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Efficacy and Cost of Negative Pressure Wound Therapy (NPWT) Dressing versus Tie-Over Bolster Dressing on Integrating Split-Thickness Skin Grafts

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Objective: This study aimed to compare two dressing methods used as skin graft bolsters. The two dressings were compared as to efficacy (% graft take), ease of application, pain scores, safety (complication rate) and cost.

Methods: This is a prospective randomized controlled trial involving 34 patients. The basis of comparison between the two dressing methods included: efficacy determined by percentage of graft take on the 7th and 14th day post-Split Thickness Skin Grafting; ease of the application (amount of time to apply dressing); pain (VAS) scores at 1st, 7th and 14th day post-Split Thickness Skin Grafting; complications and costs.

Results: The NPWT group has statistically significant differences from the Tie-Over Bolster group. NPWT took less time to apply the dressing (1-10mins vs 6-15mins), had a higher percentage of graft take (99.05% vs 96.52%), had lower pain scores overall, had lower complication rates (infection: 0% vs 2.94%), and cost less (Php 2,917.00 vs Php 3,684.00).

Discussion: The Low-Cost NPWT system was developed in this institution due to the exorbitant cost of commercial NPWT pump and dressing systems. Thus, a week-long NPWT therapy using commercial NPWT systems may cost as much as Php 24,000.00, while the low-cost NPWT alternative only costs Php2,917.00.

Conclusions: The locally-developed, low-cost NPWT dressing has been proven to be faster to apply, more effective in integrating split-thickness skin grafts, has less discomfort and complications, and is actually cheaper than the conventional tie-over bolster dressings.

Key words: Negative pressure wound therapy, Tie-over bolster dressing, Split thickness skin grafting

The management of extensive traumatic wounds remains a challenge to physicians worldwide. Constant innovations in the management of these wounds were developed from the vast available substances for external use such as creams and ointment to the different types of dressings. For wounds that are not managed by primary closure, delayed secondary closure using of soft tissue flap is done. In such wounds, split-thickness skin graft (STSG) can be used for wound coverage.[1,2] The graft relies on new blood vessels from the recipient site bed to be generated. The integration of these grafts to the recipient area consists of 3 phases: revascularization, lymphatic revascularization, and re-innervations.[3] The major causes of skin graft loss are the result of the formation of blisters or hematoma under the graft that interferes directly with the serous imbibition and revascularization process, and the infection of the graft that frequently leads to partial or total graft loss.

There were techniques developed to augment the graft take to the recipient site and prevent graft loss. Application of a dressing to the grafted wound is as important as any other step in achieving a healed wound.[4] Negative pressure wound therapy (NPWT) has revolutionized the management of open wounds by mechanisms of bacteria clearance, moisture elimination, edema reduction, and angiogenesis stimulation.[5,6] Wounds treated with NPWT appeared much healthier on gross examination and histology which remains the primary indicator of wound progress.[7,8] Use of NPWT in skin grafting improves graft take, tissue markers, prevents hematoma and seroma formation, acts as a splint and

bridges the gap between the graft and the granulation tissue.[9,10] However, it is costly and not easily afforded by the charity patients admitted in government hospitals in the country. Tie-on bolster dressing is the traditionally-known technique in securing the graft to its wound bed especially in irregularly surfaced wound like areas near the joints.[11] Thus, there is a need for innovating and re-evaluating the dressing techniques used for dressing the recipient sites to improve graft take, prevent graft loss and determine the available options that are more efficacious.

The study aimed to introduce an innovation to NPWT system using a locally developed pump and compare it to the Tie-over Bolster-dressing technique using the following parameters: ease of the technique, measured by the length of time consumed in the application of the dressing immediately after anchoring the graft to the STSG recipient site; percentages of graft take on 7th and 14th day post-STSG; level of pain perceived by the patient, using VAS scores at 1st, 7th and 14th day post-STSG; presence of complications, in terms of presence or absence of infection and skin maceration and breakdown; and the average costs. Given the positive impact and advantages of the NPWT treatment group, the researchers hypothesized that there is a significant difference between the NPWT-assisted recipient site dressing and Tie-over Bolster-assisted recipient site dressing on STSG.

Methods

A randomized controlled trial was conducted in Corazon Locsin Montelibano Memorial Regional Hospital, a tertiary hospital in Bacolod City, Negros Occidental, Philippines with the approval by CLMMRH Research Ethics Review Committee.

From October 2013 to September 2015, all patients who were admitted at the hospital with acute traumatic injuries and skin loss which was not amenable for primary closure, those who underwent adequate debridement of their wound, had a good granulating bed ready for Split Thickness Skin Grafting and those who gave informed consent were included. Those who had surgical contraindications because of medical conditions, those who had infection and necrotic tissues on the wound and those who refused to be included in the study were excluded from the study. (Table 1). Patients included in this study were randomized into two groups according to the type of intervention using the fishbowl method, (Figure 1). The circulating nurse assigned in the operating room was asked to randomly pick a rolled paper from the bowl to determine the type of intervention. The dressing materials for both groups were packed and sterilized in separate containers. The procedures of both treatment groups were done by a single surgeon and followed the standard protocol of the operating room of the institution.

Table 1. Inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Acute traumatic injuries and skin loss not amenable for primary closure	Surgical contraindication because of medical conditions
Underwent adequate debridement with good granulating bed	Presence of infection and necrotic tissues in the wound

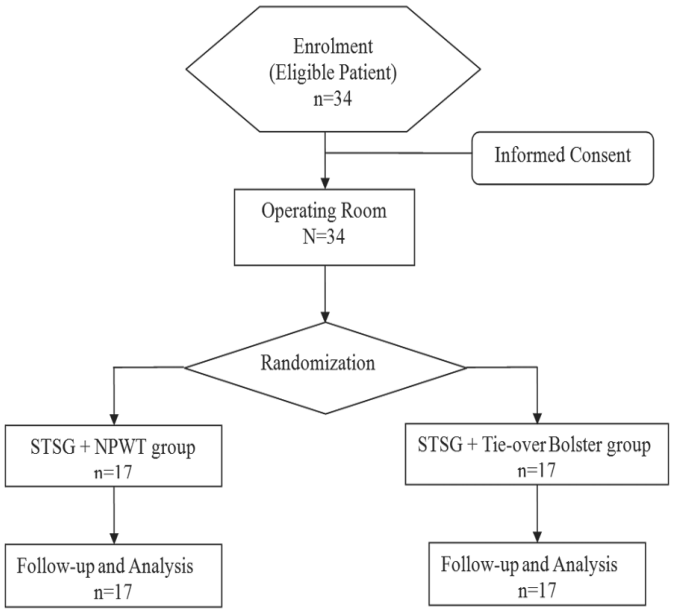

Figure 1. Study algorithm.

There were a total of 34 patients eligible and included in the study. They were randomized into the two groups according to the type of intervention and followed the standard protocol of the institution's operation room. They were followed up and assessed.

Techniques

Split Thickness Skin Grafting (STSG). The thickness graft used in the study was Split-thickness skin graft-medium (STSG-M; 0.012-0.018 in. or 0.3-0.45mm).

Donor Site Selection and Dressing. Appropriate donor sites for STSGs include the lower extremities, buttock, trunk, and occasionally the upper extremities. Donor sites selected were aesthetically acceptable and easily concealed, such as the buttock or the proximal thigh. The donor site was dressed using semi-open dressing technique. The dressing was removed and changed every 2-3 days postoperatively.

Graft Harvest. The method for harvesting split-thickness skin grafts utilized in this study was freehand with a knife. The installation and depth of setting were checked by inserting the beveled edge of a no.15 scalpel blade on the Humby knife which simulates the intermediate thickness of harvested skin grafts. The knife was advanced in a smooth continuous, sliding motion over the skin with gentle downward pressure. After an appropriate length has been harvested, the knife was tilted away from the skin and lifted off of the skin to cut the distal edge of the graft and complete the harvesting.

Meshing of Graft. The graft was placed on a plastic carrier and multiple small "pie crust" incisions with a scalpel blade no. 11 were made on the graft done manually. The mesh incisions were approximated at 0.5cm long and 0.5cm apart in an alternate pie crust fashion.

Placement of Graft. Re-inspection and hemostasis was done for the presence of bleeders. The graft was then placed over the wound bed with the dermal side down. The graft was secured using multiple simple interrupted sutures using nylon 4.0 done by passing the suture in the graft first before anchoring it to the edges of the wound bed as to prevent lifting of the graft. The wound bed size was measured using a 0.5cm grid (OpSite Flexigrid, Smith & Nephew, UK) before the Split Thickness Skin graft was applied on the wound bed. The grid was subsequently labeled and kept in a separate brown envelop to be used for reference, reassessment and measurement guide of the Split Thickness Skin graft take.

Interventions

Negative Pressure Wound Therapy-assisted Post-STSG Dressing. The dressing used a gauze-based technique by placement of a non-adherent dressing (vaselinized gauze) over the graft.[12] A 1cm thick gauze was applied over the wound and secured to the surrounding skin using cling wrap and elastic bandage. A splint was applied to the extremity to immobilize the extremity. A vacuum or suction machine was then placed to continuous negative 80-100mmHg suction.[13] Continuous negative pressure was checked by clamping the suction tubing and assessing for an air leak within the dressing. If an air leak was present, the leaking site was identified and repaired with a strip of the adherent plaster. The suction dressing was left decompressed and clamped while the patient was transported to the recovery room and back to the hospital ward room. Once back in the hospital ward room, the wound suction was attached to the NPWT machine until the dressing was changed on the 7th day. The negative pressure was monitored periodically and rechecked for any signs of leaks or loss in the negative pressure. The NPWT group set-up is shown in Figure 2.

Tie-over Bolster-assisted Post-STSG Dressing. A non-adherent dressing (vaselinized gauze) was placed over the graft. The bolster was constructed from gauze folded over sterile cotton balls or gauze balls moistened with normal saline solution. Anchoring sutures was applied around the graft recipient site using Silk 0 with needle sutures. These dressings were then secured tying the sutures to each other over the bolster

dressing.[14] Elastic bandage and a splint were applied to immobilize the extremity. Figure 3 shows the Tie-over bolster set-up.

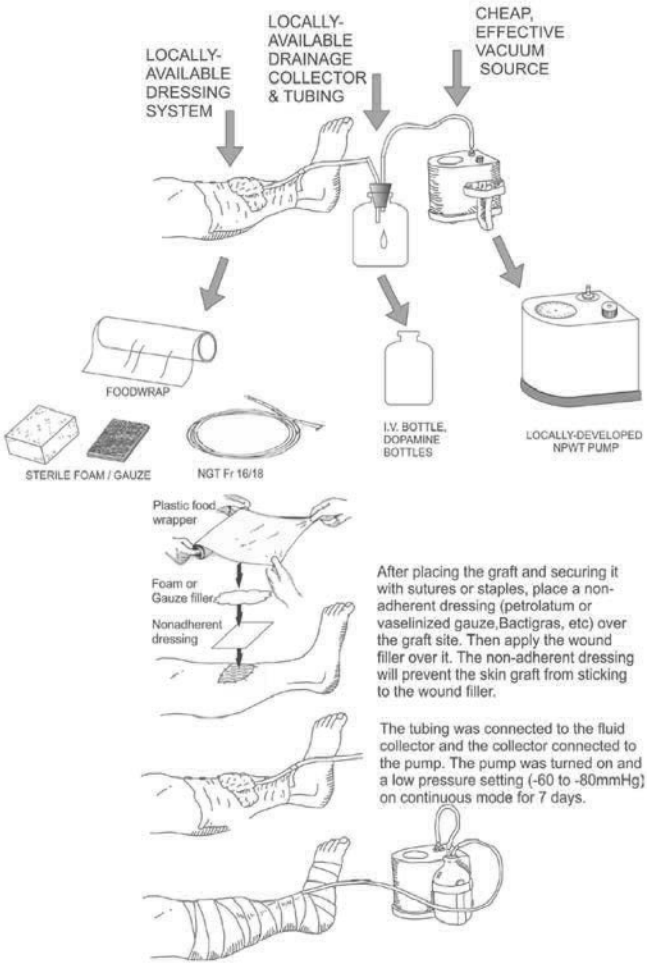

Figure 2. Low cost NPWT set up.

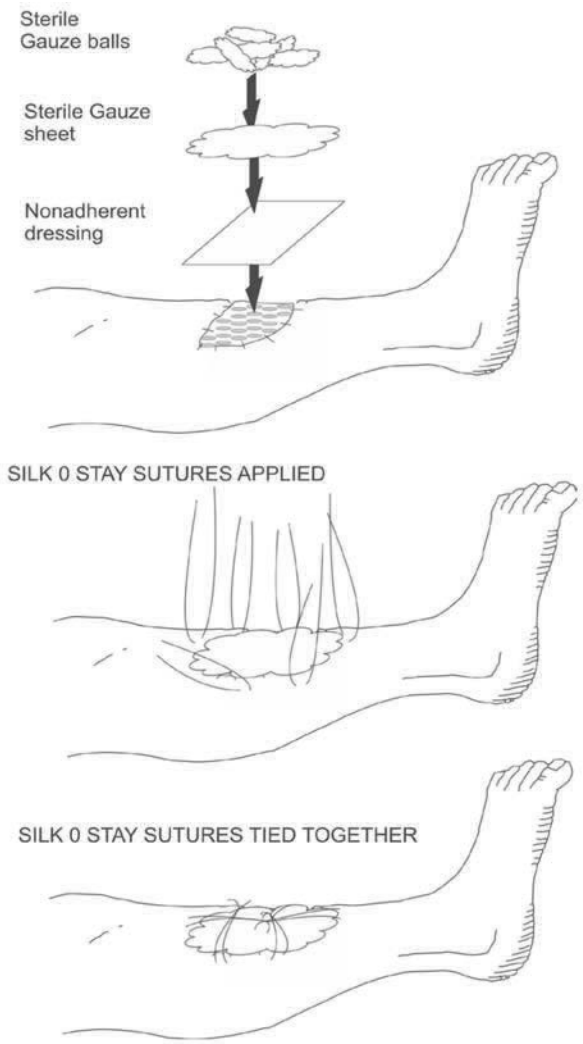

Figure 3. Tie-over bolster set up.

Follow-up and Evaluation

The subjects of the two groups were assessed according to the following variables:

1) *Ease of Technique*. Ease was measured by the time it took to complete procedure. The circulating nurse, with a stopwatch, would measure the time from start to finish of the application of the dressing. Specifically, the start of the application of the dressing construct started following the last anchor suture of the graft to the wound bed, and ended when the last component of the dressing construct was applied.

2) *Percentage of Graft Take*. The area of successful graft take was measured using the OpSite Flexigrid, on the 7th and 14th day post-STSG. This was compared with the initial grid made from the wound before placement of the graft.

3) *Pain*. Pain perceived by the patient was measured using a Visual Analog Scale (VAS) on 1st, 7th and

14th day post-STSGT. The intensity of the experience of pain was categorized into five values to be represented in the VAS as No Pain=0, Mild=1, Moderate=2, Severe=3 and Worst pain=4. The 7th day pain scores were also assessed with the subsequent removal of sutures on both the post-STSG dressing.

4) *Complications*. The complication of interest was infection.

5) *Cost*. The average cost of each dressing set-up based on the institution and local supermarket prices.

Sample Size: The sample size was calculated to allow a comparison of percentage of graft take on the 14th day. To achieve 70% statistical power and a significance (alpha) level of 5%, the estimated sample size required was 34 participants, with 17 participants per treatment arm.

Statistics: The PASW Statistics software, (version 17.0; SPSS, Chicago, Illinois) was used. The effectiveness of the two treatment groups, NPWT-assisted dressing and the Tie-over Bolster dressing, in terms of the graft take and level of pain measured using VAS scoring was analyzed using t-test. The p values are two-sided with a level of significance of 0.05. The relationship between the two treatment groups in terms of the length of time in the dressing and complications was determined through cross-tabulation of the variables. The study determined the level of significance to reject the null hypothesis at 5% level of significance.

Results

Patients were predominantly males with 82.35% in both treatment groups. Most of the injuries that required STSG were located at the leg and foot with 64.7% in the NPWT group and 88.23% in the Tie-over Bolster group. The predominant cause of injuries was avulsion injury with 47.06% in the NPWT group and 58.82% in the Tie-over Bolster group. The majority of the patients in the NPWT group had wound size of 51-100cm^2 and the 41.18% patients in the Tie-over Bolster group had wound size of 101-150cm^2. (Table 2)

Table 1. The demographics of the patients in the NPWT and tie-over bolster groups.

Variable	Classification	NPWT Group (n=17)		Tie-over Bolster group (n=17)	
		Frequency	Percentage (%)	Frequency	Percentage (%)
Sex	Male	14	82.35	14	82.35
	Female	3	17.65	3	17.65
Extremity Involved	Forearm	4	23.53	1	5.88
	Hand	2	11.76	1	5.88
	Leg	5	29.41	9	52.94
	Foot	6	35.29	6	35.29
Mechanism of Injury	Avulsion	8	47.06	10	58.82
	Crushing	3	17.65	2	11.76
	Laceration	1	5.88	1	5.88
	Pneumatic Tire Injury	3	17.65	0	0
	Secondary to Surgery	2	11.76	4	23.53
Wound Size (cm^2)	1-50	2	11.76	1	5.88
	51-100	6	35.29	5	29.41
	101-150	1	5.88	7	41.18
	151-200	5	29.41	3	17.65
	201-250	1	5.88	1	5.88
	251-300	2	11.76	0	0
	Total	17	100	17	100

Table 3. Length of time consumed in the application of the dressing in the NPWT and tie-over bolster groups.

Time (minutes)	Type of Dressing		Total
	NPWT group	Tie-over Bolster group	
<6	13	0	13
6- 10	4	10	14
11-15	0	6	6
>15	0	1	1
Total	17	17	34

Table 4. The percentage of graft take on the wounds in terms of the type of dressing applied to the graft recipient site on 7th and 14th day with 17 patients per group.

Variable	Classification	Mean	SD	n	t value	p value	Interpretation
Type of Dressing 7th day	NPWT group	99.05	1.71	17	2.515	0.017	Significant Difference
	Tie-over Bolster group	96.53	3.78	17			
Type of Dressing 14th day	NPWT group	99.05	1.71	17	2.515	0.017	Significant Difference
	Tie-over Bolster group	96.53	3.78	17			

Ease of Technique. More than 80% had an average of 5 minutes in the application of the dressing. Based on the cross-tabulation of the variables, patients in the NPWT group had the fastest time of 1 to 10 minutes only, and the tie-over booster had a minimum time of wound dressing at 6 minutes and has the longest time with more than 15 minutes (Table 3).

Percentage of Graft Take. NPWT group has higher mean percentage graft take [99.05% (SD = 1.71%, n =17)] than Tie-over Bolster group [96.52% (SD = 3.78, n = 17)] on both 7th and 14th day of Post-STSG. There were no changes on the graft take on the wounds at 7th and 14th days of post-STSG. The results are shown in table 4.

Pain. VAS scores on day 1 for NPWT group were higher (mean of 1.59) as compared to Tie-over group mean of 1. VAS scores on day 7 for NPWT group decreased to a mean of 0.48. No pain was felt on the 14th day post STSG for both treatment groups. Tie-over had a minimal difference on pain from the initial day. For the NPWT, there was 25% reduction on the pain perceived by the patients from the initial 1st day compared to the 7th and 14th day post STSG. (Table 5)

Complications. It is evident that all patients under the NPWT group had no complications of infection and 1 out of 17 (2.94%), in the Tie-over bolster group had an infection. No skin maceration or breakdown was noted in both groups.

Cost. The average costs of NPWT and Tie-over Bolster dressing construct were Php 2,917.00 and Php 3,684.50 respectively. The NPWT suction machine was reused frequently with a machine to patient ratio of 1:4. The cling wrap roll was enough for an average of 4 NPWT dressings with a roll to patient ratio of 1:4 (Table 6).

Discussion

In this prospective randomized clinical trial comparing the efficacy of the NPWT dressing versus Tie-over

Table 5. VAS scores according to the type of dressing in 1st, 7th and 14th day post STSG.

Variable		Classification	Mean	SD	n	t value	p value	Interpretation
1st day	Type of Dressing	NPWT group	1.59	0.51	17	3.405	0.002	Significant Difference
		Tie-over Bolster group	1.00	0.50	17			
7th day	Type of Dressing	NPWT group	0.48	0.51	17	-2.401	0.002	Significant Difference
		Tie-over Bolster group	0.88	0.49	17			
14th day	Type of Dressing	NPWT group	0.00	0.00	17	NA	NA	NA
		Tie-over Bolster group	0.00	0.00	17			

NPWT- Negative Pressure Wound Therapy

Table 6. Average cost of the NPWT and tie-over bolster groups.

Materials	Price (Php)*	Average Number of Items Used		Average Cost per Dressing Construct (Php)	
		NPWT	Tie-over Bolster	NPWT	Tie-over Bolster
Surgical sponge 4inx8in	200.00	1	2	200.00	400.00
Surgical sponge balls	150.00	0	4	0.00	600.00
Vaselinized gauze	156.25	2	2	312.50	312.50
Nylon 4.0 with needle suture	300.00	4	4	1,200.00	1,200.00
Silk 0 with needle suture	180.00	0	6	0.00	1,080.00
Elastic bandage 4in roll	23.00	4	4	92.00	92.00
NGT Fr. 16 (tubings)	25.00	2	0	50.00	0.00
Locally-made NPWT pump	4,000.00	1:4	0	1,000.00	0.00
Clingwrap roll	250.00	1:4	0	62.50	0.00
TOTAL				2,917.00	3,684.50

Bolster dressing in the integration of the split thickness skin grafts. Majority of the patients were male and the most frequently involved parts of the extremity were the leg and foot and were due to skin and soft tissue avulsions in both treatment groups. Majority of the patients had wound size of 51-100 cm^2 with 38.24% of both treatment groups.

The study showed that more than 80% had a faster time in the application of the wound dressing construct at 1-10 minutes. The NPWT group had the faster time ranging from 1-10 minutes compared to the tie-over booster which had a range of 6-15 minutes. This would imply the utilization of NPWT dressing construct was appropriate and can be a better choice of method.

The authors observed that the percentage of graft take on the STSG graft recipient site was higher in the NPWT group which has an absolute higher mean percentage graft take with 99.05% than Tie-over Bolster group with 96.52% ($p = 0.017$) on both the 7th and 14th day of Post-STSG. These findings agree with the study done by Dunn, et al. and Sarovath, et al. where there was higher graft take rate of 90%-96% observed with the use of NPWT or VAC on top of an STSG.[15] This technique is extremely efficacious, with increased graft

take due to total immobilization of the graft with complete contact of the skin graft and the recipient bed, thereby limiting shearing forces, eliminating fluid collection, bridging of the graft and decreasing bacterial contamination.[16]

Generally, there was greater pain perceived on the initial day or first day post-STSG and regressed to no pain felt on the 14th day post STSG on both treatment groups. There was a higher VAS score on the NPWT group on the initial day and can be attributed to the constant pressure sensation brought about by the sub-atmospheric pressure on the dressing. However, there was higher VAS score on the Tie-over Bolster group on the 7th day and can be associated with the discomfort associated with the removal of multiple anchor sutures. Tie-over Bolster dressing may cause unnecessary trauma to the graft when removed since the blood-soaked gauzes inevitably get hard quickly and stick to the skin graft, causing pain and discomfort when they are removed and pose a higher risk of graft displacement from the wound bed.[17] For the NPWT, there is 25% reduction on the pain perceived by the patients from the initial 1st day compared to the 7th and 14th day post STSG.

STSG graft failure may be caused by inadequate recipient bed, hematoma, seroma, graft shearing due to inadequate graft fixation, technical errors (too thick or thin grafts, upside-down graft, systemic health problems and bad nutritional status.[18] No complication was observed in the NPWT group and noted one in 17 patients in the Tie-on Bolster group had an occurrence of infection. This finding supports the claims that NPWT group had reduced bacterial levels and a cytological profile indicating a healing wound.[19]

The average costs of the NPWT group and the Tie-over Bolster group were Php 2,917.00 and Php 3,684.50 respectively. A difference of 20% favoring the NPWT group was noted. The reusability of the NPWT machine and use of the cling wrap roll for three NPWT dressings provide an affordable option for long term practice. The use and non-use of NPWT also contribute to the total cost of hospitalization since NPWT use contributes to a shortened hospital stay.[20]

With the given parameters in the evaluation of the two dressing techniques, the authors concluded that the NPWT dressing was more efficacious, with less discomfort and less costly, compared to Tie-over Bolster dressing in the integration of the split thickness skin grafts

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