


CLINICAL ARTICLE

Effect of Modified Allgöwer–Donati Suture Technique on Wound Cosmetics in Spinal Surgery

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Objective: To analyze the efficacy of modified Allgöwer–Donati suture (MADS) technique on cosmetic outcomes compared with vertical mattress suture (VMS) technique in spinal surgery wounds.

Methods: This randomized controlled trial was conducted at the First Hospital of Lanzhou University (Gansu, China) from September 2019 to August 2020. The patients were randomly divided into two groups, a VMS group and a MADS group, by staff not involved in the treatment using a computer-based random number table program (no restrictions on age or sex). Both procedures were performed by the same group of physicians as well as assistants. All suture wounds were completed by the same person. The primary endpoint was the scar area, and the postoperative scar area was scored by the Patient and Observer Scar Scale Assessment (POSAS). The scar area was calculated by ImageJ software. The second outcome measure was wound complications, including poor wound healing, wound edge necrosis, and infection. The trial was recorded in the Chinese Clinical Trial Register on 18 August 2019 (ChiCTR1900024548).

Results: A total of 143 patients were included: 72 in the VMS group and 71 in the MADS group. There was no significant difference in their demographics in terms of age (49.71 ± 8.91 vs 50.15 ± 6.79 years, $P = 0.737$), sex (M/F, 30/41 vs 31/41, $P = 0.923$), suture time (3.39 ± 0.22 vs 3.47 ± 0.25 s/mm, $P = 0.057$), or body mass index (BMI, 23.88 ± 3.50 vs 24.05 ± 3.50 , $P = 0.765$) for MADS to VMS. The postoperative scar area was compared between the two groups transversely on day 12, the MADS wound scars decreased by 58.95% (75,133.24/127,452.58). In the POSAS evaluation, after MADS treatment, surface area score decreased from 5 (4, 5) to 2 (2, 3) ($P < 0.0001$), observer's overall opinion from 5 (4, 5) to 3 (2, 3) ($P < 0.0001$), itching from 3 (3, 4) to 3 (2, 3) ($P = 0.001$), color from 4 (4, 5) to 3 (2–4) ($P < 0.0001$), stiffness 4 (3–4.75) to 3 (3, 4) ($P < 0.0001$), or thickness from 4 (3–5) to 4 (3, 4) ($P = 0.004$). In terms of overall opinion evaluation, the MADS showed a significant difference in observer's overall opinion to the VMS (5 (4, 5) vs 3 (2, 3), $P < 0.0001$) and in patient's overall opinion 5 (5, 6) to 3 (3, 4), ($P < 0.0001$). There was no significant statistical difference in poor wound healing (3 vs 0, $P = 0.245$), wound edge necrosis (3 vs 0, $P = 0.245$), and infection (1 vs 0, $P = 1.000$) with the MADS to the VMS.

Conclusion: The results of this study show that the MADS effectively reduced the surgical scar area to 58.95% with no additional adverse events compared with that of the VMS in spine surgery.

Key words: Allgöwer–Donati; Cosmetic; Spinal; Suture

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Introduction

The use of spinal surgery has increased considerably over the last 20 years¹⁻³. The number of individuals diagnosed with symptomatic cervical and lumbar disc herniation increases with age, and the incidence of these diseases is higher in women than in men⁴. Surgical incision inevitably causes skin scarring. The successful completion of surgery is no longer the only concern that patients have about the surgery. The subjective opinion of patients regarding the surgical scar often constitutes the standard for judging the success or failure of the procedure⁵. Scars may lead to an array of functional, cosmetic, and psychological consequences⁶. All such wounds that penetrate the dermis result in some degree of scar formation⁷. The goals of cutaneous wound repair are to avoid infection and to minimize the amount of dysfunction and disfigurement⁸. Although non-intradermal non-absorbable suture techniques such as VMS ensure good wound healing in spinal surgery without increasing additional material costs, they leave a similar “crab foot”-like surgical scar around the postoperative incision.

The Allgöwer–Donati suture technique has been used for ankle wound closure and maintains control of skin tension in orthopaedic surgery⁹. This technique achieves some cosmetic results by means of unilateral intermittent embedding of the wound. In the study of this technique to further reduce the formation of surgical scars while maintaining better skin tension, we partially modified the suture technique by redesigning the suture method and adding a cushioning material between the suture and the skin. Sterile gauze dressings are used in direct contact with the wound to absorb exudate, maintain a sterile environment, and further avoid wound infection^{10,11}. The purpose of this study was to achieve the following objectives: (i) to observe the healing effect of modified Allgöwer–Donati suture method (MADS), including poor wound healing, wound edge necrosis, and infection; and (ii) to compare MADS with the vertical mattress suture method (VMS) to understand whether it improves the cosmetic outcome of postoperative wound. We hope that this approach will be as generalizable as possible, as more cosmetic skin healing can be achieved by changing only the suture method.

Methods

Inclusion, Exclusion, and Withdrawal Criteria

The inclusion criteria followed the PICOS principle: (i) patients must have been diagnosed with spinal disease and treated with non-minimally invasive surgery; (ii) patients with no skin defects in the surgical area, no restrictions on sex and age; (iii) interventions were performed at the time of surgical entry into the skin suture stage and patients were assigned to the modified suture group (given Allgöwer–Donati intradermal suture and gauze pieces isolated suture) or the vertical mattress suture group (routinely given vertical sutures); (iv) outcomes included Scar

Assessment Scale, scar area, poor wound healing, wound edge necrosis, and infection.

The exclusion criteria were as follows: (i) preoperative diabetes; (ii) patients with lumbar tuberculosis; (iii) current smokers and patients with HIV, hepatitis C, or syphilis infection; (iv) preoperative long-term use of painkillers or corticosteroids.

The withdrawal criteria were as follows: (i) excessive intraoperative bleeding requiring blood transfusion; (ii) patients with scar formation on the surgical skin; (iii) family members and patients refused to further participate in the experiment; (iv) critically ill patients requiring tracheal intubation; (v) patients lost to follow-up.

Study

We conducted a clinical randomized controlled trial to identify the reliability and validity of a new suturing method. This clinical randomized clinical trial involved one surgeon (W.W.J.) and two assistants (Z.X.L., and L.E.L.) from September 2019 to August 2020. The present study was registered on the Chinese Clinical Trial Registry (ChiCTR1900024548), and it has been approved by the First Hospital of Lanzhou University Ethics Committee and conforms to the provisions of the Declaration of Helsinki. The written informed consent was obtained from all participants.

Patient Information

According to the inclusion and exclusion criteria, 143 patients were finally included: age (49.93 ± 7.91 years), male/female (61/82), and BMI (23.96 ± 3.49). The patients were divided into a VMS group and a MADS group according to different skin suture methods by the staff not involved in the treatment using the computer-based random number table program. All eligible patients who agreed to participate in the study were randomly assigned to the VMS group or the MADS group, in order of admission time, starting from one, with odd numbers in the VMS group and even numbers in MADS group.

Surgical Procedure

Preoperative Confirmation

All patients underwent preoperative blood routine, biochemical routine, routine bleeding and coagulation tests to rule out anesthesia contraindications and surgical contraindications.

Anesthesia and Position

All patients were placed in the prone position and all surgeries were performed under general gas anesthesia by the same surgical team specializing in spinal surgery *via* a posterior approach, with the principal surgeon being one of the authors (W.W.J.). In all cases, after the routine procedure was completed, the suturing stage was entered.

Skin Closure Procedure

All sutures were completed by the same surgeon (L.E.L.), and another member recorded the suturing time. There was a uniform selection of 4-0 silks braided non-absorbable sutures (Manufacture by Johnson & Johnson Medical Ltd., China). The VMS group and MADS group were randomly selected for skin wound suture. For the MADS, medical absorbent gauze pieces (produced by Henan Yadu Industrial Co., Ltd. Henan, China) were completely immersed in 75% alcohol. Then as much alcohol as possible was removed and the gauze was fully expanded and folded into three layers, cut to a distance of width ab (Fig. 1A, B); the length was consistent with the wound length, and covered between the skin and the suture (Fig. 2). In the VMS group (Supporting Information Fig. S1), the same medical absorbent gauze pieces were routinely removed, soaked in alcohol, as much alcohol as possible was removed, and cut until the gauze size covered the wound and suture surface. The same bandaging method was used in the two groups. Then, the patient was transported to the recovery ward.

Postoperative Management

Prophylactic anti-infection treatment was used for 24 h after the surgery. Grade I nursing care was given after postoperative 24 h and changed to routine nursing care after 24 h. The patients received routine aseptic dressing change on postoperative day 2, day 5, day 8, and day 12, respectively. The stitches were removed on postoperative day 12, and the

wound excipients were replaced immediately when wound exudation occurred (Supporting Information Fig. S2).

Outcome Measures

Scar Assessment Scale

The patient and observer scar assessment scale (POSAS) was used to assess postoperative scarring. The POSAS consists of two scales: the observer scale and the patient scale. Both scales contain six items that score numerically. Each of the six items on both scales has a 10-step score, with 10 indicating the worst imaginable scar or sensation. The total score of both scales consists of adding the scores of each of the six items (range, 6 to 60). The lowest score, 6, reflects normal skin, whereas the highest score, 60, reflects the worst imaginable scar⁶.

Scar Area Calculation

We used Image J software (an open-source Java image processing program inspired by National Institutes of Health Image, <https://imagej.net/ImageJ>) to calculate the scar area, and to avoid errors, we uniformly set the total area included in the calculation to 14×7 mm (containing an independent skin suture). Select the same site at the same time point for transverse comparison of postoperative scar area formed by different surgical method. The scar area is calculated by the area calculation function of the software. We labeled the scar area of the vertical mattress suture as A. Due to the scar area of the modified suture group being a discontinuous area, it is

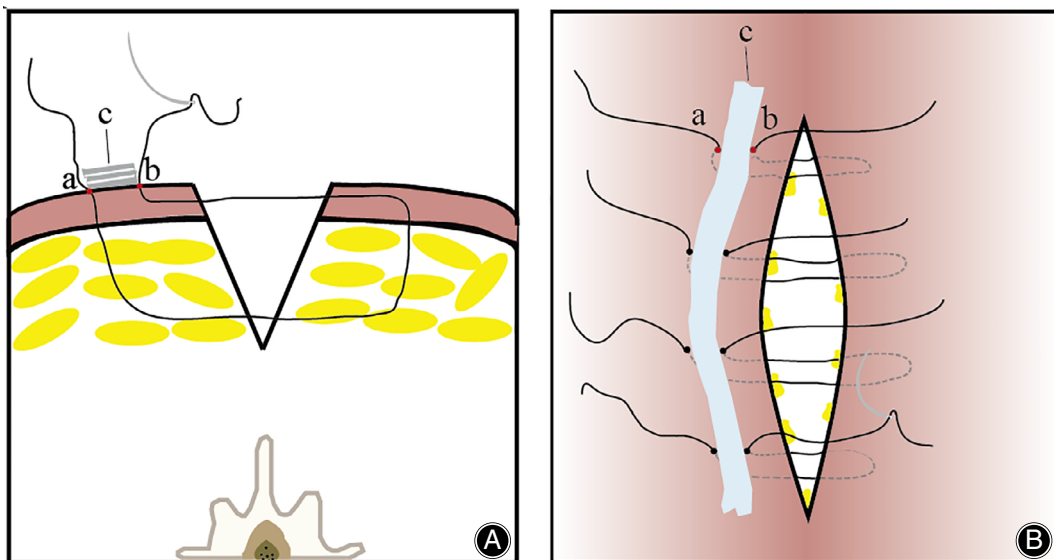


Fig. 1 Schematic diagram of modified suture surgery. (A) Insert the needle from point a through the subcutaneous tissue on the same side as well as part of the fat layer, penetrate out from the fat layer and skin on the other side (do not penetrate out of the skin) through the skin on the side of the needle insertion point and then penetrate out from point b, medical absorbent gauze pieces soaked in 75% alcohol (c) were placed between points a and b. (B) Surgeon's View, points a and b are on the same side of the wound, and the length of medical absorbent gauze pieces is about the same as the wound (created on Adobe Illustrator 2019, Version:23.1.1).

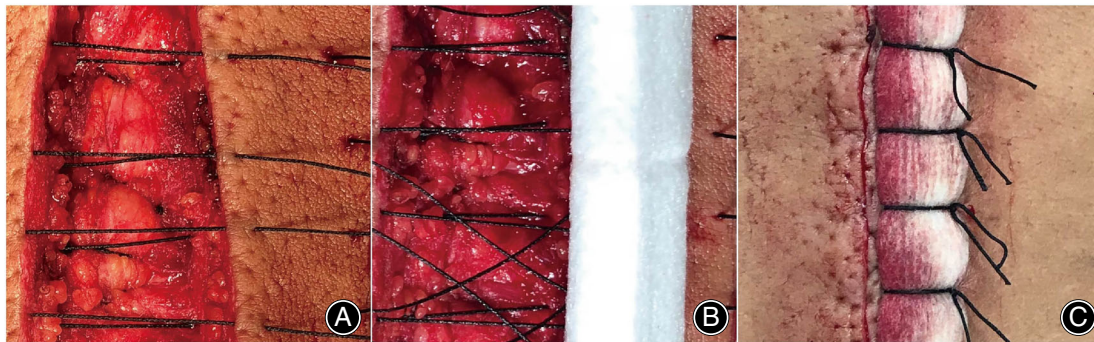


Fig. 2 Modified specific procedure for suturing, (A) Allgöwer-Donati suturing. (B) Added to medical absorbent gauze pieces soaked in 75% alcohol. (C) Completed.

TABLE 1 Patient demographics

	Vertical mattress suture group	Modified suture group	P value
Patients	72	71	
Age, y	49.71 ± 8.91	50.15 ± 6.79	0.737
Sex: male: female	31:41	30:41	0.923
BMI, kg/m ²	23.88 ± 3.50	24.05 ± 3.50	0.765
Suturing time, s/mm	3.39 ± 0.22	3.47 ± 0.25	0.057

divided into area B (wound scar) and area b (pinhole scar), and its total area is the sum of area B and area b. Mark the modified suture group relative reduction area by %, and the formula is as follows:

$$\% = \frac{[(B1 + b1) + \dots + (Bn + bn)]/n}{(A1 + \dots + AN)/N}$$

n: number of patients included in vertical mattress suture group;

N: Number of patients included in modified suture group.

Statistical Analysis

All statistical analyses were done with SPSS version 26.0 software (IBM, Armonk, NY, USA). Continuous variables, such as age, BMI, and suturing time, were tested for normal distribution using the Kolmogorov-Smirnov test. Continuous data with normal distribution were expressed as mean ± standard deviation ($\bar{x} \pm s$), t-test was used for intergroup comparison. If numerical variables had non-normal distributions or unequal variances, Wilcoxon Mann-Whitney U tests were used. Categorical variables, such as sex and complications, were presented as frequencies and analyzed using χ^2 test or Fisher's exact test as appropriate. Differences were considered statistically significant at a P value of less than 0.05.

Results

Characteristics of the Patients

A total of 143 patients were included: 71 in the modified suture group and 72 in the vertical mattress suture group. There was no significant difference in their demographics in terms of age (49.71 ± 8.91 vs 50.15 ± 6.79 years, $P = 0.737$), sex (male/female, 30/41 vs 31/41, $P = 0.923$), suture time (3.39 ± 0.22 vs 3.47 ± 0.25 s/mm, $P = 0.057$), or body mass index (BMI, 23.88 ± 3.50 vs 24.05 ± 3.50 , $P = 0.765$) for MADS to VMS (Table 1).

Scar Assessment Scale

In the Observer Scar Assessment Scale, there was no significant difference in vascularity, pigmentation, thickness, relief, or pliability, but surface area score decreased from 5 (4, 5) to 2 (2, 3) ($P < 0.0001$), Observer's overall opinion decreased from 5 (4, 5) to 3 (2, 3) ($P < 0.0001$) for MADS to VMS (Fig. 3) (Supporting Information Table S1). In the Patient Scar Assessment Scale, there was no significant difference in the evaluation of pain, irregularity, but itching decreased from 3 (3, 4) to 3 (2, 3) ($P = 0.001$), color from 4 (4, 5) to 3 (2-4) ($P < 0.0001$), stiffness from 4 (3-4.75) to 3 (3, 4) ($P < 0.0001$), and thickness from 4 (3-5) to 4 (3, 4) ($P = 0.004$) for MADS to VMS. In terms of overall opinion evaluation, the MADS showed a significant difference in patients' overall opinions, which decreased from 5 (5, 6) to 3 (3, 4), ($P < 0.0001$) (Fig. 3) (Supporting Information Table S1).

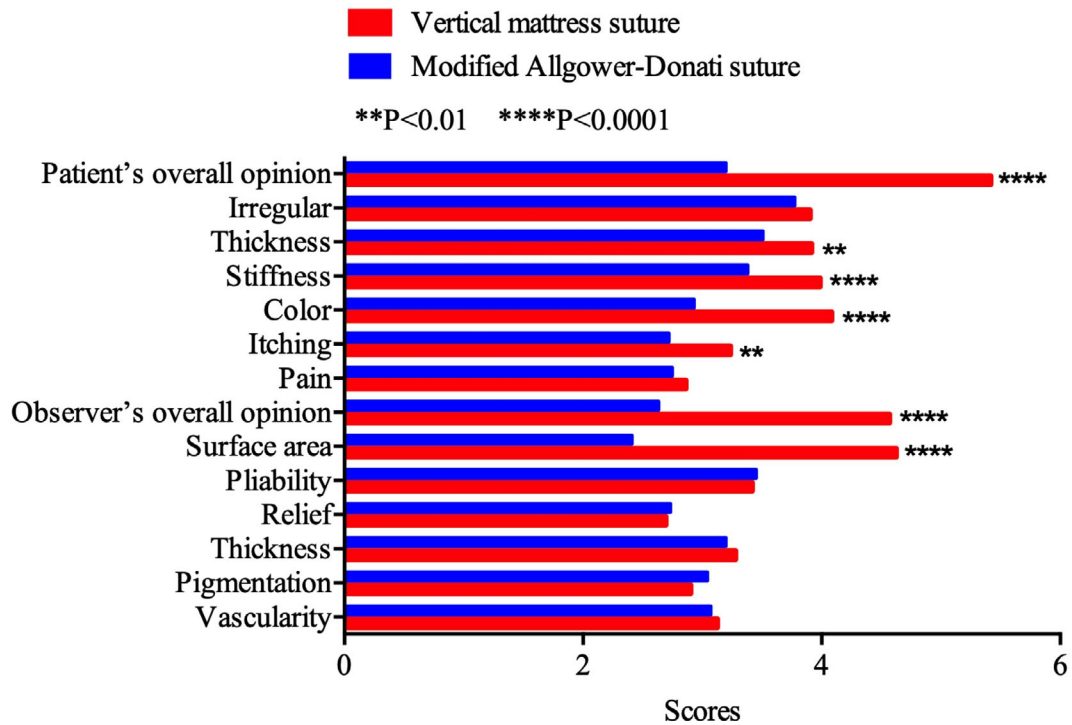


Fig. 3 Patient and Observer Scar Assessment Scale. There was a significant difference in the surface area ($P < 0.0001$), itching ($P = 0.001$), color ($P < 0.0001$), stiffness ($P < 0.0001$), thickness ($P = 0.004$) and overall evaluation ($P < 0.0001$) for MADS to VMS. By Mann-Whitney U-test.



Fig. 4 Scar area (Day 12). (A) VMS group, wound takes on a cross shape. (B) MADS group, wound takes shape of line. There was a significant statistical difference between the two groups ($P < 0.001$). The scar area, quantitative index, and calculation method were calculated for the same area in the two groups using ImageJ software (Appendix, Supporting Information S1).



Fig. 5 Comparison of scar between the two groups at the same time (Day 12). (A) VMS group, wound takes on regular scar shape. (B) MADS group, only one side of the wound is left with a partial pinhole, while the other side of the skin is completely free of scarring.

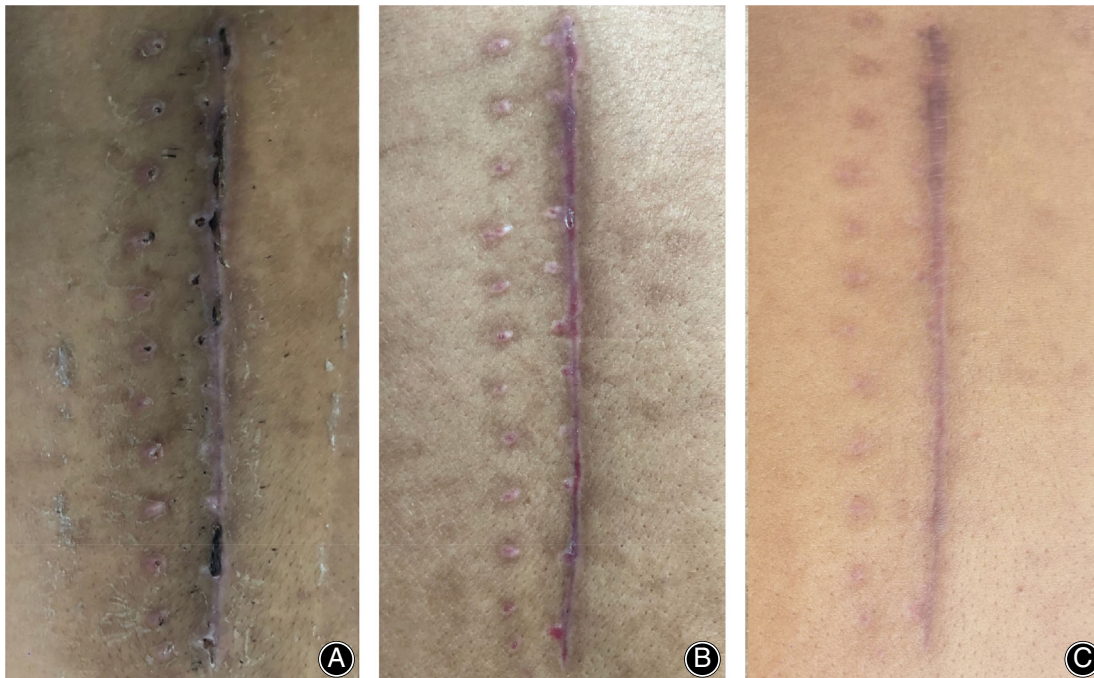


Fig. 6 Comparison of scar at different time points in the MADS group. (A) Formation and shedding of wound blood scab (Day 12). (B) Complete sloughing of blood scab (Day 15). (C) Some wounds heal close to normal skin (Day 31).

Scar Area Calculation

Seventy-one patients were included in MADS group and 72 patients were included in VMS group. The MADS group averaged 64,520.89 in area B, 10,612.35 in area b, and 75,133.24 in area B + b, and the VMS group averaged 127,452.58 in area A. There was a significant statistical difference between the two groups ($P < 0.001$). The MADS group decreased to 58.95% (75,133.24/127,452.58) in all patients when the scar area was calculated by Image J software (Fig. 4) (Supporting Information Table S2).

During subsequent follow-up, after comparing the two groups at the same time (Fig. 5) and at different times (Fig. 6), the visual appearance of the MADS group was better than that of the VMS group.

Complication

In terms of complications, there were three cases of poor wound healing in the VMS group that showed prolonged wound healing, extending suture removal to 21 days after compression bandaging; and three cases of wound edge necrosis, manifested as skin color darkening and blackening at the wound edge. After appropriate suture release, the wound healing occurred at 15, 17, and 18 days after operation, and one patient had wound infection on postoperative day 2, manifested as increased skin temperature of wound skin, bright red skin, and obvious local pain. After intravenous injection of Cefazolin Sodium 1 g/12 h, the frequency of routine sterile dressing change was increased (once daily). The above symptoms disappeared on day 7. On day 14, the wound healed, and the suture was removed. There was no such cases in

the MADS group. Fisher's exact test was used for poor wound healing (3 vs 0, $P = 0.245$), wound edge necrosis (3 vs 0, $P = 0.245$), and infection (1 vs 0, $P = 1.000$) for MADS to VMS.

Discussion

MADS Reduces Wound Scarring but Does Not Add Additional Costs

In this study, we modified the Allgöwer–Donati technique for increasing the cosmetic appearance of the spinal surgical incision. Our results demonstrate that MADS is effective in reducing wound scarring to 58.95% of patients when compared to VMS by only altering it without adding additional material. To our knowledge, this suture method is the first application to the skin of adults undergoing spinal surgery. Current wound closure methods include VMS, barbed suture material, intradermal sutures, skin staples, and isoamyl 2-cyanoacrylate^{12–14}. Compared to VMS, other suture methods may have better cosmetic results but increase the hospitalization costs and reduce the ability to resist wound tension. Barbed suture material costs US\$47.4 more per total knee arthroplasty than traditional sutures (61.5 vs 14.5)¹². Compared with VMS, MADS is only a change in the suturing technique of the surgeon, and there is no change in the suturing material.

MADS Technical Characteristics

The Allgöwer–Donati suture technique has historically been recommended by the AO-ASIF Group as the closure of

choice for posttraumatic tenuous skin flaps¹⁵. Compared with the VMS methods, as the suture materials for the wound have not been changed, it is simply the suture method that is changed. It reduces part of the scar through the subcutaneous channel on one side of the wound, further reducing the formation of scars. Because of the inherent characteristics of this technique, in which the suture is passed intradermally from one side of the wound to the other without surfacing extracutaneously and enclosing the suture, we began to pay attention to its cosmetic effects and applied the technique in spinal surgery. Needle punctures of normal skin and sutures are still cut and compress the skin, which is the pathological basis of crab-like scars. For the first time, we tried to use medical absorbent gauze pieces to isolate the suture from normal skin and reduce the damage from the suture to the skin to further reduce the formation of scars. In a previous study of medical absorbent gauze pieces and the number of layers, it was demonstrated that three layers of alcohol-soaked and fully deployed medical absorbent gauze pads had a better effect than one or two layers in reducing scar formation and had an advantage in patient comfort in the supine position compared to more than four layers.

How to Evaluate MADS Cosmetic Results

On the choice of scale to assess scarring, we favor the POSAS scale over the Vancouver Scar Scale because the authors of the original article on the Vancouver Scar Scale have already stated that their scale lacked the rating of symptoms such as itching and pain, which they considered important in the treatment of scars¹⁶. The POSAS scale incorporates itching and pain. In cross-cultural validation of the reliability and validity of the POSAS, the POSAS is a valid, reliable, and culturally appropriate survey for evaluating hypertrophic scars¹⁷. Therefore, we have reason to believe that this scar evaluation scale is still suitable for Chinese patients. When comparing the overall opinion score that patients and observers assign to scars, patients tend to have higher scores than observers, which may be due to some subjective feelings of patients such as itching and pain, which cannot be objectively evaluated by observers. The same occurs on the overall evaluation of scars. This finding may be due in part to the lack of separation between the two groups of patients after surgery, which creates a subjective contrast that has a meaningful subjective visual difference for the modified suture group of patients but is objective for the observer.

Some studies have always applied the Allgöwer–Donati suture technique in calcaneal fractures as well as ankle fractures but not in vertebral surgery. Shannon *et al.*¹⁸ measured incision perfusion by intraoperative application of the laser-assisted indocyanine green angiography (LA-ICGA) imaging technique and showed that the Allgöwer–Donati suture technique had less mean incision perfusion injury than the vertical mattress technique. To

our knowledge, this study is the first to apply the MADS technique to spinal surgery to reduce postoperative scar formation. We applied medical absorbent gauze pieces between the suture knot and the skin in combination with the Allgöwer–Donati suture technique in the posterior approach to spinal surgery. The results showed that compared to the vertical mattress suture group, the modified suture group had a 58.95% reduced area of wound scar, and it was further confirmed that the scar formation between the surgical incision and the needle was related to the compression of local tissue by the suture. Wound healing is a complex and highly regulated process, and the most effective way is to avoid bacterial colonization of the wound and maintain adequate tissue perfusion¹⁹. There were no significant differences between the groups. Although previous studies have shown different results, in our study, the Allgöwer–Donati suture technique had the least effect on cutaneous blood flow²⁰, and after MADS treatment, no infection, poor wound healing, or wound edge necrosis events occurred, which may be related to our sample size, but we attribute the reason more to the effect of alcohol on medical absorbent gauze pieces.

Future of MADS

At present, we are studying the application of polyvinyl alcohol material to replace the medical absorbent gauze pieces. Polyvinyl alcohol (PVA) is a hydrophilic hydrogel polymer, which is widely used in dressings, drug delivery, and medical applications²¹. After that, we will complete the plasticity and drug-loading of PVA, so that it can obtain better skin conformity and carry antibacterial drugs (Patent No. 202022922785.1).

Limitations

A limitation of this study is that only VMS is compared with MADS and only a single-centre study is carried out. For further in-depth study and promotion of this method, the comparison between multi-centres and multiple suture methods is still a needed.

Conclusion

The results of this study show that the MADS effectively reduced the surgical scar area to 58.95% with no additional adverse events compared with that of the VMS in spine surgery.

Author Contributions

Conceptualization, methodology: Erliang Li, Qiong Ma, Wenji Wang, Xueliang Zhang, Bo Liao. Data curation, writing—original draft preparation: Erliang Li. Investigation, case collection: Erliang Li, Tong Zhang. Supervision: Qiong Ma, Xueliang Zhang. Software, statistical analysis: Erliang Li, Kang Yan. Writing—reviewing and editing: Erliang Li, Bo Liao, Wenji Wang.

Ethical Approval

Approval was obtained from the Ethics Committee of the First Hospital of Lanzhou University on 7 August 2019, No.: LDYLL2019-220 and all patients signed informed consent forms.

Supporting Information

Additional Supporting Information may be found in the online version of this article on the publisher's web-site:

Appendix S1. Supporting Information**References**

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