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Comparison of Different Surgical Techniques in the Management of Oroantral Fistula

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Abstract

Oroantral fistula (OAF) is a disease pathology of the oral cavity to the maxillary sinus, which most frequently occurs after the removal of maxillary posterior teeth. Different surgical interventions have been suggested to deal with it, though no agreement has been attained as to the most efficient method in the various clinical conditions. This experiment was to compare clinical results of various surgical methods that are available in management of oroantral fistula. A potential comparative clinical trial was done on 40 patients well balanced in four groups based on the type of surgical process applied to them, which was the buccal advancement flap, palatal rotational flap, buccal fat pad flap, and the combined use of both layers in the process of most closure. The 3-month postoperative evaluation was in terms of clinical success of closure, postoperative pain, healing time, complications, changes of the depth in the patient, and satisfaction. The outcomes demonstrated that total closure was observed in 100.0 and 100.0 percent of the cases in the buccal fat pad and combined technique group respectively, and 90.0 percent in buccal advancement and palatal flap group respectively. The buccal fat pad group showed the best postoperative pain and the least amount of time to heal. The buccal advancement flap exhibited the least amount of operative time (31.5 ± 3.0 minutes) and the highest amount of decrease in the depth of the vestibule (3.22 ± 0.28 mm). Palatal flap group had more postoperative pains and took more time to heal (20.1 ± 1.7 days). The buccal fat pad and combined groups showed no recurrence whilst the buccal and palatal flap groups showed recurrence in 10.0%. The patient satisfaction rate was the greatest in the group of the buccal fat pad (8.84 ± 0.23). Within the scope of this paper, the buccal fat pad flap had better overall clinical performance, whereas the combined use of the two-layer technique was very productive in more complicated cases. Consequently, the choice of the surgical method is to be individualized, regarding defect features and clinical conditions.

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Introduction

Oroantral fistula (OAF) is a pathological, epithelialized communication between the oral cavity and the maxillary issuance in the event of failure of spontaneous closure of oroantral communication. It has been most often related to surgical operations in the posterior maxilla, especially removal of maxillary molars and maxillary premolars, due to the instability of the roots of these teeth in relation to the sinus floor. Clinically, OAF remains the predominant etiology, but OAF implies can be contaminated between the oral cavity and the maxillary sinus

continuously, because it is a biologically active tract, even though other etiologies, such as implant-associated complications, cystic lesions, trauma, and other maxillary operations have likewise been identified [1,2]. Persistent communication pre-disposes the patient to chronic maxillary sinusitis, nasal fluid regurgitation, altered phonation, fetid discharge, facial pain, and inability to score well in relation to mastication, which relates to quality of life. Literature in recent years has noted that to treat it successfully, closing the fistulous on its own is not sufficient but it is important to manage related sinus disease and remove epithelialized/infected tissue prior to its closure [3].

This management approach to OAF is affected by a number of interconnected factors that may be the size of the defect, chronicity, epithelialization, as well as tissue quality surrounding the fistula, and the presence or absence of maxillary sinus infection. A recent systematic review of diagnostic and treating measures stated that small communications can sometimes be treated with a conservative approach, but in cases when there is defect >5mm, chronic lesions or when associated with sinus pathology treatment, surgically. Similarly, the contemporary clinical recommendations are in favor of early intervention, as OAF has an opportunity to be epithelialized and transformed into chronic fistulas which are harder to treat through application of local surgeries [4]. The most popular local procedures in OAF closure are the buccal advancement flap, palatal rotational flap, and buccal fat pad flap. The buccal advancement flap gets its popularity due to its technical simplicity, good vascularization, and the possibility of harvesting it around the defect with relatively simple operative procedure. But it might decrease the depth of the vestibular, and this can be clinically important in patients who can subsequently demand prosthetic rehabilitation [5].

The palatal rotational flap provides well-vascularized tissue that is particularly thick and well-resilient, and he popularly thought more useful in defects that were more palatally situated or in isolated recurrently observed cases. One of the benefits of this technique is that it maintains the buccal vestibule. However, it has been found to have limited mobility, discomfort in the donor site, and hindrance of secondary healing of the exposed palatal surface, making it problematic and potentially creating a high level of postoperative morbidity in certain patients [6]. The anatomy and surgical observations of the BFP indicate that it is a well-vascularized tissue that is easily accessible, with good closeness to the posterior maxillary defects, relatively simple to mobilize and prompt to attain epithelialization. The latter features render it especially appealing in intermediate and large defects, when the local mucosa has been compromised, or when the depth of the vestibular preservation should be of importance [7]. The other concept that is very relevant in the modern generation is that multidisciplinary testing of the chosen patients is required especially where OAF is accompanied by odontogenic sinusitis [8]. Most recent clinical data indicate that oral defect and sinus management together would be effective in symptom resolution and minimize recurrence, particularly with longstanding cases or cases of infection. This supports the opinion that surgical comparison cannot solely be on flap survival, but also based on healing time, pain, postoperative morbidity, recurrence, and patient-centered functional outcomes [9]. The aim of this study was to determine the clinical outcome of various methods of surgery use in management of oroantral fistula.

Literature Review

Several other studies have investigated the effectiveness of surgical methods of carrying out oroantral fistula repair, although not with consistent results. In a review of local flap procedures, Kwon et al. [10] had defined the buccal advancement flap as the most popular procedure due to its technical ease, good vascularity, and relative predictability of closure. Nevertheless, they also highlighted one of its principal drawbacks, i.e. the decrease in the depth of the vestibular, which can adversely impact the subsequent rehabilitation of the prosthetics in future. Gheisari et al. [11] in a retrospective larger study, performed an assessment of 147 cases undergoing buccal flap, palatal flap, or buccal fat pad and found the significant statistically significant differences between the success rates of each method. Their findings revealed that the buccal fat pad was most successful (98.3%), then the buccal flap (89.8) and palatal flap (85.7). Similarly, Bereczki-Temistocle et al. [12] reviewed 140 cases, and also, on the reserved one, the buccal flap proved to be the most common procedure, with the highest level of relapse rates, and Bichat fat pad flap treated those cases excellently during the primary management and relapse cases. All these studies point to a general direction of indicating that the buccal flap can still be used in the routine practice, but its effectiveness can be reduced when it comes to more difficult clinical cases.

There have also been direct comparative clinical studies that have given helpful evidence. In a clinical study conducted by Shukla et al. [5], the authors compared two techniques of buccal advancement flap and buccal fat pad flap and the conclusion drawn was that these two techniques were both helpful in OAF closure, although buccal fat pad proved to be the one that was preferable in most cases, especially when an assessment of long-term effect was done. Even though, the buccal fat pad group experienced higher early postoperative morbidity, including passing pains and edema, they disappears with time, and the procedure proved to have desirable healing. Such a tendency was supported by a more recent systematic review by Pizzolante et al. [14] as it suggested that a smaller number of comparative studies demonstrated a greater likelihood of success with buccal advancement flap as compared to buccal fat pad flap. They also critiqued the reconstructive benefits of having the buccal fat pad, in particular, in fistulas greater than 5 mm in percentage and where the preservation of the depth of the vestibulum is a clinical concern. Based on these findings, therefore, we may conclude that the buccal fat pad, though not just a credible alternative, in most cases could be a better choice in the way of reconstructions.

Higher level evidence has also helped in clarifying performance of various techniques, relative to one another. In a 2024 network meta-analysis and systematic review, Oliva et al. [6] indicated a statistically significant benefit of the buccal fat pad compared to the buccal advancement flap and the palatal rotational flap. They have concluded that the buccal fat pad had the most successful results in communication closure as well as reducing risks of relapse, given the restrictions of the evidence available. Conversely, Sabatino et al. [3] dwelled on the patients who had odontogenic sinuosity related to oroantral communication or fistula and ultimately proved that the management of the sinus component is a conclusive factor of treatment success. Through their retrospective study involving 41 patients, they were able to resolve their symptoms and close the fistula, and the majority of patients received a combined or multidisciplinary model. This observation is especially significant as it indicates that the success of OAF surgery is not necessarily related only to the designs of flaps, but appropriate control of related sinu pathology as well. Although such advances were demonstrated in these studies, there is still significant diversity in the literature regarding methods of study design and sample size, degree of defect, duration of follow-up, and evaluation of outcomes. This variability has been directly recognized in recent systematic evidence and has been documented to restrict generalizability and make direct comparison of studies challenging. [17]. Thus, a potential comparative, clinical study under controlled conditions is still warranted to give a better assessment of comparative

efficacy of various surgical methods in the treatment of oroantral fistula.

Materials and Methods

The study was a cross-sectional comparative clinical study in nature with the aim of comparing the possible clinical outcomes of various surgical methods adopted in the treatment of oroantral fistula. The research was to be conducted to examine the performance of the identified methods considering fistula repair, postoperative recovery, morbidity, and patient outcomes in standard clinical conditions.

The exploration was done in the location of Center of Oral and Maxillofacial Surgery, Al-Shaeed Ghazi Al-Hariri hospital of surgery specialization, Medical city complex, Baghdad, Iraq, in a span of 12 months. The hospital was chosen as it is an actual tertiary surgery hospital in Baghdad, which has recorded oral and maxillofacial surgery activity in the Medical City complex. All the clinical processes and postoperative follow-ups and data have been conducted in the same institutional setting so that there should be a consistency in the diagnosis, surgical handling, and outcome measurement.

The study used 40 patients with an oral antral fistula who were diagnosed. Every patient met the specified criteria of eligibility and was recruited one after another according to the course of the study. The population was deemed to be adequate in making comparative clinical assessment of the chosen surgical methods.

The registered patients were divided into four equal groups based on the surgery performed on closing the fistula and there were 10 patients in the group. Buccal advancement flap technique was used as treatment group I. Group II was closed with palatal rotational flap. Group III was treated using the buccal fat pad flap. There was combined double-layer closure that was applied on Group IV. This classification enabled a literal comparison between the most used surgical modalities that are used in the treatment of oroantral fistula.

Patients included were 18 years and above and a clinically and radiographically confirmed oroantral fistula. Only patients who had a fistula longer than three weeks were taken to make sure that the cases included developed communications that had to be operated on. Moreover, all the defects were included and deemed fit to be closed with one of the techniques chosen.

The patients were not allowed to participate in the study in case they had uncontrolled systemic diseases that were likely to interfere with the healing process or otherwise influence the surgical results. Those having history of radiotherapy in maxillofacial were also left out. Patients who came with an active sinu pathology that needed a sinus procedure of an otorhinolaryngologist were excluded. Moreover, patients who were lacked compliance or those who were unlikely to turn up to record routine after operation visits were eliminated to maintain the validity of follow-up evaluation.

A thorough preoperative examination was conducted in all the patients having a preoperative surgical intervention. This involved taking of detailed medical and dental history, which was then followed by careful clinical examination of the fistula area and tissues around it. To plan the treatment and compare it with the results after the surgery, the fistula size was measured in millimeters. Radiographic evaluation was done based on the needs of the specific case on the panoramic radiography and/or cone-beam computed tomography. The state of the maxillary sinus, the scope of its damage, and the absence of other pathological alterations were particularly taken into consideration.

All the procedures were carried out in the local anesthesia in accordance with the usual aseptic measures. Preoperative treatment involved intake of antibiotics, nasal clearance, and antistomatology dental mouth rinse to decrease infection likelihood and enhance the local healing circumstances. In surgery the epithelial lining of the fistulus tract was removed and the edges of the defect re-freshened to leave a viable surgical field. The fistula was then closed following the surgical method prescribed in each of the study groups. At all times, attention was paid to carefully handling tissues and tension-free dissection to facilitate the most optimal healing process and reduce the recurrence.

Successful oroantral fistula closure 3 months after the operation was the primary outcome measure. Complete clinical healing of the oral cavity with no signs of persistent communication between the oral and maxillary cavity was considered successful closure.

Second outcome measures involved the postoperative pain, operative time, healing time, postoperative complications, voter depth changes, and patient satisfaction. The time taken to carry out the surgery was measured in minutes since the commencement of the procedure up to the closure of the wound. The visual analog scale (VAS) was used to measure postoperative pain. The time spent on healing is relied on the time to have the complete mucosal healing. The complications that emerged after the operation were infection, dehiscence of the wound and incidence of the fistula. Vestibular depth measurements were also considered especially in instances whereby flap advancement has the potential of affecting the anatomy of the vestibular. Patient satisfaction also was measured during the follow-up visits as per the postoperative comfort and result of the treatment.

Follow up of all patients was done based on a standardized postoperative program on the first day after operation, on the seventh day, the fourteenth day and one month after and after three months. During these visits, clinical healing, intensity of pain, integrity at closure, occurrence of complications and patient-reported satisfaction were documented. This program enabled immediate and late evaluation of the results of surgery.

The data acquired were converted and analyzed with the Statistical Package of the Social Sciences (SPSS) software. Introduction of quantitative variables often included them using mean x SSD, and frequently, categorical variables were as frequencies and percentages. Quantitative variables were compared using one-way analysis of variance (ANOVA) when comparing the four study groups, whereas quantitative variables were compared using Chi-square test when using categorical variables. Given a p-value of less than 0.05 was regarded as having a statistically significant value.

Results

The study included 40 patients, which were distributed equally in the four groups of the study and had 10 patients each. The average age of the patients per group was 35.9 +5.8 in Group I and 37.5 +5.0 in Group IV with no statistically significant differences between the groups ($p = 0.916$). In most groups, the proportion of male patients was a little higher, though the distribution of the genders was equal in all groups ($p = 0.959$). In the current study, the most frequent reason of oroantral fistula would be tooth extraction as it constituted most cases in all groups. The data on the mean duration of fistula were 5.3 + 1.2 weeks in Groups I and III and 6.3 + 1.2 weeks in Group IV, and the difference was not statistically significant ($p = 0.209$). Similarly, in Group I, the mean fistula size was 5.8600 0079 mm and in Group IV, the mean fistula size was 6.6800 0048 mm and the difference between the groups was not significantly different ($p = 0.079$). The most common tooth with fistula formation was the maxillary first molar.

At the methodological level, the study flow demonstrated that all 40 recruited patients completed the allocated intervention and postoperative follow-up up to 3 months, with no loss to follow-up.

There was statistically significant difference ($p < 0.001$) in the duration of operations between the four methods of surgery. Group I (buccal advancement flap) recorded the least operation time with the mean of 31.5 ± 3.0 minutes with the Group IV (combined double-layer closure) recording the highest operation time with the mean of 42.8 ± 2.8 minutes. Group III (buccal fat pad flap) depicted good ratio between the time of operation and technical viability. On the question of the simplicity of the procedure, the most common rating was set as having an easy procedure with the buccal advancement flap but the combination technique received a more moderate to difficult rating. All the patients who had the buccal fat pad flap received tension-free closure and then the combined technique, but slightly lower values were experienced with the buccal and palatal flap.

All groups had progressive reduction in postoperative pain scores (Table 3). Figure 2 displays the trend of alleviation of pain with time. The four groups also had a significant difference in the healing time ($p < 0.001$).

A very noticeble distinction was observed in the depth change in the vestibular between the four methods of surgeries ($p < 0.001$) (Table 4).

To offer a multidimensional comparison of total work of the four methods, a radar chart was developed using the closure success, low pain, rapid healing, retained vestibular depth, low complication rate as well as patient satisfaction (Figure 3). Analysis of the chart shows very clearly the better overall performance of Group III, which is then succeeded by Group IV. Exploratory analysis indicated that reduced size of fistula, reduced length of time and no preoperative sinusitis were correlated with a favorable outcome of surgery (Table 5). Fistulas of 6mm or less and those that took a period of 6 weeks or less recorded the best success rates. Similarly, the patients that had no based sinusitis had better results in terms of closure as compared to the patients in whom there was a sinus involvement. On the level of the surgical technique, the buccal fat pad flap and the combined double-layer closure were the most successful ones in relation to zero recurrence rates.

The correlation between fistula size and time to heal based on the surgical procedure is presented using the following scatter plot which indicates that there is a simple correlation between growing defect size and long healing time, especially in Group I and II (Figure 4).

Discussion

The current prospective comparative study has shown that the most desirable overall clinical performance of all the techniques assessed was the buccal fat pad flap (Group III). It had a 100.0% closure rate at 3 months, no reoccurrence, lowest postoperative pain scores and was related to the shortest healing time. The double-layered closure (Group IV) was also performing very well, success rate of 100.0, and no recurrence and the reason behind this is that it healed very fast, even though it was the longest to conduct the operation. On the contrary, the buccal advancement flap (Group I) was the quickest method intraoperatively but demonstrated a higher loss in the depth of the vestibular and marginally more often postoperative complications. Group II (Palatal rotational flap) was found to result in stable closure, but with increased postoperative pain scores, and slower healing than Group III and IV.

Such results indicate that the fat pad flap of the buccal pads provides the most supported combination of closed wound success, comfort after the operation, efficacy and efficiency of healing as well as maintenance of functional anatomy. The hybrid method also does not seem to be ineffective especially where extra reinforcement of soft tissues is needed. In comparison, the buccal advancement flap is appealing due to its simplicity and lesser time of operation, though, this might be compensated by the fact that more depth is lost at the cost of the vestibular depth. In a nutshell, the current findings also suggest that the decision of the technique not to be based on technical simplicity alone, but on a wider consideration of success, morbidity, healing, and functional maintenance [5,11].

The enhanced outcomes of the buccal fat pad flap in the current study are aligned with the findings of some other studies done before. Shukla et al. [5] found that buccal advancement flap and buccal fat pad flap were equally effective as shown to close OAF, yet that the long-term choice was made by comparing buccal fat pad as a better choice than buccal advancement flap, albeit with a few short-term morbidity. Likewise, Gheisari et al. [10] reported that the buccal fat pad flap had the greatest success rate of those using local techniques, especially when the defect is bigger than 5 mm and relapse is more likely after buccal flap repair. Bereczki-Temistocle et al. [11] also reported excellent results of Bichat fat pad flap especially in recurrent or demanding case and relapse occurs more frequently post Bichat flap repair. The above-mentioned observations do resonate well with the current results where Group III revealed total closure devoid of recurrence and a better healing effect than the other approaches [1].

There is also the higher level of evidence that corroborates the current results well. In their 2024 network meta-analysis and systematic review, Oliva et al. [6] observed statistically significant superiority in the use of the buccal fat pad over the use of the palatal rotational flap, as well as the buccal advancement flap, in measures of relapse reduction (zero additional benefits) and closure success (six additional benefits). Pizzolante et al. [12] also found in their systematic review that the buccal fat pad flap appears to be more reliable in terms of reconstructive consistency than the buccal advancement flap especially with defect sizes larger than 5 mm or with preservation of a dentulous ridge depth of greater significance. Recent studies have also continued to endorse the effectiveness of Bichat buccal fat pad in ensuring a stable closure with a minimal number of complications, all to support it as an initial use in appropriate cases [14].

The palatal rotational flap had a reasonably good success rate in closure in the study, and it was also less associated with the treatment with lesser postoperative suffering and shorter healing period than the buccal fat pad and combined methodology. This does not come as a surprise pattern. Kwon et al. [1] characterized the palatal flap as a viable choice because vascularity is good and it retains the depth of the vestibules yet they have their limitations that involve donor-site morbidity and pain concerning the raw palatal surface. Similarly, previous clinical evidence by Anavi et al. [17] suggests that palatal rotation-advancement flap should be used in delayed repair due to its thickness and vascularity, even though it has more selective indications. The current results can be explained by this answer: the palatal flap has not been replaced by a more comfortable version like the buccal fat pad flap; possibly, this is still a very useful solution on the clinical side [1,19].

The double-layer closure method with add-on technique was also very favorable in the current series as the closure was completely closed, there was no recurrence, and the healing process was very fast despite their operative being longer compared to all the other groups. Clinically, this is plausible since layered closure has the potential to add better tissue volume and sealing and mechanical stability in more complicated defects. A combined or multidisciplinary approach has been highlighted in the recent literature particularly where fistula formation can be accompanied with chronic sinuosity disease or impaired local tissues. According to Sabatino et al., [3], odontogenic sinuses can only be managed successfully under

the condition of proper management of the sinus component as well as the oral defect when using oroantral communication or fistula. Similarly, Kocum et al. [18] illustrated the advantage of combined ENT and dental surgeon intervention during odontogenic sinus treatment, and Dipalma et al. [2] indicated that the size and chronicity of the defect, epithelialization, and the infection of sinus must be taken as the determinant in planning the surgeon intervention. Such reports contribute to the understanding of the reason why the mixed method worked especially well in the given study [2,16].

The exploratory analysis of the current study also indicated that smaller fistula size, shorter period and no preoperative sinusitis were related to the better outcomes. Though these associations were not found to be significant statistically, probably due to the small sample size, they are still of clinical significance. The latest evidence-based practice has always focused on how the selection of treatments must be personalized depending on the level of defect, chronicity, epithelialization, and sinus. Alomari et al. [9] advanced a clinical decision-making algorithm which is specifically developed based on these factors, whereas Dipalma et al. [2] emphasized that the diagnostic and therapeutic approaches must be based on the communication size and related infection. As such, the current trend analysis is in accordance to the current body of evidence where statistical power remained low [2,9].

Clinically, the result of this study suggests that treatment of OAF should be differential and not homogenous. Buccal advancement flap can still find its use with small and simple defects when the quick and technically easy healing is required, particularly in an environment where the amount of time spent operating is a critical factor. But due to the increased loss of the depth of the vestibule in the current study and slightly higher complication burden, it might not be the best in case of prosthetic rehabilitation as well as the future use of the vestibular in cases where such a factor is significant. This observation is in line with findings of Kwon et al. [10] as well as with recent review of treatment that still characterize flap of the Bucca as helpful and anatomically disadvantageous in specific situations [10].

The buccal fat pad flap seems to be the most appropriate to use in moderate defects, cases with greater than 5 mm, and where importance is placed on the need to retain vestibular depth and minimal morbidity in the postoperative period. Its success in closure, low profile of pain and excellent healing in the study being discussed give it a wider clinical application. The overlapping bilayered closure can also be used in bigger, chronic, recurrent or sinus-related situation which the added tissue assistance is beneficial. Palatal rotational flap is still a viable alternative in cases where the buccal tissue is not enough or the healing and retention of the buccal sulcus is of utmost priority, nevertheless, patient discomfort and healing need to be expected. In general, current findings endorse existing algorithm-informed findings that choice of technique depends on defect size, chronicity, the presence of sine, and local tissue quality as opposed to being based on habit routine alone [19].

One of the strongest points of the current study is that it compared directly four different surgical methods, used in the same institutional and clinical environment. This enabled a more sensible evaluation of the relative performance than can be conducted in heterogeneous retrospective reports. The use of several outcome measures, in addition to closure success and recurrence, postoperative pain, healing time, change in depth of the vestibular, operative time, patient satisfaction is another strength. This multidimensional assessment has a more clinical meaning aspect, and it more accurately presents the practical aspects of surgical decision-making.

The research is also limited. To start with, the sample size was quite small thereby potentially decreasing the statistical power of exploratory analyses to predictors of success and recurrence. Second, the follow-up duration was 3 months; this amount of time is enough to determine the early closure and postoperative recovery, but a follow-up period longer than one year would give more data on the long-term stability and late recurrence. Third, the paper was conducted in one center, which could create obstacles to the external applicability of the results. These shortcomings are like those described in the larger OAF literature, in which the heterogeneity in sample size, design, and follow-up has been a known focus due to which heterogeneity has been identified as a problem [2].

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Table 1. Baseline demographic and clinical characteristics of the study groups.

Variable	Group I Buccal Advancement Flap (n=10)	Group II Palatal Rotational Flap (n=10)	Group III Buccal Fat Pad Flap (n=10)	Group IV Combined Double-Layer Closure (n=10)	p-value
Age (years), mean ± SD	35.9 ± 5.8	36.8 ± 6.1	36.3 ± 5.4	37.5 ± 5.0	0.916
Gender (Male/Female)	4-Jun	4-Jun	5-May	4-Jun	0.959
Cause of fistula – Tooth extraction, n (%)	7 (70.0)	7 (70.0)	7 (70.0)	7 (70.0)	1
Cause of fistula – Implant-related, n (%)	2 (20.0)	2 (20.0)	2 (20.0)	2 (20.0)	1
Cause of fistula – Cyst/enucleation, n (%)	1 (10.0)	1 (10.0)	1 (10.0)	1 (10.0)	1
Duration (weeks), mean ± SD	5.3 ± 1.2	5.8 ± 1.4	5.3 ± 1.2	6.3 ± 1.2	0.209
Size (mm), mean ± SD	5.86 ± 0.79	6.18 ± 0.63	6.33 ± 0.52	6.68 ± 0.48	0.079
Affected tooth – First molar, n (%)	5 (50.0)	5 (50.0)	6 (60.0)	5 (50.0)	0.957
Affected tooth – Second molar, n (%)	3 (30.0)	3 (30.0)	2 (20.0)	3 (30.0)	0.918
Affected tooth – Second premolar, n (%)	2 (20.0)	2 (20.0)	2 (20.0)	2 (20.0)	1

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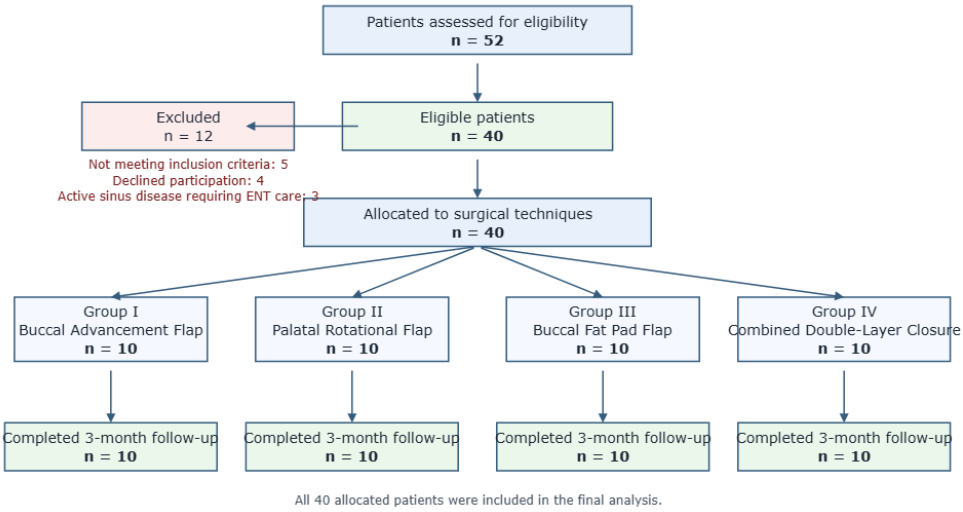

Figure 1. Flow diagram of patient selection, allocation into study groups, surgical intervention, and follow-up throughout the study period.

Table 2. Comparison of intraoperative variables among surgical techniques.

Variable	Group I Buccal Advancement Flap (n=10)	Group II Palatal Rotational Flap (n=10)	Group III Buccal Fat Pad Flap (n=10)	Group IV Combined Double-Layer Closure (n=10)	p-value
Operative time (min), mean ± SD	31.5 ± 3.0	38.7 ± 3.0	35.2 ± 2.3	42.8 ± 2.8	<0.001
Mild bleeding, n (%)	7 (70.0)	5 (50.0)	6 (60.0)	4 (40.0)	0.576
Moderate bleeding, n (%)	3 (30.0)	4 (40.0)	4 (40.0)	5 (50.0)	0.764
Severe bleeding, n (%)	0 (0.0)	1 (10.0)	0 (0.0)	1 (10.0)	0.577
Easy procedure, n (%)	7 (70.0)	3 (30.0)	5 (50.0)	2 (20.0)	0.004
Moderate procedure, n (%)	3 (30.0)	5 (50.0)	4 (40.0)	4 (40.0)	0.781
Difficult procedure, n (%)	0 (0.0)	2 (20.0)	1 (10.0)	4 (40.0)	0.021
Tension-free closure achieved, n (%)	8 (80.0)	8 (80.0)	10 (100.0)	9 (90.0)	0.426

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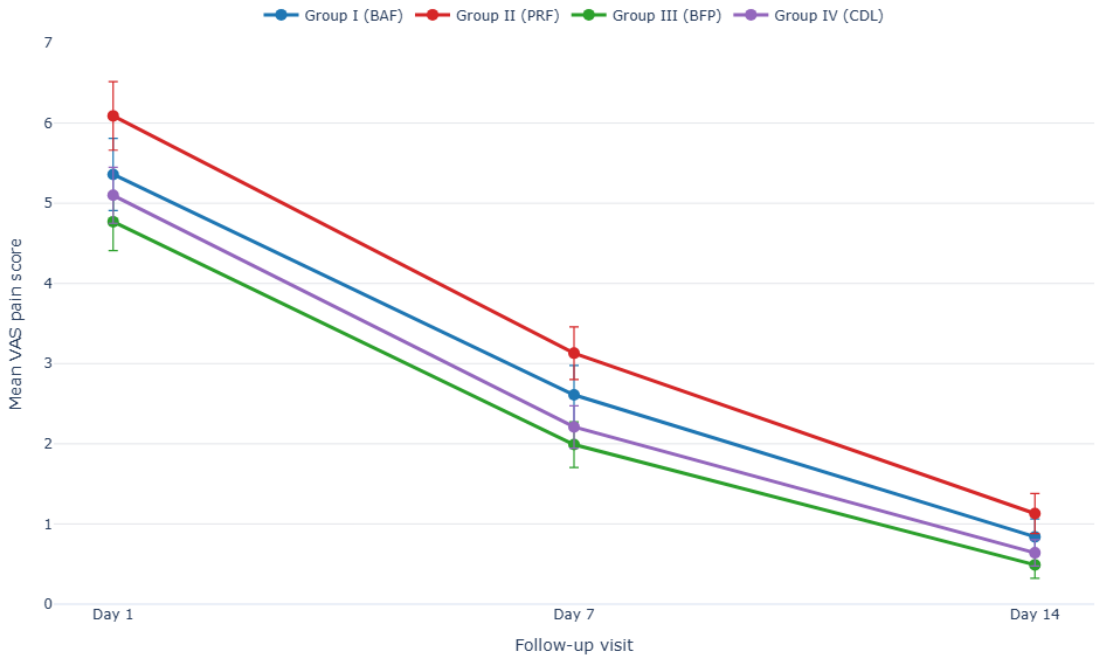

Figure 2. Comparison of postoperative pain scores (VAS) among the four surgical techniques over different follow-up intervals (Day 1, Day 7, and Day 14).

Table 3. Postoperative outcomes and complications.

Variable	Group I Buccal Advancement Flap (n=10)	Group II Palatal Rotational Flap (n=10)	Group III Buccal Fat Pad Flap (n=10)	Group IV Combined Double-Layer Closure (n=10)	p-value
Pain score Day 1 (VAS), mean ± SD	6.48 ± 0.46	7.18 ± 0.42	4.77 ± 0.36	5.32 ± 0.42	<0.001
Pain score Day 7 (VAS), mean ± SD	3.09 ± 0.27	3.52 ± 0.31	1.99 ± 0.28	2.33 ± 0.24	<0.001
Pain score Day 14 (VAS), mean ± SD	0.88 ± 0.22	1.14 ± 0.20	0.49 ± 0.17	0.61 ± 0.15	<0.001
Edema, n (%)	4 (40.0)	3 (30.0)	2 (20.0)	2 (20.0)	0.71
Infection, n (%)	1 (10.0)	1 (10.0)	0 (0.0)	0 (0.0)	0.559
Dehiscence, n (%)	2 (20.0)	1 (10.0)	0 (0.0)	1 (10.0)	0.636
Recurrence, n (%)	1 (10.0)	1 (10.0)	0 (0.0)	0 (0.0)	0.559
Healing time (days), mean ± SD	18.6 ± 1.5	20.1 ± 1.7	15.8 ± 1.3	16.4 ± 1.2	<0.001
Successful closure at 3 months, n (%)	9 (90.0)	9 (90.0)	10 (100.0)	10 (100.0)	0.559

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Table 4. Functional outcomes and patient satisfaction.

Variable	Group I Buccal Advancement Flap (n=10)	Group II Palatal Rotational Flap (n=10)	Group III Buccal Fat Pad Flap (n=10)	Group IV Combined Double-Layer Closure (n=10)	p-value
Vestibular depth change (mm), mean ± SD	3.22 ± 0.28	1.23 ± 0.17	0.79 ± 0.14	1.03 ± 0.18	<0.001
Difficulty in mastication (score /10), mean ± SD	3.19 ± 0.36	3.49 ± 0.31	2.07 ± 0.26	2.21 ± 0.26	<0.001
Patient satisfaction (score /10), mean ± SD	7.82 ± 0.34	7.44 ± 0.29	8.84 ± 0.23	8.75 ± 0.21	<0.001

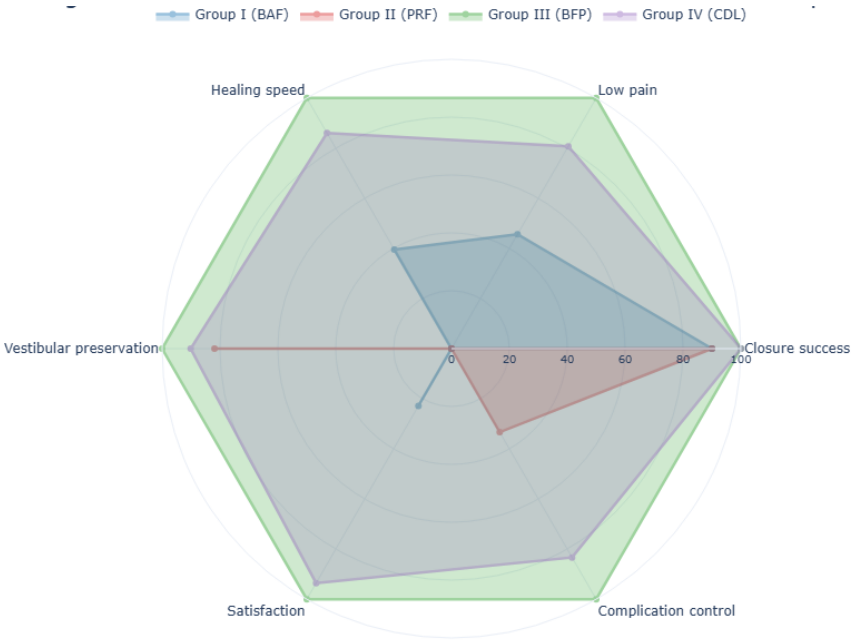

Figure 3. Radar chart illustrating the overall clinical performance of the four surgical techniques based on multiple outcome parameters including closure success, postoperative pain, healing time, complication rate, vestibular depth preservation, and patient satisfaction.

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Table 5. Factors influencing success and recurrence.

Factor	Category	Cases (n)	Successful closure n (%)	Recurrence n (%)	p-value
Fistula size	≤6 mm	14	14 (100.0)	0 (0.0)	0.287
	>6 mm	26	24 (92.3)	2 (7.7)	
Duration	≤6 weeks	29	29 (100.0)	0 (0.0)	0.071
	>6 weeks	11	9 (81.8)	2 (18.2)	
Preoperative sinusitis	Absent	23	23 (100.0)	0 (0.0)	0.104
	Present	17	15 (88.2)	2 (11.8)	
Surgical technique	Group I	10	9 (90.0)	1 (10.0)	0.559
	Group II	10	9 (90.0)	1 (10.0)	
	Group III	10	10 (100.0)	0 (0.0)	
	Group IV	10	10 (100.0)	0 (0.0)	

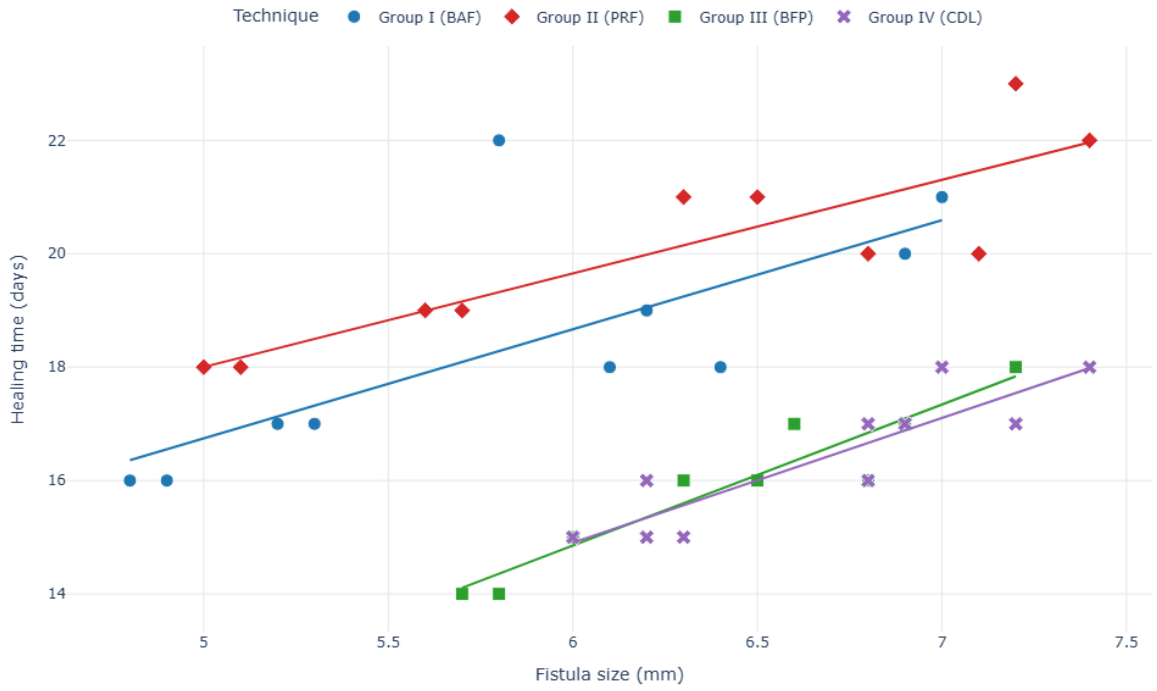

Figure 4. Scatter plot showing the relationship between fistula size and healing time across different surgical techniques.