---------|-----------------------------------------------|-------------------|----------------|---------------------------------|
| 1  | 20/F    | Delayed reconstruction of leiomyosarcoma      | Combined          |                | VFFF                            |
| 2  | 21/F    | Central giant cell lesion                     | Combined          |                | VFFF                            |
| 3  | 20/F    | Delayed reconstruction of central giant cell lesion | Combined         |                | ICG                             |
| 4  | 22/F    | Central giant cell lesion                     | Combined          |                | ICG                             |
| 5  | 34/F    | Granular cell Ameloblastoma                   | Combined          |                | ICG                             |
| 6  | 29/M    | Ameloblastoma                                 | Combined          |                | ICG with immediate implant placement |
| 7  | 40/F    | Ossifying Fibroma                             | Combined          |                | ICG                             |
| 8  | 8/F     | Aneurysmal bone cyst                          | Combined          |                | CCG                             |
| 9  | 13/M    | Plexiform Ameloblastoma                       | Combined          |                | RG                              |
| 10 | 14/M    | Aneurysmal bone cyst                          | Combined          |                | CCG                             |
| 11 | 15/M    | Plexiform Ameloblastoma                       | Combined          |                | CCG                             |

(continued)
### Table 2 (continued)

| #  | Age/Sex | Diagnosis                                      | Surgical approach | Type of defect | Reconstruction          |
|----|---------|------------------------------------------------|-------------------|----------------|-------------------------|
| 12 | 19/F    | Plexiform Ameloblastoma                        | Combined          |                | RG                      |
| 13 | 28/M    | Osteonecrosis secondary to gun shot injury      | Combined          |                | Reconstruction plate    |
| 14 | 34/M    | Unicystic Ameloblastoma                        | Combined          |                | Reconstruction plate    |
| 15 | 42/M    | Delayed reconstruction of Fibrosarcoma         | Combined          |                | Reconstruction plate    |
| 16 | 35/M    | Ameloblastoma                                  | Combined          |                | Reconstruction plate    |
| 17 | 45/M    | Plate fracture                                 | Combined          |                | Plate replacement       |
| 18 | 63/M    | Intra oral plate exposure                      | Combined          |                | Plate replacement       |
| 19 | 7/F     | Neurofibromatosis                              | Combined          |                | Titanium mesh           |
| 20 | 23/M    | Fibrous Dysplasia                              | Combined          |                | Titanium mesh           |
| 21 | 38/F    | Central giant cell lesion                      | Combined          |                | Titanium mesh           |

Combined - Combined Extraoral & Intraoral approach; H - Hemi-mandibulectomy including the condyle; C - Central mandibulectomy defect including bilateral canines; L - Lateral mandibulectomy defects excluding the condyle (Boyd’s HCL classification); Type II - Maxillectomy excluding the orbit; Type III-Maxillectomy involving the orbital adnexae with orbital retention, b - defect involving less than or equal to unilateral palate (Brown’s classification of maxillary defects); VFFF - Vascularized Free Fibular Flap; ICG - Anterior Iliac Crest Graft; CCG - Costochondral grafts; RG - Rib Graft.
Table 3. Characteristics of the Patients, Defects & Surgical Procedure without using SLA (Group B).

| #  | Age/Sex | Diagnosis                      | Surgical approach | Type of defect | Reconstruction |
|----|---------|--------------------------------|-------------------|----------------|----------------|
| 1  | 20/F    | Juvenile ossifying Fibroma     | Combined          |                | ICG            |
| 2  | 60/F    | Acanthomatous Ameloblastoma    | Combined          |                | ICG            |
| 3  | 18/M    | Ameloblastoma                  | Combined          |                | ICG            |
| 4  | 12/F    | Aneurysmal bone cyst           | Combined          |                | CCG            |
| 5  | 12/M    | Plexiform Ameloblastoma        | Combined          |                | CCG            |
| 6  | 49/M    | Basal cell Ameloblastoma       | Combined          |                | ICG            |
| 7  | 36/M    | Plate fracture                 | Combined          |                | ICG            |
| 8  | 18/M    | Ameloblastoma                  | Combined          |                | CCG            |
| 9  | 30/F    | Ossifying Fibroma              | Combined          |                | Reconstruction plate |
| 10 | 40/F    | Recurrent Ameloblastoma        | Combined          |                | Reconstruction plate |
| 11 | 35/M    | Ameloblastoma                  | Combined          |                | Reconstruction plate |

(continued)
| #  | Age/Sex | Diagnosis                          | Surgical approach | Type of defect | Reconstruction |
|----|---------|------------------------------------|-------------------|----------------|----------------|
| 12 | 20/M    | Follicular Ameloblastoma           | Combined          |                | Reconstruction plate |
| 13 | 32/F    | Intra oral plate exposure          | Combined          |                | Plate replacement |
| 14 | 35/M    | Ameloblastoma                      | Combined          |                | Reconstruction plate |
| 15 | 15/M    | Odontogenic myxoma                 | Combined          |                | Reconstruction plate |
| 16 | 35/F    | Displaced plate                    | Combined          |                | Plate replacement |
| 17 | 35/M    | Intra oral plate exposure          | Combined          |                | Plate replacement |
| 18 | 17/F    | Intra oral plate exposure          | Combined          |                | Plate replacement |
| 19 | 45/F    | Recurrent odontogenic keratocyst   | Combined          |                | Reconstruction plate |
| 20 | 50/M    | Chronic osteomyelitis              | Combined          |                | Reconstruction plate |
| 21 | 30/M    | Plexiform Ameloblastoma            | Combined          |                | Reconstruction plate |
| 22 | 30/F    | Intra oral plate exposure          | Combined          |                | Plate replacement |
Results

The included patients were 26 males & 24 females with age groups, ranging from 7 to 63 years (Mean age ± Standard deviation = 30.38 ± 13.57 years) with pathologies or defect involving either maxilla or mandible. Of these cases, 1 case was a second surgery for osteonecrosis due to gunshot wound and 2 plate failure cases; others were of pathologic nature in which 3 cases were reconstructed secondarily.

In this study while 21 cases (11 males, 10 females) were included in group A while 29 cases (15 males, 14 females) were included in group B. The immediate post-operative period of patients in group A was uneventful and showed good aesthetic results with satisfactory functional movements.

Comparison of reconstruction using vascularized flaps (n = 2) were not included in the study (both the cases were reconstructed using pre adapted plates). The details of 48 cases included in the study are presented in Table 4. The values obtained were taken for comparison and statistical analysis was done by unpaired t-test except for analysis of

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Table 3. (continued)

| #  | Age/Sex | Diagnosis                  | Surgical approach | Type of defect | Reconstruction   |
|----|---------|---------------------------|-------------------|----------------|-----------------|
| 23 | 40/F    | Glandular odontogenic cyst | Combined          | Reconstruction plate |                |
| 24 | 37/F    | Mucoepidermoid carcinoma  | Combined          | Reconstruction plate |                |
| 25 | 30/F    | Odontogenic myxoma        | Combined          | Reconstruction plate |                |
| 26 | 40/M    | Ameloblastoma             | Combined          | Reconstruction plate |                |
| 27 | 20/M    | Osteoblastoma             | Combined          | Titanium mesh     |                 |
| 28 | 60/F    | Fibrosarcoma              | Combined          | Titanium mesh     |                 |
| 29 | 48/M    | Ameloblastoma             | Combined          | Titanium mesh     |                 |

Combined - Combined Extraoral & Intraoral approach; H - Hemi-mandibulectomy including the condyle; C - Central mandibulectomy defect including bilateral canines; L - Lateral mandibulectomy defects excluding the condyle (Boyd’s HCL classification); Type II - Maxillectomy excluding the orbit; b - defect involving less than or equal to unilateral palate (Brown’s classification of maxillary defects); ICG - Anterior Iliac Crest Graft; CCG - Costochondral grafts
incidence of infection were Chi-square test was done using statistical package SPSS 17.0 software (SPSS Inc., Chicago, IL, USA). Time taken for surgery was assessed from operative notes in each patient’s record and we found that mean operative time was 204.05 ± 31.63 minutes for cases done in group A, while it was 239.31 ± 74.26 minutes for cases done after planning with group B. This revealed 14.75% (35.26 minutes) reduction in operative time and was statistically significant (*P = .029). All the 48 patients included in this study was assessed as a routine protocol during immediate postoperative period to determine the pain score, mouth opening and presence of infection. While the reduction in mean VAS score was statistically significant (*P = .003), increase in immediate post-operative mouth opening was not found to be statistically significant (P = .471). The details of comparison of mean operative time, VAS score and Mouth opening is given in Table 5. When it came to incidence of infection, 4 patients (31.03%) were found to have infection.
among patient operated in group B, while it was only 1 (26.31%) in group A. This was found to be non-significant and details of the same are given in Table 6.

### UW-QOL Results

All the 48 patients responded to our interview for assessing UW-QOL either personally or telephonically. The follow up period ranged from 9 months to 2 years.

For comparison, the mean scores of each domain obtained from UW-QOL questionnaire was used in each subgroup. Percentage of patient selecting best score (%Best Score) for physical and social function was taken as the percentage of patients who awarded ‘100’ for that particular domain and that of global questions was percentage scoring 50, 75 or 100 for first question, i.e. Health related QOL compared to month before disease and percentage scoring 60, 80 or 100 for next 2 questions, i.e. Health related QOL during the past 7 days and Overall QOL during the past 7 days.

In the quality-of-life assessment using UW-QOL questionnaire, statistically significant $P$-value was found in

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**Table 4. Details of Cases Included in the Study.**

| SUBGROUPS                          | Group A                      | Group B                      | Total Cases* |
|------------------------------------|------------------------------|------------------------------|--------------|
| Non vascularized graft in mandible | 10 (4 males, 6 females)      | 8 (5 males, 3 females)       | 18 (9 males, 9 females) |
| Mandibular reconstruction plate    | 6 (6 males)                  | 18 (8 males, 10 females)     | 24 (14 males, 10 females) |
| Maxilla reconstruction             | 3 (1 males, 2 females)       | 3 (2 males, 1 female)        | 6 (3 males, 3 females)   |
| Total                              | 19 (11 males, 8 females)     | 29 (15 males, 14 females)    | 48 (26 males, 24 females) |

*Two cases reconstructed using Vascularized flaps excluded as these cases were done utilizing pre adapted plates. Bold values are only for emphasis and to denote the total no of cases ( irrespective of the gender).
saliva (*0.004) and mood (*0.002) with respect to NVG group. In RP group, pain (*0.026), swallowing (*0.041) and taste (*0.008) was found to be statistically significant. In MR group, only pain (*0.037) showed statistically significant difference. With regard to global questions, none of the parameters showed statistical significance in any of the groups. The detailed description of means scores with standard deviation and percentage best scores with their comparison and statistical analysis for significance of each group are demonstrated in Tables 7–9. For detailed description of UW-QOL results, please refer supplemental tables & figures.

Discussion

The primary goal of a reconstructive surgeon is to ‘restore the form and function’ of an anatomical structure lost due to pathologic or traumatic event. Reconstruction of the maxillofacial region is particularly challenging because of the need to maintain proper aesthetic contour and

| Variable                  | Group A                          | Group B                          | Group mean ± SD | Total mean ± SD | Standard Error (SE) | t-statistic | P-value |
|---------------------------|----------------------------------|----------------------------------|-----------------|-----------------|---------------------|-------------|---------|
| OPERATIVE TIME            | Group A (N = 19)                 |                                  |                  |                 |                     |             |         |
|                           | NVG (n = 10)                     |                                  | 210.6 ± 25.6 mins | 239.31 ± 74.26 mins | 13.79               | 2.262       | *0.029 |
|                           | RP (n = 6)                       |                                  | 195.83 ± 36.48 mins | 198.67 ± 29.17 mins |                     |             |         |
|                           | MR (n = 3)                       |                                  | 220.63 ± 50.96 mins | 204.05 ± 31.63 mins | 7.26                |             |         |
|                           | Group B (N = 29)                 |                                  |                  |                 |                     |             |         |
|                           | NVG (n = 8)                      |                                  | 6.7 ± 0.9        | 7.76 ± 1.12     | .21                 | 3.183       | *0.003 |
|                           | RP (n = 8)                       |                                  | 6.17 ± 1.07      | 7.67 ± 1.25     |                     |             |         |
|                           | MR (n = 3)                       |                                  | 8±1              | 6.68 ± 1.16     | .27                 |             |         |
| Visual Analogue Score     | Group A (N = 19)                 |                                  |                  |                 |                     |             |         |
|                           | NVG (n = 10)                     |                                  | 23.1 ± 5.13 mm   | 23.66 ± 4.94 mm | .92                 | -.728       | .471   |
|                           | RP (n = 6)                       |                                  | 25 ± 2.52 mm     | 29.3 ± 1.25 mm  |                     |             |         |
|                           | MR (n = 3)                       |                                  | 22.75 ± 5.5 mm   | 24.68 ± 4.70 mm | 1.08                |             |         |
| MOUTH OPENING             | Group A (N = 19)                 |                                  |                  |                 |                     |             |         |
|                           | NVG (n = 8)                      |                                  | 24.78 ± 4.42 mm  | 24.78 ± 4.42 mm | .92                 | -.728       | .471   |
|                           | RP (n = 8)                       |                                  | 19.33 ± 1.24 mm  | 19.33 ± 1.24 mm |                     |             |         |

NVG - Non-vascularized grafts; MR - Maxillary reconstruction; RP: Reconstruction plate

| Infection                | Group A | Group B |
|--------------------------|---------|---------|
| Subgroups                | n       | %       | n       | %       |
| Non-vascularized grafts  | 1       | 10.00%  | 1       | 12.50%  |
| Reconstruction plate     | 3       | 50.00%  | 0       | 33.30%  |
| Maxillary reconstruction | 0       | .00%    | 0       | .00%    |
| TOTAL                    | 4       | 21.05%  | 1       | 3.44%   |

INTRA GROUP COMPARISON

P-value = .867

P-value = .285
occlusion. The success rate of maxillofacial reconstruction has increased as a result of advances in plate design and materials. However, inadequate contouring and adaptation of the reconstruction plate to the extant mandible still represents the most common cause of plate failure, malocclusion or condylar malposition.\textsuperscript{14-17} Adjustive bending of the plates intraoperatively can lead to fracture of the reconstruction plates postoperatively because of generated residual stresses, which affect the mean stress in fatigue loading.\textsuperscript{7,18,19} Incidence of plate removal due to plate fracture has already been reported to as high as 18%.\textsuperscript{20} Our institutional experience with 126 patients from last 10 years suggested a failure rate of 19.8 % (25 patients) when plate was not pre-adapted. To function without failure, the

| Domain       | Group A (N = 10) | Group B (N = 8) | P-Value |
|--------------|------------------|----------------|---------|
| **PAIN**     | 45 ± 24.49       | 31.25 ± 24.21  | .252    |
| **APPEARANCE** | 47.5 ± 32.5  | 43.75 ± 27.24  | .791    |
| **ACTIVITY** | 45 ± 31.22       | 43.75 ± 16.54  | .920    |
| **RECREATION** | 45 ± 24.5    | 34.38 ± 24.8   | .377    |
| **SWALLOWING** | 33 ± 27.22  | 18.75 ± 14.52  | .201    |
| **CHEWING** | 25 ± 25          | 18.75 ± 24.21  | .600    |
| **SPEECH**  | 58 ± 27.5        | 50 ± 30.41     | .566    |
| **TASTE**   | 71 ± 24.27       | 67.5 ± 24.87   | .767    |
| **SALIVA**  | 100 ± 0          | 62.5 ± 35.97   | .004*   |
| **MOOD**    | 77.5 ± 17.5      | 46.88 ± 19.52  | .002*   |
| **ANXIETY** | 54 ± 28.35       | 46.25 ± 34.26  | .605    |

**GLOBAL QUESTIONS COMPARISON**

|          | Group A (N = 10) | Group B (N = 8) | P-Value |
|----------|-----------------|----------------|---------|
| Preop    | 37.5 ± 23.05    | 37.5 ± 23.05   | .999    |
| Postop   | 58 ± 24.41      | 58 ± 24.41     | .789    |
| Overall  | 64 ± 33.23      | 64 ± 33.23     | .946    |

Table 8. Comparison of University of Washington - Quality of life Mean Scores and % Best Scores for Patients Treated With Reconstruction Plate (RP) Only for Mandibular Defects.

| Domain       | Group A (N = 6) | Group B (N = 18) | P-Value |
|--------------|-----------------|------------------|---------|
| **PAIN**     | 50 ± 20.41      | 26.39 ± 21.2     | .026*   |
| **APPEARANCE** | 50 ± 28.87   | 38.89 ± 22.4     | .337    |
| **ACTIVITY** | 45.83 ± 26.68   | 30.56 ± 22.91    | .187    |
| **RECREATION** | 41.67 ± 23.57 | 30.56 ± 27.07    | .380    |
| **SWALLOWING** | 38.33 ± 24.78 | 17.22 ± 19.38    | .041*   |
| **CHEWING** | 33.33 ± 37.27   | 19.44 ± 29.53    | .359    |
| **SPEECH**  | 50 ± 20         | 50 ± 33.17       | .999    |
| **TASTE**   | 95 ± 11.18      | 62.22 ± 26.78    | .008*   |
| **SALIVA**  | 83.33 ± 26.25   | 71.67 ± 27.34    | .371    |
| **MOOD**    | 66.67 ± 11.79   | 47.22 ± 23.41    | .066    |
| **ANXIETY** | 55 ± 37.75      | 38.33 ± 32.87    | .310    |

**GLOBAL QUESTIONS COMPARISON**

|          | Group A (N = 6) | Group B (N = 18) | P-Value |
|----------|-----------------|------------------|---------|
| Preop    | 33.33 ± 18.63   | 43.06 ± 21.74    | .338    |
| Postop   | 76.67 ± 21.34   | 63.33 ± 23.33    | .229    |
| Overall  | 66.67 ± 33.99   | 65.56 ± 23.86    | .930    |
plates should be pre-bent preoperatively, so as to match closely and passively with the three-dimensional shape of the mandible in order to avoid any bending during the surgery. This human error can be to a good extent obviated by use of 3d-printed models, thereby enhancing the qualitative improvement in the end result. Azuma et al reported that the use of reconstruction plates that are pre-bent to fit 3d-printed models in mandibular reconstructive surgery resulted in improved aesthetic outcomes with potential for improved QOL of the patients compared to the use of conventional reconstructive methods. Wilde et al and Naros et al also reported about the superior accuracy of pre-bent plates over intraoperative bending method. Rapid prototyping using 3d-printed model have also been utilized for variety of other purposes since its introduction. 3d-printed model are an effective surgical tool when planning resections and reconstruction in the maxillofacial region as they aid in planning the osteotomy lines, deciding on the graft size, construction of custom-made hardware and determining plate and screw position. Studies suggest that computer assisted surgeries reduces surgical time and ischemia time for maxillofacial reconstructive surgeries. Erickson et al in their study reported reduction of operating time from 17% to 60%, with an average of 20%. According to Toro et al, the reduction in operative time amounted to almost 1-1.5 hours when using pre-bent reconstruction plates. In our study, we found a reduction of 14.75% in operative time.

In our study, we found that there is significant reduction in post-operative pain and immediate post-operative mouth opening. This could be possibly due to avoidance of unnecessary muscle stripping which could lead to trismus and pain. The same reason could be attributed to the reduction in surgical site infection.

Quality of life was assessed using UW-QOL questionnaire as described by Young et al. Comparison of the social and functional domain showed that the all the group of patients in group A fared better than those without medical prototyping and most of the patients chose the best scores in domain saliva and taste. The burden of symptoms related to swallowing and chewing was selected as poor to worse by most of the patients in each group. In global questions, the overall QOL during the past 7 days of assessment appeared to be similar in NVG group and RP group but in MR group the patients using 3d-printed model fared better. Percentage best scores of UW-QOL revealed that group A patients opted better scores compared to group B. One of the caveats in our QOL assessment was the wide range in follow up period extending from 9 to 2 years.

At our institute, while treating maxillofacial pathologies, traumatic defects and an osteonecrotic defect due to a gunshot wound, 3d-printed model were made using an open source software already approved by institutional ethical committee and were incorporated for treatment planning, patient education and motivation. With our prior experience of intraoperatively adapted plates, it was noted that the imprecision in a few cases had resulted in plate

| Maxillary reconstruction Domain | Group A (N = 3) | Group B (N=3) | P-Value |
|--------------------------------|----------------|---------------|---------|
| **PAIN**                       | 75 ± 20.41     | 33.33         | 33.33 ± 11.79 | 0 | .037* |
| **APPEARANCE**                 | 83.33 ± 11.79  | 33.33         | 33.33 ± 31.18 | 0 | .060 |
| **ACTIVITY**                   | 50 ± 20.41     | 25 ± 20.41    | 50 ± 20.41    | 0 | .208 |
| **RECREATION**                 | 25 ± 20.41     | 10 ± 14.14    | 0             | .261 |
| **SWALLOWING**                 | 43.33 ± 41.9   | 10 ± 14.14    | 0             | .261 |
| **CHEWING**                    | 33.33 ± 23.57  | 16.67 ± 23.57 | 0             | .435 |
| **SPEECH**                     | 56.67 ± 18.86  | 33.33 ± 28.67 | 0             | .304 |
| **TASTE**                      | 80 ± 14.14     | 80 ± 14.14    | 33.33         | .999 |
| **SALIVA**                     | 90 ± 14.14     | 90 ± 14.14    | 66.67         | .999 |
| **MOOD**                       | 75 ± 20.41     | 50 ± 20.41    | 0             | .208 |
| **ANXIETY**                    | 20 ± 14.14     | 0             | 10 ± 14.14    | .435 |

**GLOBAL COMPARISON**

|                  | PREOP | %BEST | POSTOP | %BEST | OVERALL | %BEST | P-VALUE |
|------------------|-------|-------|--------|-------|---------|-------|---------|
| *PAIN* 66.67 ± 11.9 | 100   | 41.67 ± 31.18 | 66.67 | .263 |
| *APPEARANCE* 66.67 ± 24.94 | 66.67 | 40 ± 32.66 | 33.33 | .323 |
| *ACTIVITY* 73.33 ± 24.94 | 66.67 | 40 ± 16.33 | 33.33 | .124 |
failures, including TMJ pain as a result of a displaced condylar segment. To overcome this debacle the 3d-printed model were used to accurately adapt reconstruction plates preoperatively. They were also used for determining the size of the graft or flap as well as the position of the immediate implant in the graft prior to reconstruction. In cases where the size of the lesion or defect distorted the regional anatomy thereby causing trouble in defining the original contour of the skeleton; mirroring of the healthy contralateral side or sculpting of the bio-model was done for assessment and planning, so as to rebuild the diseased.

Preadapting and contouring of the reconstruction plates and the mesh lead to reduced operative time, better postoperative period and an aesthetic outcome in all the cases. It was also found that the 3d-printed model played an important role in resident training as it offered hands on experience with reconstruction hardware. Another advantage in our experience was that, the 3d-printed model could be kept as a record for future evaluation of patients and could be used again in any case of recurrence of the disease.

As noted by Salgueiro et al and Isler et al, the principal disadvantage of using an 3d-printed model is its high cost, however since preplanning using 3d-printed model leads to a better patient satisfaction and reduced chance of plate failure, additional preoperative costs may be justified. Since our institution is a tertiary care center, catering to the needs of average to below average, economically weak patient population, it is not uncommon to come across such cases. In 1 such case, we improvised using a stock mandibular model of comparable dimension verified by assessing the dimension of the inferior border of mandible using an axial view of 3-D CT and got good results post-operatively. In our experience, planning with 3d-printed model, is a more affordable option than computer-designed patient specific implants [PSI] even though PSI offers higher accuracy and adaptation compared to pre-bent plates.

One limitation of our study was that we opted manual sculpting of 3d-printed model rather than digital sculpting in lesions crossing midline. Also no surgical cutting guides or resection templates were made using the bio-models as it would have caused financial burden on the patients. Another drawback of this study was its confounding factors associated with varied number of patients and pathologies. There still remains a paucity of large-scale, well-controlled clinical studies supporting the use of 3D printing technologies.

**Conclusion**

The versatile usage of 3d-printed models for maxillofacial reconstruction as a very useful tool in treatment planning, resident training, patient education & record maintenance, has been amply explained and demonstrated in the 21 cases discussed in the above article. This further amplifies the successful use of bio-models for improving the predictability of treatment of maxillofacial defects secondary to traumatic or pathologic conditions. With increased success rate, and patients reporting better quality of life, the authors are of the strong opinion that it is time to revisit the surgical protocol used for reconstruction and include 3d-printed models as a primary tool or technology across the board for all patients notwithstanding the comparative cost, as the results offset the financial aspect.

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**Ethical Clearance**

This study was exempted by Ethical Committee of Maulana Azad institute of Dental Sciences as it was a retrospective study. Consent was taken from all patients for publication of clinical photographs.

**ORCID iD**

Zainab Chaudhary https://orcid.org/0000-0001-7800-6435

**Supplemental Material**

Supplemental material for this article is available online.

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### Appendix

#### Abbreviations List

| Abbreviation | Description |
|--------------|-------------|
| UW-QOL       | University of Washington - Quality of life |
| VAS          | Visual analogue score |
| NVG          | Non-vascularized grafts |
| RP           | Reconstruction plate |
| MR           | Maxillary reconstruction |
| 3D           | Three-dimension |
| MT           | Temporomandibular Joint |
| CAD-CAM      | Computer-aided design & computer-aided manufacturing |
| CT           | Computed tomography |
| DICOM        | Digital Imaging and Communications in Medicine |
| VFFF         | Vascularized free fibula flap |
| OPG          | Orthopantomogram |
| ICG          | Iliac crest graft |
| CCG          | Costochondral graft |
| RG           | Rib graft |
| IMF          | Intermaxillary fixation |
| PSI          | Patient Specific Implants |
| SLA          | Stereolithographic models |