Outcomes of Cutaneous Scar Revision During Surgical Implant Removal in Children with Cerebral Palsy

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Background: Children who have had surgery involving the placement of an implant frequently undergo a subsequent surgery for hardware removal. The cosmesis of surgical scars following initial and subsequent surgeries is unpredictable. Scar incision (subsequent surgical incision through the initial scar) or excision (around the initial scar) is selected on the basis of the quality of the initial scar. The outcomes following these techniques have not been determined.

Methods: This prospective, consecutive case series was designed to compare outcomes following surgical scar incision versus excision at the time of implant removal in children with cerebral palsy. Photographs of the scars were made preoperatively and at 6 and 12 months following implant removal and were graded for scar quality utilizing the modified Stony Brook Scar Evaluation Scale (SBSES). Parental assessment of scar appearance was performed at the same time points utilizing a visual analog cosmetic scale (VACS).

Results: The scars that were selected for incision had significantly worse SBSES scores at 6 and 12 months following the second surgery compared with preoperative values. However, parents' VACS scores of the incised scars, although worse at 6 months, were comparable with preoperative scores at 12 months. Scars that were selected for excision had significantly worse SBSES scores at 6 months but scores that were comparable with preoperative values at 12 months. VACS scores for the excised scars were comparable at the 3 time points.

Conclusions: Surgical incisions that initially healed with good scar quality generally healed well (from the parents' perspective) following subsequent incision through the previous scar. Surgical incisions that initially healed with poor scar quality did not heal better following excision of the previous scar. In such situations, surgical excision of the existing scar should occur in conjunction with additional adjuvant therapies to improve cosmesis.

Level of Evidence: Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

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The healing of surgical incisions is influenced by biological and mechanical factors[1-4]. Healing can be unpredictable, despite meticulous surgical technique and detailed postoperative management. Additionally, surgical incisions on the same patient may heal differently, depending on anatomical location. There is little objective research evaluating outcomes of surgical incisions following various surgical techniques and wound-management strategies.

Children who have surgery that includes the use of internal fixation frequently undergo a subsequent surgery for implant removal[5]. At this point, the surgeon must choose between scar incision (second surgical incision directly through

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TABLE I Modified SBSES*

	No. of Points
Width in mm	
>2	0
≤2	1
Height	
Elevated	0
Depressed	1
Flat	2
Color	
Darker	0
Lighter	1
Same as skin color	2
Overall appearance†	
Poor: <1/3 of scar has score of ≥4	0
Fair: ≥1/3 to <2/3 of scar has score of ≥4	1
Good: ≥2/3 of scar has score of ≥4	2
Total score‡	0-7

*The greater the value of the score, the better the visual quality of the scar. †Describes the quality of scar-healing relative to the length of the surgical incision. ‡Maximum possible score of 7 points.

TABLE II Intraobserver and Interobserver Reliability of the Modified SBSES

	ICC	
Parameter	Intraobserver	Interobserver
Width	0.84	0.60
Height	0.86	0.67
Color	0.93	0.61
Overall appearance	0.87	0.52
Total score	0.93	0.76

the previous incision) or excision (second surgical incision about the margins of the previous incision). Scar incision is usually selected when the initial incision has healed optimally. Scar excision is usually selected when the initial incision has healed poorly, with excessive width, surface hypertrophy or depression, or discoloration. The outcomes following this decision-making paradigm, to our knowledge, have not been previously investigated.

The current study was designed to evaluate the following hypotheses: (1) surgeons choose an incision versus excision strategy on the basis of scar appearance, (2) scars selected for incision have cosmetic outcomes following the second procedure that are comparable to those following the initial procedure, (3) scars selected for excision have better cosmetic outcomes following the second procedure than following the initial procedure, and (4) scars selected for excision at the time of implant removal have outcomes that are comparable to those of scars selected for incision.

Materials and Methods

This prospective, consecutive case series was designed to compare outcomes following surgical scar incision versus excision at the time of implant removal in children with cerebral palsy (CP). The selection of incision or excision was made according to surgeon preference following discussion with parents. The study design was approved by our institution's research review committee. Two surgeons agreed on surgical closure techniques (which included deep and superficial dermal-layer closures, the same size and type of absorbable suture, and the use of skin closure strips without additional adhesive) and postoperative management (which included the use of a dry dressing, changed at 2 weeks, scar massage as described in a handout provided to families, and support of individual patient/family preference for the use of over-the-counter topical lotions once the skin had healed).

Patients of the 2 surgeons were recruited at the time of implant removal, which occurred at a mean of 1.8 years (range, 1.0 to 2.1 years) following the index procedure. Photographs of the surgical scar were made preoperatively and at 6 and 12 months following surgical implant removal. All photographs were made with a single camera, using the same photographic techniques. The quality of the incisional scar was graded by a co-author (K.D.) who was not involved in the care of the patients, utilizing a modified version of the Stony Brook Scar Evaluation Scale (SBSES)[6]. The SBSES was the only validated instrument for scar evaluation found in a PubMed search of the medical literature from 1980 to the time of our investigation (keywords: *surgical scar evaluation*), with a reported interobserver reliability of 0.73 to 0.85[6]. The greater the value of the SBSES score, the better the visual quality of the scar (Table I, Figs. 1-A

TABLE III SBSES Scores for Scars in the Incision Group (N = 27)

				P Value*	
Parameter	Preop.†	6 Mo†	12 Mo†	6 Mo Vs. Preop.	12 Mo Vs. Preop.
Width	1.15 ± 0.82	1.11 ± 0.85	0.85 ± 0.77	NS	NS
Height	1.48 ± 0.80	1.33 ± 0.88	1.33 ± 0.92	NS	NS
Color	0.78 ± 0.89	0.26 ± 0.66	0.41 ± 0.69	0.041	NS
Overall appearance	1.56 ± 0.64	0.78 ± 0.85	0.89 ± 0.85	0.001	0.008
Total score	4.96 ± 1.85	3.48 ± 2.06	3.48 ± 1.70	0.014	0.014

*ANOVA; $p < 0.05$ = significant. NS = not significant. †The values are given as the mean and the standard deviation.

TABLE IV SBSES Scores for Scars in the Excision Group (N = 31)

Parameter	Preop.†	6 Mo†	12 Mo†	P Value*	
				6 Mo Vs. Preop.	12 Mo Vs. Preop.
Width	0.45 ± 0.77	0.45 ± 0.68	0.61 ± 0.80	NS	NS
Height	1.26 ± 0.93	0.55 ± 0.85	1.00 ± 0.89	0.007	NS
Color	0.52 ± 0.81	0.00 ± 0.00	0.23 ± 0.43	0.001	NS
Overall appearance	0.94 ± 0.85	0.26 ± 0.58	0.68 ± 0.87	0.003	NS
Total score	3.16 ± 2.71	1.26 ± 1.59	2.52 ± 2.41	0.004	NS

*ANOVA; $p < 0.05$ = significant. NS = not significant. †The values are given as the mean and the standard deviation.

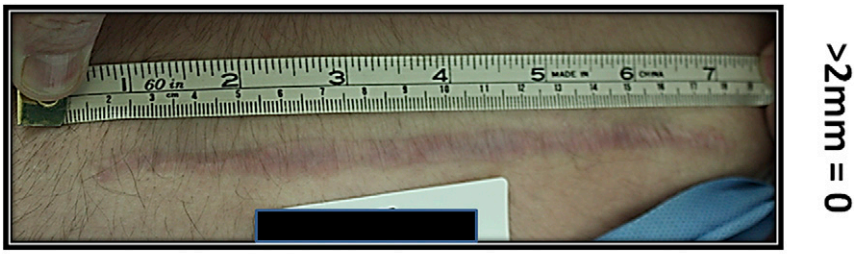

Fig. 1-A

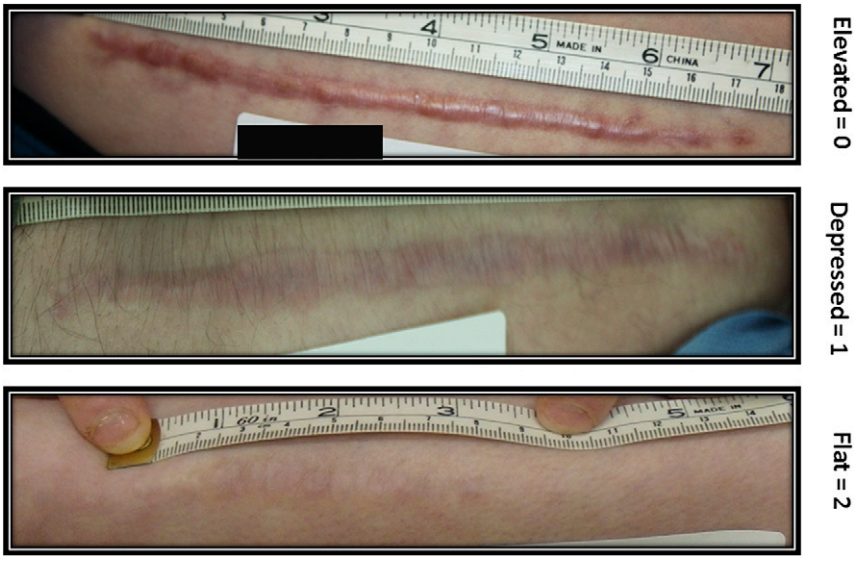

Fig. 1-B

Figs. 1-A through 1-D Sample photographs demonstrating scar characteristics as assessed using the modified Stony Brook Scar Evaluation Scale (SBSES). **Fig. 1-A** Scar width and corresponding SBSES score. **Fig. 1-B** Scar height and corresponding SBSES score.

through 1-D). We made 1 modification to the SBSES, which involved the removal of points for the presence of "hatch or suture marks," which were not present in any of the cases, as the surgeons utilized a running subcuticular closure in all cases. Those points were replaced with points for the extent of scar healing relative to the overall length of the incision. This subscale was named *overall appearance,* and allowed for the grading of scars with varying healing profiles along the incision. To score this parameter, the scar length was divided into thirds: if less than one-third of the scar had a combined score of ≥4 points for width, height, and color, then the overall appearance was scored as 0 points (poor). If at least one-third but less than two-thirds of the scar had a combined score of ≥4 points, then the overall appearance was scored as 1 point (fair). If two-thirds of the scar or more had a combined score of ≥4 points, then the overall appearance was scored as 2 points (good). The intraobserver reliability of the modified SBSES was determined by repeat scoring (by co-author K.D.) of photographs of the 58 included scars after an interval of 11 months. The interobserver reliability was determined by comparing the scores for these photographs by the initial examiner with those of another examiner following training in the SBSES.

Parent assessment of scar appearance was also performed preoperatively and at 6 and 12 months following implant removal with use of a visual analog cosmetic scale (VACS), a validated, 100-mm vertical scale ranging from "best possible, most attractive" to "worst possible, least attractive"[7-9] (Fig. 2). Excellent intraobserver and interobserver reliability (0.73 to 0.87, and 0.75 to 0.92, respectively) was established in a previous study[8]. Scoring of the VACS was performed by a single co-author (K.D.), utilizing the same length-measurement technique. The greater the value of the VACS score, the worse the parental assessment of the visual quality of the scar.

Statistical analysis of the intraobserver and interobserver reliability of the modified SBSES was performed utilizing intraclass correlation coefficients (ICCs). A correlation of >0.80 was considered excellent; 0.60 to 0.79, good; 0.40 to 0.59, fair; and <0.40, poor[10].

An analysis of variance (ANOVA) was used to compare SBSES scores among the 3 time points (preoperatively and 6 and 12 months following

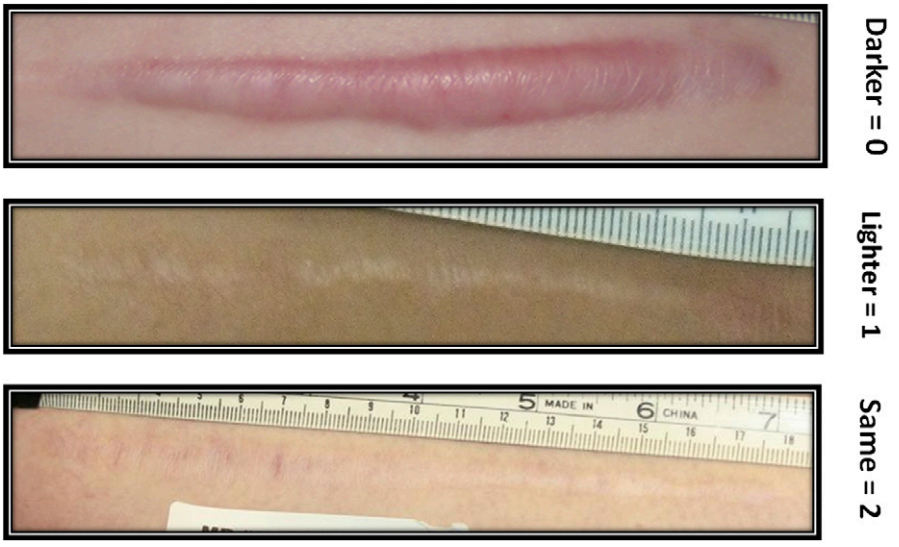

Fig. 1-C

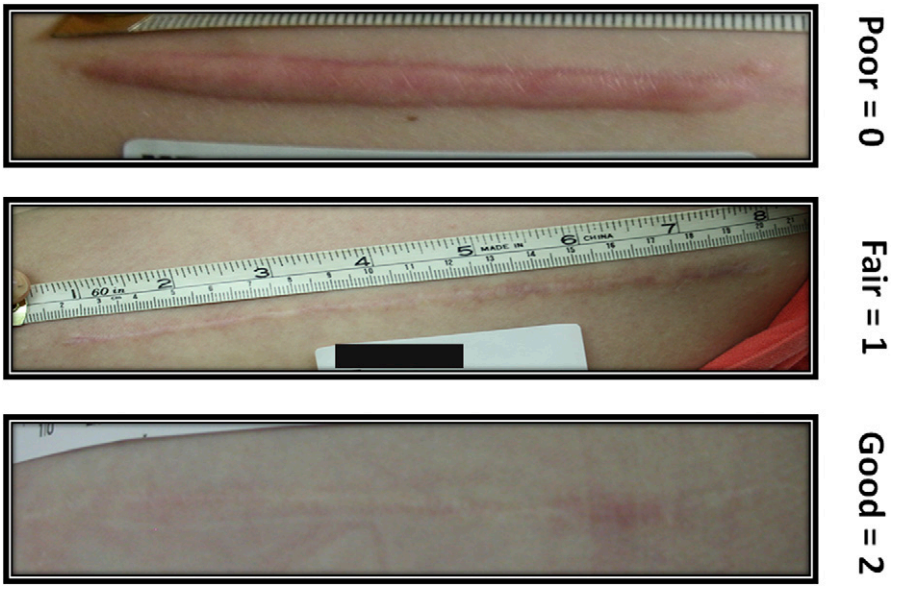

Fig. 1-D

Fig. 1-C Scar color and corresponding SBSES score. **Fig. 1-D** Scar overall appearance and corresponding SBSES score.

TABLE V SBSES Scores for Incision (N = 27) Versus Excision (N = 31)

	Preop.			6 Mo			12 Mo		
Parameter	Incision*	Excision*	P Value†	Incision*	Excision*	P Value†	Incision*	Excision*	P Value†
Width	1.15 ± 0.82	0.45 ± 0.77	0.001	1.11 ± 0.85	0.45 ± 0.68	0.002	0.85 ± 0.77	0.61 ± 0.80	NS
Height	1.48 ± 0.80	1.26 ± 0.93	NS	1.33 ± 0.88	0.55 ± 0.85	0.001	1.33 ± 0.92	1.00 ± 0.89	NS
Color	0.78 ± 0.89	0.52 ± 0.81	NS	0.26 ± 0.66	0.00 ± 0.00	0.050	0.41 ± 0.69	0.23 ± 0.43	NS
Overall appearance	1.56 ± 0.64	0.94 ± 0.85	0.003	0.78 ± 0.85	0.26 ± 0.58	0.010	0.89 ± 0.85	0.68 ± 0.87	NS
Total score	4.96 ± 1.85	3.16 ± 2.71	0.004	3.48 ± 2.06	1.26 ± 1.59	<0.000	3.48 ± 1.70	2.52 ± 2.41	NS

*The values are given as the mean and the standard deviation. †Independent t test; $p < 0.05$ = significant. NS = not significant.

implant removal) for the scars that underwent incision and for those that underwent excision. A similar analysis was performed for the VACS scores. SBSES and VACS scores were also compared between the incision and excision groups at the 3 time points utilizing independent t tests. The level of significance was set at $p < 0.05$.

Results

Patient Demographics

A total of 81 patients were enrolled and completed the preoperative evaluation. Thirty-eight patients underwent scar incision, and 43 patients underwent scar excision. Forty-four patients did not complete the entire study (26 did not complete the 6-month follow-up, and an additional 18 did not complete the 12-month follow-up). Thirty-seven patients (25 male and 12 female) with 58 involved extremities (30 femora and 28 tibiae; 1 extremity in 19 children, 2 extremities in 16 children, 3 extremities in 1 child, and 4 extremities in 1 child) completed the study and were included in the final analysis. Sixteen patients underwent scar incision, and 21 patients underwent scar excision. All of the patients carried the diagnosis of CP, with the distribution according to the Gross Motor Function Classification Scale (GMFCS) as follows: level I = 9 children, level II = 11, level III = 13, level IV = 2, and level V = 2[11]. The mean age at the time of implant removal surgery was 11.4 years (range, 7.6 to 16.6 years). The mean scar length was 12.9 cm (range, 7 to 21 cm).

Modified SBSES Reliability

The intraobserver and interobserver reliability of the modified SBSES is summarized in Table II. The intraobserver reliability was excellent for the total score and for each of the individual parameters evaluated. The interobserver reliability was good for the total score and for 3 of the 4 parameters (width, height, and color) and fair for the remaining parameter (overall appearance).

Modified SBSES Outcomes

The SBSES scores for scars that were incised at the time of implant removal (n = 27) are summarized in Table III. The total score as well as the scores for color and overall appearance were significantly worse at 6 months following incision compared with preoperatively. The color score improved and was not different relative to the preoperative value at 12 months. The total score and the score for overall appearance continued to be significantly worse relative to preoperative values at 12 months following incision.

The SBSES scores for scars that were excised at the time of implant removal (n = 31) are summarized in Table IV. The total score as well as the scores for height, color, and overall appearance were significantly worse at 6 months following excision compared with preoperatively. The total score at 12 months was comparable with the preoperative score, and no

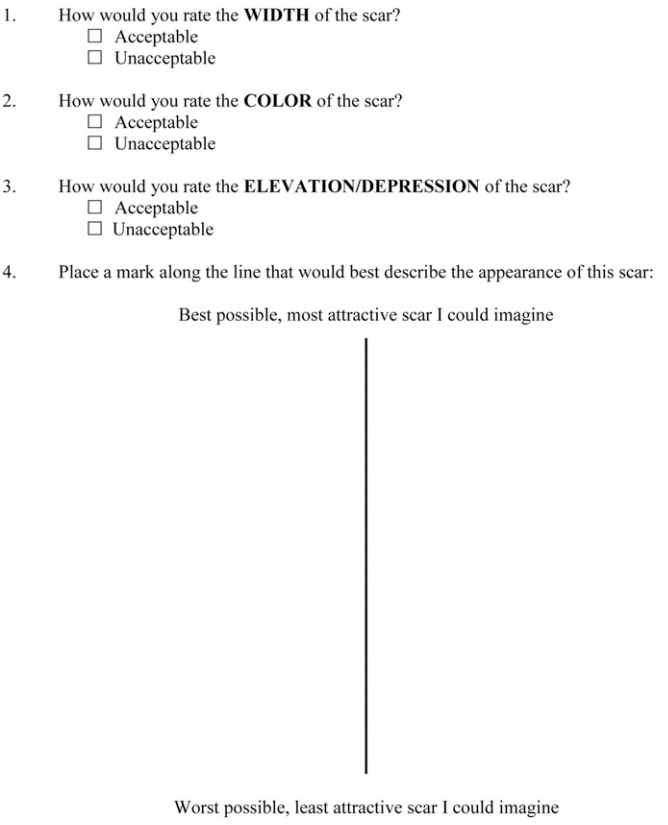

Fig. 2
The visual analog cosmetic scale (VACS).

TABLE VI VACS Scores for All Scars by Time Point*

	Preop.			6 Mo				12 Mo			
						P Value				P Value	
	Incision	Excision	P Value	Incision	Excision	Incision Vs. Excision	6 Mo Vs. Preop.	Incision	Excision	Incision Vs. Excision	12 Vs. 6 Mo
Scar appearance	18.1 ± 9.4	33.2 ± 21.5	0.001	28.4 ± 20.0	33.5 ± 19.5	NS	0.025 for incision; NS for excision	19.6 ± 14.5	31.5 ± 25.9	0.032	0.035 for incision; NS for excision

*Scores are given as the mean and the standard deviation. P < 0.05 = significant. NS = not significant.

significant differences were found between the 12-month and preoperative scores for the other parameters.

The SBSES score comparisons of scars in the incision group with those in the excision group are summarized in Table V. Preoperatively, the total score was significantly worse for the scars that were excised. The scores for width and overall appearance were also significantly worse in the excision group compared with the incision group. At 6 months following implant removal, the total score remained significantly worse for the scars that were excised, and scores for all other parameters of the SBSES were also significantly worse in the excision group at this time point. At 12 months following implant removal, although the scores for all parameters remained worse in the excision group, they were no longer significantly different from the scores in the incision group.

VACS Outcomes

The results of parental VACS scoring of all scars, at all 3 time points, are summarized in Table VI. Parents' VACS scores revealed that scars selected for incision looked better than scars selected for excision both preoperatively and at 12 months of follow-up. Scars in the incision group were worse at 6 months relative to preoperatively, but at 12 months, they had improved significantly and were comparable in appearance with that noted preoperatively. Scars that were selected for excision were comparable at the preoperative and 6 and 12-month time points.

Discussion

Excessive cutaneous scarring following surgery may occur in 15% of cases[12]. This scarring is thought to be the consequence of abnormal wound-healing in which tissue repair and regeneration processes are disrupted[2,4,13]. The pathogenesis may be related to patient-specific (genetic, racial, or hormonal), topographic (specific to the skin site), and environmental factors (mechanical or thermal trauma, tension, infection, or inflammation)[1-4,13].

Although there is a wide clinical spectrum of cutaneous scarring, most scars can be classified as hypertrophic or keloid[2-4,12,13]. Hypertrophic scars stay within the boundaries of the original lesion or incision and may be further classified as linear (usually following elective surgical incision or trauma) or widespread (usually following burns). Keloids grow beyond the boundaries of the original wound. Hypertrophic scars and keloids have distinct histopathologies, natural histories, and responses to treatment[2,4,12-14].

There is little objective evidence to guide clinicians in the management of hypertrophic scarring. Strategies may be classified as preventive or reconstructive, and interventions may be classified as invasive or noninvasive[12,13]. Recently, an international, multidisciplinary group of 24 experienced clinicians developed evidence-based guidelines for the management of excessive cutaneous scarring[12,14]. For linear hypertrophic scars, preventive measures (such as moisturizing, taping, or applying silicone gel sheets) are recommended to begin 6 weeks following the index incision or trauma. Additional preventive measures (such as intralesional corticosteroid injection or pressure therapy) are recommended if scar hypertrophy is present at 6 months. Hypertrophic scarring is considered to be permanent after 12 months, and surgical revision of the scar is recommended.

This study determined the outcomes of incisional scar revision, which was selected for incisions that had previously healed with minimal scarring, and excisional scar revision, selected for incisions that had previously healed with excessive scarring, in a series of children with CP. All of the scars in the latter group would be classified as linear hypertrophic scars, and none were keloid. Four hypotheses were considered:

Hypothesis 1 was that surgeons choose an incision versus excision strategy on the basis of scar appearance. The data supported this hypothesis. Scars selected for excision had significantly worse preoperative total SBSES and parental VACS scores than did those selected for incision. Scars selected for excision also had significantly worse preoperative scores for width and overall appearance than did scars selected for incision. The surgeons in this study tended to select scars that they qualitatively judged to be narrow, flat, and less discolored relative to the surrounding skin for incision at the time of the second surgery.

Hypothesis 2 was that scars selected for incision have cosmetic outcomes following the second procedure that are comparable to those following the initial procedure. The data partially supported this hypothesis. Scars that were incised had significantly worse SBSES total scores and scores for overall appearance at 6 and 12 months following the implant removal surgery. Interestingly, the parental VACS score was in agreement

with the SBSES score at 6 months (i.e., the scar looked worse relative to preoperatively) but not at 12 months (parental VACS scores improved and were comparable with preoperative scores). Although the more objective outcome assessment determined that the scar quality was worse at 1 year following incision, families scored these scars at a level comparable with the preoperative appearance. Differences in outcomes between assessment domains are not uncommon, are related to the complexity of the phenomena being studied, and can reflect true differences in perception.

Hypothesis 3 was that scars selected for excision have better cosmetic outcomes following the second procedure than following the initial procedure. The data did not support this hypothesis. Scars that were excised had significantly worse SBSES scores at 6 months following the implant removal surgery. SBSES scores improved and were comparable to preoperative values at 12 months. The parental VACS scores were unchanged at each time point, which was in agreement with the SBSES scores at 12 months (i.e., scar appearance was comparable to the preoperative appearance). Our findings suggest that surgical incisions that do not heal well initially are no better following revision by excision.

Hypothesis 4 was that scars selected for excision at the time of implant removal will have outcomes that are comparable with those of scars selected for incision. The data partially supported this hypothesis. SBSES and parental VACS scores demonstrated agreement in that scars selected for excision were significantly worse preoperatively relative to those selected for incision. Interestingly, the SBSES scores remained worse at 12 months for the excision group, although no longer significantly different from scores for the incision group, while the parental VACS scores indicated that scar quality was significantly worse at 12 months for the scars treated by excision compared with incision. The apparent discrepancy between SBSES and VACS scores is not easily explained. It is possible that the parental VACS scoring was biased by the initial scar-healing experience.

The principal limitations of this study included the analysis of multiple extremities from the same patient, the patient dropout rate, the clinical profile of the study group, and the limited applicability of the results to other patient populations. Eighteen (49%) of the 37 patients had >1 extremity included in the study, and 39 (67%) of the 58 extremities were from patients with >1 extremity included in the study. While this introduces potential bias of individualized wound-healing characteristics, the fact that wounds in different locations in the same patient healed differently suggests that topographic factors are the dominant variable and justify the analysis of each extremity independently.

Dropout is common to prospective studies and is inevitable with time. Statistical consequences of attrition may vary depending on the design and aims of the study[15]. The dropout rate in studies of musculoskeletal disorders has ranged from 7% to 57%[16]. Investigators have concluded that it is not possible to determine fixed levels for "acceptable" follow-up rates[15,16]. Our dropout rate of 54% is within the range of previous prospective studies, and it seems unlikely that the results were compromised, as comparable proportions of patients in the incision (58%) and excision (51%) groups did not complete the study.

Although all of the children in the study group had CP, the range of motor impairment spanned all GMFCS levels. Patients at GMFCS levels IV and V (4 patients) may have had suboptimal nutritional status, which is associated with increased complications (including wound infection) following spine surgery for scoliosis[17]. Malnourished patients can develop pressure ulcers and infections and experience delayed wound-healing[18]. No patient in the current study had any of these complications, and the number of patients at GMFCS levels IV and V was inadequate to allow for analysis of the relation between nutrition and healing.

Although we know of no evidence in the literature suggesting that cutaneous healing for children at GMFCS levels I through III is any different than that of typically developing children, caution is appropriate in applying our results to other patients (i.e., children without CP). Factors such as postoperative spasticity and poor postoperative nutritional status may compromise wound-healing. The findings of a previous study suggest that nutritional status (as indicated by body mass index) is comparable between higher-functioning children with CP (GMFCS levels I and II) and typically developing peers[19]. Our experience suggests that the results of the study are applicable to other populations, but additional study will be required to establish the outcomes of scar incision versus excision in other children.

In summary, surgical incisions that healed with good scar quality following the index surgery generally healed well following incision through the previous scar at the time of implant removal (measurably worse by the SBSES but no worse by parental assessment). Surgical incisions that healed poorly initially did not heal better following excision around the previous scar. The results of this study, in conjunction with the recently published guidelines for the management of excessive cutaneous scarring, have impacted our management of surgical scars, following both initial surgery and subsequent surgery[2,12-14,20,21]. Following the initial surgery, hypertrophic scarring present between 6 weeks and 6 months is managed with the use of silicone gel sheets. Patients with persistent hypertrophic scarring between 6 and 12 months are referred to a dermatologist. When a second surgery is required (e.g., for implant removal), if the existing scar has healed well, then incision through the scar is recommended, with follow-up management similar to that described above following the initial procedure. If the primary scar has healed poorly, surgical excision around the existing scar is performed following preoperative consultation with a dermatologist, with application of silicone gel sheets as soon as the wound is healed and demonstrates complete re-epithelialization (usually 4 weeks following surgery). The silicone gel sheets are continued for 4 months. If there is recurrent hypertrophic scar formation at 4 months, the patient is referred to the previously identified dermatologist for consideration of intralesional corticosteroid

injection or laser therapy. Additional study will be required to establish the efficacy of this protocol. ■

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