ORIGINAL ARTICLE

Single-Incision Mini-Slings for Stress Urinary Incontinence in Women

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ABSTRACT

BACKGROUND

Until recently, synthetic midurethral slings (made of mesh or tape) were the standard surgical treatment worldwide for female stress urinary incontinence, if conservative management failed. Data comparing the effectiveness and safety of newer single-incision mini-slings with those of standard midurethral slings are limited.

METHODS

We performed a pragmatic, noninferiority, randomized trial comparing mini-slings with midurethral slings among women at 21 U.K. hospitals during 36 months of follow-up. The primary outcome was patient-reported success (defined as a response of very much or much improved on the Patient Global Impression of Improvement questionnaire) at 15 months after randomization (approximately 1 year after surgery). The noninferiority margin was 10 percentage points.

RESULTS

A total of 298 women were assigned to receive mini-slings and 298 were assigned to receive midurethral slings. At 15 months, success was reported by 212 of 268 patients (79.1%) in the mini-sling group and by 189 of 250 patients (75.6%) in the midurethral-sling group (adjusted risk difference, 4.6 percentage points; 95% confidence interval [CI], –2.7 to 11.8; P<0.001 for noninferiority). At the 36-month follow-up, success was reported by 177 of 246 patients (72.0%) and by 157 of 235 patients (66.8%) in the respective groups (adjusted risk difference, 5.7 percentage points; 95% CI, –1.3 to 12.8). At 36 months, the percentage of patients with groin or thigh pain was 14.1% with mini-slings and 14.9% with midurethral slings. Over the 36-month follow-up period, the percentage of patients with tape or mesh exposure was 3.3% with mini-slings and 1.9% with midurethral slings, and the percentage who underwent further surgery for stress urinary incontinence was 2.5% and 1.1%, respectively. Outcomes with respect to quality of life and sexual function were similar in the two groups, with the exception of dyspareunia; among 290 women responding to a validated questionnaire, dyspareunia was reported by 11.7% in the mini-sling group and 4.8% in the midurethral-sling group.

CONCLUSIONS

Single-incision mini-slings were noninferior to standard midurethral slings with respect to patient-reported success at 15 months, and the percentage of patients reporting success remained similar in the two groups at the 36-month follow-up. (Funded by the National Institute for Health Research.)

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The lifetime risk of primary surgery for stress urinary incontinence in women is 3.6% in the United Kingdom and 13% in the United States.[1,2] Synthetic mesh midurethral slings have until recently been the most common surgical treatment for stress urinary incontinence worldwide. In England, 100,516 midurethral-sling procedures were performed between 2008 and 2017, as compared with 1195 for all other continence procedures.[3]

The first midurethral sling was retropubic tension-free vaginal tape (retropubic tape), a minimally invasive day-surgery procedure with excellent short-term outcomes.[4] Retropubic tapes use a polypropylene mesh strip to create a suburethral hammock. Concerns about the blind insertion of the trocar into the retropubic trajectory and potential bladder or bowel injury led to the development of second-generation standard-length midurethral slings placed through the transobturator route (outside-in and inside-out obturator tapes).[5,6]

Studies have shown similar percentages of patients reporting success with retropubic tapes and obturator tapes.[7] Retropubic tapes were associated with higher incidences of bladder injury and postoperative voiding dysfunction, whereas obturator tapes were associated with a higher incidence of postoperative groin or thigh pain.[7,8] More recently, single-incision mini-slings (mini-slings) were introduced. These used shorter polypropylene mesh and avoided both retropubic trajectory and adductor muscle perforation; hence, they were proposed to reduce perioperative morbidity.[9]

In a systematic review published in 2014, we found that the percentages of patients with patient-reported and objective success with mini-slings (excluding TVT-Secur devices, which were discontinued by the manufacturer for commercial reasons) were similar to those with midurethral slings during a median follow-up at 18 months[10]; mini-slings were associated with less postoperative pain and a shorter recovery time. However, trials included in this review were small and heterogeneous and had a high risk of bias. A Cochrane review recommended an adequately powered randomized, controlled trial with long-term follow-up to evaluate the clinical benefits and risks and the cost-effectiveness of mini-slings.[11] We performed a pragmatic, multicenter, noninferiority, randomized, controlled trial (the SIMS trial) comparing outcomes of adjustable anchored mini-slings with those of tension-free midurethral slings in women with stress urinary incontinence.

Methods

Trial Design and Patients

We conducted a randomized noninferiority trial at 21 hospitals in the United Kingdom. We report here the clinical outcomes through 36 months of follow-up.

We included women 18 years of age or older who had predominant symptoms of stress urinary incontinence and in whom conservative treatment had failed or who had declined such treatment; all the women planned to undergo a midurethral-sling procedure. Exclusion criteria were anterior or apical prolapse of stage 2 or higher, previous surgery for stress urinary incontinence, predominant symptoms of overactive bladder, planned concomitant surgery, previous pelvic irradiation, pregnancy or planning pregnancy, and an inability to understand consent in English.

Eligible women received a trial information leaflet, and trial patients provided written informed consent.[12] Patients were randomly assigned in a 1:1 ratio to receive mini-slings or midurethral slings. Randomization was performed with the use of a remote Web-based system and was stratified with the use of minimization according to center and previous supervised pelvic-floor muscle training within 2 years.

Trial Oversight

The trial was funded by the U.K. National Institute for Health Research. The University of Aberdeen and NHS Grampian were the scientific sponsors of the trial and had overall responsibility for the trial governance. The trial did not receive any financial support from industry. Collaborating sites purchased the devices through their standard NHS procurement procedures.

All the authors take full responsibility for the submitted manuscript and vouch for the fidelity of the trial to the protocol, which was published previously[12] and is also available with the full text of this article at NEJM.org. The second author and the last two authors confirm the accuracy and completeness of the data reported.

INTERVENTIONS

The interventions are described in detail in the protocol. Adjustable anchored mini-slings met prespecified criteria that were identified in previous research as being necessary for their success.[12] The two main types of mini-slings used were Ajust (C.R. Bard) and Altis (Coloplast). Midurethral slings were either retropubic or obturator (inside-out or outside-in) tapes. The choice of device in both trial groups was made according to the surgeons' standard practice. Mini-sling procedures were performed with the patient under local anesthesia unless the patient requested general anesthesia. Cystoscopy (rigid or flexible) was performed regardless of trial group. Standardized guidance was provided for participating surgeons regarding the administration of local anesthesia and the assessment of postoperative voiding (see the Supplementary Appendix, available at NEJM.org).

Participating surgeons were experienced in performing at least one type of mini-sling procedure and at least one type of midurethral-sling procedure according to the protocol.[12] Clinical experts in the trial team visited 90% of the collaborating hospitals before starting local recruitment to observe participating surgeons perform two mini-sling procedures with the patient under local anesthesia, in order to confirm surgeons' competence and to discuss standardization of surgical techniques and protocols.[12]

Making surgeons and patients unaware of the trial-group assignments was not possible given the different anesthesia typically used for the two different types of procedures. All follow-up was patient-reported through postal questionnaires.

DATA COLLECTION

We collected patient-reported data at baseline; 4 weeks and 3 months after surgery; and 15, 24, and 36 months after randomization (approximately 12, 21, and 33 months after surgery) (Table S1A in the Supplementary Appendix). The data collected at 4 weeks and 3 months addressed perioperative outcomes in relation to surgery date.

OUTCOMES

The primary outcome was patient-reported success (defined as a response of very much improved or much improved on the Patient Global Impression of Improvement [PGI-I] questionnaire[13]) at 15 months. All other responses (improved, same, worse, much worse, and very much worse) were considered to indicate treatment failure.

Figure 1 (facing page). Screening, Randomization, and Follow-up.

Seven patients were ineligible for more than one reason. "Responded" indicates that the patient returned a fully or partially completed trial questionnaire. PGI-I denotes Patient Global Impression of Improvement, SIMS single-incision mini-sling, and SMUS standard midurethral sling.

Safety data included all expected adverse events during follow-up through 36 months: pain, tape or mesh exposure (exposure of tape or mesh through the vaginal wall), operative complications (lower urinary tract injuries, severe bleeding, and bowel injuries), new onset or worsening of urinary urgency, dyspareunia, and intermittent catheterization by the patient. All serious unexpected adverse events were reported by the collaborating hospitals and reviewed by the trial sponsor and the independent data monitoring committee according to the trial protocol.[12]

Secondary outcomes included postoperative pain (to 14 days), recovery (i.e., return to normal activities), objective success (defined as a 24-hour pad-test weight of <8 g), and the effect of the procedures on patients' symptom severity, quality of life, and sexual function according to validated tools or questionnaires (Table S1A and S1B). Health economic outcomes are being analyzed separately.

STATISTICAL ANALYSIS

A noninferiority margin of 10 percentage points was determined by clinical experts as the maximum acceptable margin should mini-slings be shown to be superior to midurethral slings in other outcomes such as postoperative pain and earlier recovery. Assuming 85% success for both procedures,[7,8,14] we estimated that a sample size of 550 would provide the trial with 90% power at a one-sided significance level of 2.5%; assuming a 15% dropout rate, we planned for a sample size of 650. This number was reduced (without examination of any outcome data) to 600 in November 2016, given difficulties in completing recruitment on time and within budget, thereby reducing the power from 90% to 88%. Effect

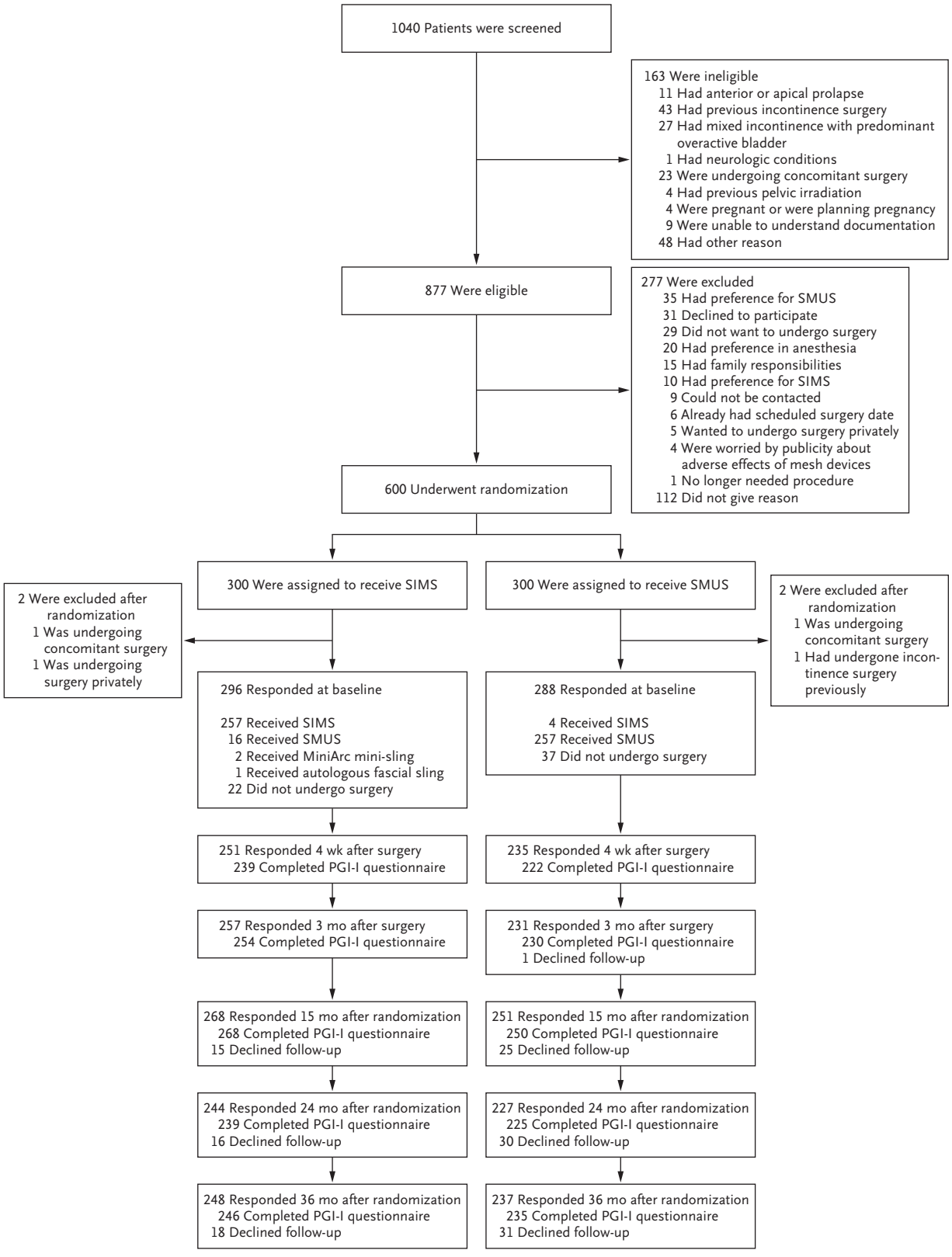

Table 1. Characteristics of the Patients at Baseline.*

Characteristic	Single-Incision Mini-Sling (N=298)	Standard Midurethral Sling (N=298)
Age		
No. of patients with available data	298	298
Mean — yr	50.4±11.0	50.7±10.9
Body-mass index		
No. of patients with available data	297	292
Mean	28.9±5.5	28.7±5.6
Parity: no. of pregnancies		
No. of patients with available data	296	294
Mean	2.4±1.1	2.4±1.1
Manual job involving heavy lifting — no. (%)	84 (28.2)	84 (28.2)
Smoker — no. (%)	52 (17.4)	43 (14.4)
Pelvic-floor muscle training in past 2 yr — no. (%)	254 (85.2)	254 (85.2)
24-Hr pad-test weight		
No. of patients with available data	234	204
Median (interquartile range) — g	39 (24–60)	40 (24–67)
EQ-5D-3L score†		
No. of patients with available data	286	284
Mean	0.86±0.20	0.83±0.25
ICIQ-UI Short Form score‡		
No. of patients with available data	284	285
Mean	14.4±3.3	14.4±3.6
Dyspareunia — no./total no. (%)§	25/145 (17.2)	21/145 (14.5)
Coital incontinence — no./total no. (%)§	60/145 (41.4)	52/145 (35.9)
Use of anticholinergic drug — no. (%)	60 (20.1)	35 (11.7)
Diagnosis based on urodynamic testing — no. (%)		
Stress incontinence	235 (78.9)	231 (77.5)
Mixed incontinence	36 (12.1)	33 (11.1)
Clinical diagnosis of stress urinary incontinence — no. (%)¶	14 (4.7)	11 (3.7)
Grade of surgeon — no./total no. (%)‖		
Subspecialist urogynecologist	65/276 (23.6)	46/261 (17.6)
Consultant gynecologist	183/276 (66.3)	160/261 (61.3)
Consultant urologist	23/276 (8.3)	9/261 (3.4)
Associate specialist or staff grade	1/276 (0.4)	3/261 (1.1)
Senior trainee	4/276 (1.4)	43/261 (16.5)
Type of procedure — no./total no. (%)**		
Midurethral sling		
Retropubic tape	7/276 (2.5)	119/261 (45.6)
Obturator tape	9/276 (3.3)	138/261 (52.9)
Mini-sling		
Ajust	62/276 (22.5)	0/261
Altis	195/276 (70.7)	4/261 (1.5)

Table 1. (Continued.)

* Plus–minus values are means ±SD. Percentages may not total 100 because of rounding. Further details on baseline characteristics are provided in Table S2 in the Supplementary Appendix.
† Scores on the EuroQol Group 5-Dimension 3-Level (EQ-5D-3L) questionnaire range from –0.594 to 1, with higher scores indicating better quality of life.
‡ Scores on the International Consultation on Incontinence Questionnaire–Urinary Incontinence (ICIQ-UI) Short Form range from 0 to 21, with higher scores indicating a poorer outcome.
§ A total of 145 patients in each group were randomly assigned to answer direct questions on dyspareunia and coital incontinence, and the rest of the patients received the formal Pelvic Organ Prolapse–Urinary Incontinence Sexual Questionnaire–IUGA (International Urogynecological Association) Revised (PISQ-IR).
¶ No urodynamic testing was performed.
‖ Consultants and associate specialists are fully trained independent practitioners equivalent to attending surgeons in the United States. Seniors trainees are in the last 2 years of their training scheme and have completed their training in placing standard midurethral slings; they are equivalent to senior residents or fellows in the United States. Placing single-incision mini-slings is not part of the training schemes in the United Kingdom.
** In the mini-sling group, three women received other procedures: two received the MiniArc mini-sling, and one received an autologous fascial sling.

sizes are presented as risk differences and 95% confidence intervals. Odds ratios are also presented. A P value for noninferiority is reported for the primary outcome.

All primary and secondary outcomes were analyzed according to the intention-to-treat principle with the use of multiple imputation with chained equations to handle missing outcomes. More information on the multiple imputation is provided in the Supplementary Appendix. All models were adjusted for minimization covariates. The primary outcome was analyzed with the use of logistic regression with robust variances for clustering according to center. A prespecified per-protocol sensitivity analysis assessed the primary outcome for patients who underwent their assigned surgery. Secondary outcomes were analyzed with the use of linear mixed models that were adjusted for baseline versions of outcome. The 14-day postoperative pain scores were compared with the use of an area-under-the-curve approach. The number of days of analgesia use was compared (post hoc) between the two groups with the use of negative binomial regression. Estimates are presented with 95% confidence intervals, with no adjustments for multiple testing. All analyses were performed with the use of Stata 15 software (details are provided in the Supplementary Appendix).[15]

Prespecified subgroup analyses were performed according to urodynamic diagnosis (urodynamic stress incontinence vs. mixed urinary incontinence) and age (younger than the median age vs. the median age or older). We also performed post hoc subgroup analyses according to an age of younger than 65 years as compared with an age of 65 years or older; supervised pelvic-floor muscle training within the preceding 2 years as compared with no training during that time; and devices withdrawn from clinical practice (Ajust mini-sling and Monarc, I-Stop, and Aris midurethral slings) as compared with devices not withdrawn (Altis mini-sling and TVT, TVT-O, Advantage, and Obtryx midurethral slings).

RESULTS

TRIAL POPULATION

A total of 600 women underwent randomization (February 2014 through July 2017) at 21 hospitals. Four women were excluded after randomization, leaving 298 assigned to receive mini-slings and 298 assigned to receive midurethral slings; 257 women (86.2%) in each group underwent their assigned surgery (Fig. 1). At 15 and 36 months after randomization, the percentage of patients who returned a fully or partially completed trial questionnaire was 87.1% and 81.4%, respectively. The characteristics of the two groups were well balanced at baseline (Tables 1 and S2), except that more women in the mini-sling group used anticholinergic treatment.

OPERATIVE DATA

Crossover between groups occurred in 16 women (5.8%) assigned to receive mini-slings and 4 (1.5%) assigned to receive midurethral slings; in addition, 3 women assigned to receive mini-slings underwent other procedures. Crossover was due to patient preference or the unavailability of a specific device or an experienced surgeon on the

Table 2. Perioperative Outcomes.*

Outcome	Single-Incision Mini-Sling (N=276)	Standard Midurethral Sling (N=261)	Adjusted Risk Difference (95% CI)†
Procedure time			
No. of patients with available data	273	258	
Mean — min	39.2±16.8	41.3±11.6	−2.2 (−5.9 to 1.6)
Type of anesthesia — no. (%)			
General	70 (25.4)	238 (91.2)	
Spinal	5 (1.8)	7 (2.7)	
Local‡	201 (72.8)	16 (6.1)	
Local anesthesia infiltration to facilitate dissection — no. (%)	270 (97.8)	235 (90.0)	
Tape was adjusted according to cough stress test — no. (%)	180 (65.2)	15 (5.7)	
Blood loss — no. (%)			0.72 (0.48 to 1.08)§
<50 ml	134 (48.6)	107 (41.0)	
50–100 ml	126 (45.7)	129 (49.4)	
≥100 ml	15 (5.4)	23 (8.8)	
Missing data	1 (0.4)	2 (0.8)	
Unplanned operative events — no. (%)			
More than one kit used	7 (2.5)	0	
Anesthesia changed	7 (2.5)	1 (0.4)	
Trocar inserted more than once	1 (0.4)	0	
Satisfactory voiding without any intervention — no. (%)	230 (83.3)	206 (78.9)	4.1 (−6.1 to 14.2)¶
Postoperative hospital stay			
No. of patients with available data	276	261	
Mean — hr	7.2±8.7	9.7±10.7	−2.5 (−4.7 to −0.3)
Return to normal activities within 28 days — no./total no. (%)	185/246 (75.2)	160/226 (70.8)	4.2 (−3.4 to 11.9)¶
Pain score up to 14 days after surgery‖			
No. of patients with available data	238	213	
Mean	19.8±19.6	28.1±22.2	−8.3 (−12.8 to −3.8)
Days of analgesia up to 14 days after surgery			
No. of patients with available data	238	213	
Mean	2.7±3.6	3.5±3.8	0.79 (0.64 to 0.98)

* Plus–minus values are means ±SD.
† Because the 95% confidence intervals (CIs) were not adjusted for multiplicity, they should not be used to infer definitive treatment effects. Detailed information on the models used is provided in the Supplementary Appendix.
‡ Of the 201 patients in the mini-sling group who received local anesthesia, 47 had intravenous sedation, 26 had oral sedation, and 128 had local anesthesia only. Of the 16 patients in the midurethral-sling group, 14 had intravenous sedation, 1 had oral sedation, and 1 had local anesthesia only.
§ Blood loss was analyzed with the use of using an ordered logistic regression, so the effect size is an odds ratio. The odds ratio of 0.72 suggests lower levels of blood loss in the mini-sling group than in the midurethral-sling group.
¶ The difference shown is in percentage points.
‖ Scores range from 0 to 130, with higher scores indicating greater pain.

day of surgery. Women in the midurethral-sling group were more likely than those in the mini-sling group to have their procedure performed by a subconsultant-grade surgeon and less likely to have their procedures under local anesthesia or the sling adjusted with the use of a cough

stress test. Most patients received intraoperative local anesthesia infiltration regardless of procedure type. Pain scores over the immediate postoperative period of 14 days appeared lower with mini-slings than with midurethral slings (Table 2).

PATIENT-REPORTED AND OBJECTIVE SUCCESS

At 15 months after randomization, success was reported by 212 of 268 patients (79.1%) in the mini-sling group and by 189 of 250 patients (75.6%) in the midurethral-sling group (adjusted risk difference, 4.6 percentage points; 95% confidence interval [CI], −2.7 to 11.8; P<0.001 for noninferiority). At the 36-month follow-up, success was reported by 177 of 246 patients (72.0%) and by 157 of 235 patients (66.8%) in the respective groups (adjusted risk difference, 5.7 percentage points; 95% CI, −1.3 to 12.8) (Table 3). The per-protocol estimates at 15, 24, and 36 months were similar to those in the intention-to-treat analysis (Table S3A). Figure S1 shows the results of the subgroup analyses; all were consistent with the results of the primary analysis.

Success objectively measured with a 24-hour pad test occurred in 102 of 119 patients (85.7%) in the mini-sling group and in 83 of 110 patients (75.5%) in the midurethral-sling group at 15 months (adjusted risk difference, 5.2 percentage points; 95% CI, −5.9 to 16.2) (Table 3). In a post hoc analysis that used results on the International Consultation on Incontinence Questionnaire–Urinary Incontinence Short Form to identify "cure" (defined as no leaking, in response to both "how often do you leak urine?" and "how much urine do you usually leak?"), cure occurred in 93 of 241 patients (38.6%) in the mini-sling group and in 72 of 217 patients (33.2%) in the midurethral-sling group at 15 months (adjusted risk difference, 6.4; 95% CI, −1.2 to 13.9) (Table 3). Table S3B shows PGI-I seven-point responses at each time point. The results of prespecified and post hoc subgroup analyses were consistent with the overall results (Fig. S1).

SECONDARY OUTCOMES

There were no material between-group differences in scores on several scales assessing lower urinary tract symptoms, quality of life, and sexual function (Table 3). Dyspareunia and coital incontinence were more common with mini-slings than with midurethral slings at almost all time points (Tables 4 and S4).

SAFETY

The percentage of patients with serious adverse events was similar in the two groups (Table 4). The percentage of patients with groin or thigh pain was higher in the mini-sling group than in the midurethral-sling group at 15 months but was similar in the two groups at 36 months (14.1% and 14.9%, respectively; risk difference, −0.8 percentage points; 95% CI, −4.1 to 2.5).

Over the 36-month follow-up period, tape or mesh exposure occurred in 3.3% of the patients in the mini-sling group and in 1.9% of those in the midurethral-sling group (risk difference, 1.3 percentage points; 95% CI, −1.7 to 4.4). One patient in the mini-sling group had persistent tape or mesh exposure after a procedure to bury the exposed mesh and subsequently underwent local excision of the exposed portion.

A total of 24 patients (8.7%) who received mini-slings and 12 (4.6%) who received midurethral slings received further surgical treatment over a period of 36 months, including further surgery for stress urinary incontinence (2.5% and 1.1%, respectively), for complete or partial removal of tape or mesh for any reason (2.9% and 1.9%), for pain (1.5% and 0.8%), or for mesh exposure (1.4% and 1.1%) (Table S4). All 4 patients (2 in each group) who received a colposuspension or autologous sling and one patient in the mini-sling group who received urethral bulking had previously undergone complete or partial tape removal.

DISCUSSION

This multicenter trial showed that mini-slings were noninferior to midurethral slings with respect to patient-reported success at 15 months and through the 36-month follow-up. Findings were similar in the per-protocol analysis and in prespecified subgroups.

Mini-sling procedures were more likely to be performed with the patient under local anesthesia, and mini-slings were associated with less postoperative pain up to 2 weeks after surgery. At 36 months, the percentage of patients with groin or thigh pain was similar in the two groups. However, more women in the mini-sling group reported dyspareunia, mesh exposure, or further surgery for urinary incontinence or treatment of adverse events. The percentage of patients who underwent mesh removal (partial or

Table 3. Patient-Reported and Objective Outcomes.*

Outcome	Single-Incision Mini-Sling	Standard Midurethral Sling	Adjusted Difference (95% CI)†
Patient-reported success according to PGI-I response — no./total no. (%)‡			
At 15 mo: primary outcome	212/268 (79.1)	189/250 (75.6)	4.6 (–2.7 to 11.8)§
At 36 mo	177/246 (72.0)	157/235 (66.8)	5.7 (–1.3 to 12.8)
Patient-reported cure on ICIQ-UI Short Form — no./total no. (%)¶			
At 15 mo	93/241 (38.6)	72/217 (33.2)	6.4 (–1.2 to 13.9)
At 36 mo	68/210 (32.4)	62/202 (30.7)	4.1 (–4.0 to 12.2)
Objective cure on 24-hr pad test — no./total no. (%)‖			
At 15 mo	102/119 (85.7)	83/110 (75.5)	5.2 (–5.9 to 16.2)
At 36 mo	75/87 (86.2)	64/79 (81.0)	3.7 (–5.0 to 12.4)
ICIQ-UI Short Form score			
At 15 mo			
No. of patients with available data	219	200	
Mean	4.4±5.0	4.7±5.0	–0.4 (–1.2 to 0.5)
At 36 mo			
No. of patients with available data	195	187	
Mean	4.9±4.8	5.3±5.2	–0.5 (–1.4 to 0.4)
ICIQ-FLUTS filling score**			
At 15 mo			
No. of patients with available data	247	220	
Mean	3.4±2.4	3.5±2.5	0.1 (–0.3 to 0.5)
At 36 mo			
No. of patients with available data	214	199	
Mean	3.6±2.4	3.6±2.4	0.0 (–0.4 to 0.4)
ICIQ-FLUTS voiding score††			
At 15 mo			
No. of patients with available data	248	217	
Mean	2.1±2.3	2.1±2.1	0.0 (–0.4 to 0.3)
At 36 mo			
No. of patients with available data	215	199	
Mean	1.9±2.1	2.0±2.1	–0.1 (–0.5 to 0.2)
ICIQ-FLUTS incontinence score‡‡			
At 15 mo			
No. of patients with available data	241	215	
Mean	3.9±4.1	4.4±4.3	–0.2 (–0.9 to 0.4)
At 36 mo			
No. of patients with available data	211	197	
Mean	4.4±4.2	4.5±4.3	–0.2 (–1.0 to 0.5)

Table 3. (Continued.)

Outcome	Single-Incision Mini-Sling	Standard Midurethral Sling	Adjusted Difference (95% CI)†
EQ-5D-3L score			
At 15 mo			
No. of patients with available data	249	219	
Mean	0.848±0.243	0.825±0.300	0.022 (–0.018 to 0.062)
At 36 mo			
No. of patients with available data	217	205	
Mean	0.836±0.261	0.821±0.294	0.013 (–0.030 to 0.056)
ICIQ-FLUTS quality-of-life score§§			
At 15 mo			
No. of patients with available data	230	202	
Mean	26.6±10.2	27.6±10.5	–0.7 (–2.5 to 1.1)
At 36 mo			
No. of patients with available data	203	181	
Mean	27.4±10.7	28.3±11.4	–1.1 (–3.1 to 0.8)
PISQ-IR score¶¶			
At 15 mo			
No. of patients with available data	75	55	
Mean	3.7±0.5	3.7±0.5	0.0 (–0.2 to 0.1)
At 36 mo			
No. of patients with available data	62	54	
Mean	3.6±0.6	3.5±0.6	0.0 (–0.1 to 0.1)

* Plus–minus values are means ±SD. The 15-month and 36-month follow-ups are timed from randomization and can be considered to be 12 and 33 months after surgery, respectively. When an outcome was missing, a value has been inserted from multiple imputation using chained equations. ICIQ-FLUTS denotes International Consultation on Incontinence Questionnaire–Female Lower Urinary Tract Symptoms.
† For the two patient-reported outcomes, adjusted risk differences are shown. For the remaining (objective) outcomes, adjusted mean differences are shown. Because the 95% confidence intervals were not adjusted for multiplicity, they should not be used to infer definitive treatment effects.
‡ Patient-reported success was defined as a response of very much improved or much improved on the Patient Global Impression of Improvement (PGI-I) questionnaire. All other responses (improved, same, worse, much worse, and very much worse) were considered to indicate treatment failure.
§ P<0.001 for noninferiority.
¶ In this post hoc analysis, a patient-reported cure on the ICIQ-UI Short Form was defined as a negative response to both "how often do you leak urine?" and "how much urine do you usually leak?"
‖ An objective cure on the 24-hour pad test was defined as a weight of less than 8 g.
** ICIQ-FLUTS filling scores range from 0 to 16, with higher scores indicating a poorer outcome.
†† ICIQ-FLUTS voiding scores range from 0 to 12, with higher scores indicating a poorer outcome.
‡‡ ICIQ-FLUTS incontinence scores range from 0 to 20, with higher scores indicating a poorer outcome.
§§ ICIQ-FLUTS quality-of-life scores range from 19 to 76, with higher scores indicating a poorer outcome.
¶¶ PISQ-IR scores range from 1 to 5, with higher scores indicating better sexual function.

complete) for any indication was low and was similar in the two groups.

Our findings of similar likelihoods of success with mini-slings and with midurethral slings are consistent with previous evidence. Two randomized, controlled trials — one comparing mini-slings (MiniArc) with obturator tapes (193 patients) and the other comparing mini-slings (MiniArc) with retropubic tapes (185 patients) — with 36 months of follow-up showed no sig-

Table 4. Adverse Events.*

Event	Single-Incision Mini-Sling	Standard Midurethral Sling	Risk Difference (95% CI)†	P Value
	no./total no. (%)			
Operative				
Bladder injury	0/276	9/261 (3.4)	−3.5 (−8.7 to 1.8)	0.18
Urethral injury	0/276	1/261 (0.4)	−0.4 (−1.2 to 0.4)	0.32
Blood loss >200 ml	5/276 (1.8)	5/261 (1.9)	−0.1 (−2.6 to 2.4)	0.94
Complications of general anesthesia	1/276 (0.4)	0/261		
Vaginal button hole‡	6/276 (2.2)	3/261 (1.1)		
Anaphylactic reaction to antibiotics§	1/276 (0.4)	0/261		
Skin reaction in the area of surgery§	0/276	1/261 (0.4)		
Intraoperative tonic–clonic seizure§	1/276 (0.4)	0/261		
Postoperative serious adverse events				
Death	0/298	1/298 (0.3)¶		
Transient ischemic attack	0/298	1/298 (0.3)		
Overdose of acetaminophen	0/298	1/298 (0.3)‖		
Lung cancer	0/298	1/298 (0.3)		
Other postoperative adverse events				
Any degree of groin or thigh pain				
At 15 mo	41/276 (14.9)	31/261 (11.9)	3.0 (−1.1 to 7.1)	0.14
At 36 mo	39/276 (14.1)	39/261 (14.9)	−0.8 (−4.1 to 2.5)	0.61
Use of any type of painkiller				
At 15 mo	24/276 (8.7)	13/261 (5.0)	3.7 (0.0 to 7.4)	0.047
At 36 mo	21/276 (7.6)	12/261 (4.6)	3.0 (−0.4 to 6.4)	0.08
Tape or mesh exposure**				
At 15 mo	2/276 (0.7)	2/261 (0.8)	0.0 (−1.6 to 1.5)	0.96
At 36 mo	1/276 (0.4)	0/261	0.4 (−0.4 to 1.1)	0.33
Dyspareunia††				
At 15 mo	25/145 (17.2)	8/145 (5.5)	11.8 (3.5 to 20.1)	0.008
At 36 mo	17/145 (11.7)	7/145 (4.8)	7.0 (1.9 to 12.1)	0.01
Additional surgical treatments‡‡	24/276 (8.7)	12/261 (4.6)	4.1 (−1.1 to 9.4)	0.12
For urinary incontinence	12/276 (4.3)	6/261 (2.3)		
For voiding dysfunction	1/276 (0.4)	2/261 (0.8)		
For pain	7/276 (2.5)	2/261 (0.8)		
For mesh exposure**	7/276 (2.5)	3/261 (1.1)		

* Details of additional surgical treatments and other adverse events are provided in Table S4.
† Effect sizes are presented for clinically important outcomes. Because the 95% confidence intervals were not adjusted for multiplicity, they should not be used to infer definitive treatment effects.
‡ Vaginal button hole is a surgical injury to the lateral vaginal sulcus.
§ These events were intraoperative serious adverse events.
¶ Death at home was attributed to drug overdose 3 years after surgery; details and death certificate were not available.
‖ The event occurred 10 days after the surgical procedure.
** Tape or mesh exposure indicates exposure of tape or mesh through the vaginal wall.
†† A total of 145 patients in each group were randomly assigned to answer direct questions on dyspareunia and coital incontinence,, and the rest of the patients received the formal PISQ-IR.
‡‡ Some patients underwent more than one additional surgery.

nificant between-group differences in the percentage of patients with patient-reported success (according to the response on the PGI-I questionnaire) or objective success.[16,17] A third randomized, controlled trial comparing mini-slings (Ajust) with obturator tapes (368 patients) and using assessment tools similar to those that we used also showed no significant differences in the percentages of patients with subjective and objective success at 1 year, but mini-slings resulted in less immediate postoperative pain, a shorter operative time, and shorter recovery.[18] Our 2014 systematic review (26 randomized, controlled trials involving 3308 patients) similarly showed no significant differences between mini-slings and midurethral slings in the percentages of patients with patient-reported and objective success at 18 months of follow-up.[10] A more recent review of longer-term outcome results (≥3 years) showed that midurethral slings were associated with a significantly higher likelihood of objective success than mini-slings, although the likelihood of patient-reported success was similar with the two types of slings.[19] The present trial was larger than previous similar studies and had consistent methods. Moreover, follow-up through postal questionnaires probably helped to minimize the rate of loss to follow-up and minimize bias.

The safety of mesh devices has been the subject of substantial scrutiny over the past decade, owing to patient reports of adverse events during extended follow-up, including tape or mesh exposure, groin or thigh pain, and dyspareunia. Lawsuits have been filed against mesh manufacturers in various countries,[20] and some manufacturers have withdrawn their products from clinical practice.[11,21] The SIMS trial was performed during heightened public debate about mesh devices; hence, patients and clinicians were unlikely to have underreported adverse events. Clinical guidelines in the United States, Europe, and the United Kingdom continue to recommend tension-free midurethral slings as surgical treatment for female stress urinary incontinence, albeit being suspended in the United Kingdom since 2018.

The incidence of tape or mesh exposure over the 36-month follow-up period was 3.3% in the mini-sling group and 1.9% in the midurethral-sling group; the incidence did not differ significantly between the two groups, but the trial was not powered for this or other uncommon outcomes. Our results are consistent with those of our 2014 systematic review showing a slightly higher, although not significantly higher, incidence of mesh exposure with mini-slings than with midurethral slings (2.3% [15 of 659] and 1.4% [8 of 564], respectively; risk ratio, 1.43; 95% CI, 0.61 to 3.35).[10]

The incidence of groin or thigh pain was higher in the mini-sling group than in the midurethral-sling group at 15 months but not at 36 months. In a previous trial (60 patients) comparing mini-slings (Ajust) with obturator tapes, 3 patients who received mini-slings reported persistent thigh pain 1 year after surgery, as compared with none who received obturator tapes.[22] In the Trial of Mid-Urethral Slings (597 patients), pain was more commonly reported with obturator tapes than with retropubic tapes (9.4% vs. 4.0%).[23] In the present trial, all 4 patients receiving tape removal for pain at up to 15 months were in the mini-sling group. However, by 36 months, 2 women in the midurethral-sling group had undergone partial removal for pain, with no further removals for pain in the mini-sling group. It is possible that surgeons, patients, or both perceived mini-slings to be easier to remove, given that they are shorter. However, the authors are aware of one report of difficulties in removing the mini-sling anchors with vaginal dissection only (Bhal K: personal communication).

In the present report, there were no cases of major visceral injuries, and intraoperative lower urinary tract injuries occurred exclusively in the midurethral-sling group. However, our 2014 systematic review showed no significant difference in lower urinary tract injuries between mini-slings and midurethral slings in 13 randomized, controlled trials (risk ratio, 0.99; 95% CI, 0.38 to 2.56).[10]

More women in the mini-sling group received further surgery for urinary incontinence or mesh-related adverse events, findings consistent with previous evidence that more women receiving mini-slings underwent further continence surgery than those receiving midurethral slings (risk ratio, 2.00; 95% CI, 0.93 to 4.31).[10] Dyspareunia was significantly more common with mini-slings in the present trial. A previous randomized trial (205 patients) comparing mini-slings (Ajust) with midurethral slings showed no

significant between-group difference in the incidence of dyspareunia at the 3-year follow-up.[24] In another randomized trial comparing mini-slings (Ajust) with obturator tapes, 2 patients in the mini-sling group, as compared with none in the obturator-tape group, reported new dyspareunia[25]; these cases were thought to be possibly due to a painful anchor in the obturator membrane, and 1 patient underwent surgical removal of the anchor. Dyspareunia may also be caused by mesh-related infection, mesh exposure, or abnormal healing leading to scarring.[26]

The main limitations of our trial were the availability of follow-up to only 3 years, a lack of blinding (for feasibility reasons), and inadequate power to detect important differences in adverse events. Late-onset adverse events, a decline in effectiveness over time, or both have been reported with both mini-slings and midurethral slings, and longer-term effectiveness and safety data are needed[27]; 10-year follow-up of trial patients is planned. More midurethral-sling procedures than mini-sling procedures were performed by subconsultant-grade surgeons, but we consider this unlikely to have affected the results. Unlike with the relatively new mini-slings, placing midurethral slings is part of the structured training program of surgeons in the United Kingdom; thus, senior trainee surgeons and associate specialists who have completed their training are likely to be skilled at performing these procedures.

We had limited data on objective success; however, patient-reported outcomes better reflect patients' experience than objective measures, which can overestimate the success of surgery for stress urinary incontinence.[28] Several mesh devices were withdrawn from the market during the heightened mesh debate. However, our trial compared two types of slings (tension-free midurethral slings and adjustable anchored mini-slings) and not specific devices; moreover, most patients received devices still on the market, and results were similar in this subgroup. Generalizability may be limited by our exclusion of women with anterior or apical prolapse beyond stage 2 and those undergoing concomitant prolapse and by the relatively young age (mean, 50 years) and nonobese body-mass index (the weight in kilograms divided by the square of the height in meters) (mean, 29) of the patients. Additional limitations include the absence of information on the race and ethnic group of the patients (Table S5) and on preoperative pain level.

In the SIMS trial, adjustable anchored mini-slings were noninferior to tension-free midurethral slings with respect to patient-reported success at 15 months, and the between-group difference remained similar at 36 months.

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