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Surgical Rates After Observation and Bracing for Adolescent Idiopathic Scoliosis

An Evidence-Based Review

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Study Design. Systematic review of clinical studies.

Objectives. To develop a pooled estimate of the prevalence of surgery after observation and after brace treatment in patients with adolescent idiopathic scoliosis (AIS).

Summary of Background Data. Critical analysis of the studies evaluating bracing in AIS yields limited evidence concerning the effect of TLSOs on curve progression, rate of surgery, and the burden of suffering associated with AIS. Many patients choose bracing without an evidence-based estimate of their risk of surgery relative to no treatment. Therefore, such an estimate is needed to promote informed decision-making.

Methods. Multiple electronic databases were searched using the key words "adolescent idiopathic scoliosis," "observation," "orthotics," "surgery," and "bracing." The search was limited to the English language. Studies were included if observation or a TLSO was evaluated and if the sample closely matched the current indications for bracing (skeletal immaturity, age <15 years, Cobb angle between 20° and 45°). One reviewer (L.A.D) selected the articles and abstracted the data, including research design, type of brace, minimum follow-up, and surgical rate. Additional data concerning inclusion criteria and risk factors for surgery included gender, Risser, age and Cobb angle at brace initiation, curve type, and dose (hours of recommended brace wear).

Results. Eighteen studies were included (observation = 3, bracing = 15). All were Level III or IV clinical series. Despite some uniformity in surgical indications, the surgical rates were extremely variable, ranging from 1 surgery of 72 patients (1%) to 51 of 120 patients (43%) after bracing, and from 2 surgeries of 15 patients (13%) to 18 of 47 patients (28%) after observation. When pooled, the bracing surgical rate was 23% compared with 22% in the observation group. Pooled estimates for surgical rate by type of brace, curve type, Cobb angle, Risser sign, and dose were also calculated.

Conclusion. Comparing the pooled rates for these two interventions shows no clear advantage of either approach. Based on the evidence presented here, one cannot recommend one approach over the other to prevent the need for surgery in AIS. This recommendation carries a grade of D, indicating that the use of bracing relative to observation is supported by "troublingly inconsistent or inconclusive studies of any level." The decision to brace for AIS is often difficult for clinicians and families. An evidence-based estimate of the risk of surgery will provide additional information to use as they weigh the costs and benefits of bracing.

Key words: bracing, adolescent idiopathic scoliosis, outcomes, evidence-based review, surgery, observation. **Spine 2007;32:S91–S100**

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Adolescent idiopathic scoliosis (AIS) is a structural lateral and rotatory curvature of the spine arising in otherwise normal children during puberty. Curvatures <10° are viewed as a variation of normal because, until a curvature has exceeded 10°, it has little potential for progression. The 1982 report of the Scoliosis Research Society[1] stated that 2% to 3% of children younger than 16 years of age will have a curvature of ≤10°, but only 0.3% to 0.5% will have a curvature of ≥20°. In the United States in 1995, there were an estimated 602,884 visits to private physician offices associated with the ICD9 code 737.30 for idiopathic scoliosis.[2] In 2000, there were more than 4500 surgeries performed in the United States for the primary diagnosis of AIS in adolescents between the ages of 10 and 18.[3]

The vast majority of AIS patients do not initially present due to symptoms, but due to truncal asymmetry noted during screening or incidentally during well-child examinations. Long-term follow-ups indicate that patients with scoliosis may have a higher prevalence of back pain, and of respiratory compromise if the curve becomes extremely large.[4] Therefore, the treatment of AIS during adolescence is mainly an attempt to prevent problems during adulthood by arresting the progression of the curve. Additionally, large curves can result in significant cosmetic deformity and associated psychologic distress. Such deformity can only be corrected through surgery.

The use of orthotics to treat AIS is a time-honored tradition in North America and in other countries around the world. Many investigators have examined the effectiveness of bracing in AIS over the past half century. Studies evaluated both the Milwaukee brace[5–17] and 2 major types of TLSOs (full-time and night-time).[13,18–54] The few studies that have compared bracing to observation have demonstrated some decreased risk of curve progression (generally defined as >5° change). Of these, the study by Nachemson and Peterson is the only prospective, multicenter controlled study (Level 2b).[43,55] Although the most rigorous to date, this

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Table 1. Characteristics of Included Studies

Reference	Year	Review	Design	Brace	Total Sample Size	Surgical Rate	Indications for Surgery
Braced							
Allington *et al*[18]	1996	1983–1985	R-C*	Wilmington	147	30.61	Progression
Bassett *et al*[19]	1986	1969–1976	R-C series†	Wilmington	79	11.00	Progression
d'Amato *et al*[25]	2001	1992–1999	R-C series	Providence	102	17.65	Not reported
Emans *et al*[26]	1985	1971–1981	R-C series	Boston	212	12.74	Pain, progression, deformity
Fernandez-Feliberti *et al*[28]	1995	1982–1990	R-C	TLSO	54	25.93	Thoracic lordosis, Cobb >40°, skeletally immature, unacceptable cosmesis
Katz *et al*[37]	1997	1978–1988	R-C	Boston vs. Providence	319	21.94	Not reported
Korovessis *et al*[38]	2000	Not reported	P-C series‡	TLSO	24	12.50	Progression to >45°
Little *et al*[64]	2000	1977–1995	R-C series	Boston or Charleston	120	42.50	>45° with 10° progression
O'Neill *et al*[60]	2005	1991–2001	R-C	Boston	276	30.07	>45°
Price *et al*[47]	1997	1984–1988	P-C series	Charleston	95	17.89	>50°
Spoonamore *et al*[61]	2004	1989–1995	R-C series	Rosenberger	71	30.99	>50°
Trivedi *et al*[48]	2001	1985–1995	R-C series	Charleston	42	7.14	Progression
Vijvermans *et al*[62]	2004	1982–1991	R-C series	Boston	151	12.58	Not reported
Wiley *et al*[50]	2000	1984–1989	R-C series	Boston	50	30.00	Not reported
Yrjonen *et al*[54]	2006	Not reported	Prospective/R-C series	Providence and Boston	72	1.39	Not reported
Observation							
Goldberg *et al*[63]	1993	1985–1988	R-C		15	13.33	<45°, other unnamed criteria
Goldberg *et al*[57]	2001	1991–?	R-C		77	12.98	Cobb angle, cosmesis, probability of future progression, maturity, wishes of patient and family
Fernandez-Feliberti *et al*[28]	1995	1982–1990	R-C		47	38.30	Thoracic lordosis, Cobb >40°, skeletally immature, unacceptable cosmesis

*Retrospective comparison study.
†Retrospective case series.
‡Prospective case series.

study was nonrandomized, nonblinded, baseline differences between the groups were not statistically adjusted for, and the results did not include the surgical rates.

Patients and families don't generally fear curve progression; they fear curve progression to the point where surgery is the only option to improve or maintain an acceptable level of cosmesis. Therefore, it is not surprising that many opt for orthotic treatment without seriously considering the approach of watchful waiting advocated by Dickson and Weinstein in England[56] and

Table 2. Subject, Treatment, and Study Characteristics

Reference	Gender	Risser	Age (yr)	Curve Type	Cobb Angle (°)	Dose
Braced						
Allington *et al*[18]	Both	0–1	9+	All	20–40	12–16/23 hr
Bassett *et al*[19]	Both	0–1	9–15	All	20–39	23
d'Amato *et al*[25]	Female only	0–2	10–16	All	20–42	8
Emans *et al*[26]	Both	0–4	11–14	All	20–49	23
Fernandez-Feliberti *et al*[28]	Both	Immature	8–15	Single curves only	30–40	23
Katz *et al*[37]	Both	0–2	10+	All	25–45	Not reported
Korovessis *et al*[38]	Female only	0–2	10–13	Thoracic, lumbar	25–40	23
Little *et al*[64]	Female only	Not reported	Not reported	Not reported	Not reported	Not reported
O'Neill *et al*[60]	Both	0–2	11–17	Not reported	25–40	18
Price *et al*[47]	Both	0–2	10–15	All	25–49	8
Spoonamore *et al*[61]	Both	0–3	9–16	All	25–45	16
Trivedi *et al*[48]	Female only	0–1	10–15	Single curves only	25–45	8
Vijvermans *et al*[62]	Both	Not reported	Mean, 13.32	King 1–4	25–40	22
Wiley *et al*[50]	Both	0–2	10–16	All	35–45	23
Yrjonen *et al*[54]	Female only	0–4	9–15	All	20–42	8 or 23
Observation						
Goldberg *et al*[63]	Female only	0–4	11–14	All	20–35	
Goldberg *et al*[57]	Both	Not reported	10–?	All	20–39	
Fernandez-Feliberti *et al*[28]	Both	Immature	8–15	Single curves only	30–40	

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Goldberg *et al*[57] in Ireland. Unfortunately, orthotic treatment is not necessarily benign in terms of the psychosocial and body image concerns it causes for many families. Therefore, we think that such a treatment decision should be based on the best evidence available concerning the rate of surgery with and without treatment, including the patient and treatment characteristics that contribute to higher rates of surgery. This evidence is an integral part of informed choice and should be available to clinicians, patients, and their parents as they contemplate bracing. To date, no systematic review has synthesized this evidence.

The objective of this review is to develop a pooled estimate of the incidence of surgery in untreated patients (treated by observation only) and in brace-treated patients with AIS, as well as for specific risk factors that may significantly affect the prevalence of surgery. Ultimately, the objective of this review is to help clinicians, patients, and parents make informed choices concerning treatment for AIS.

Methods

Criteria for Selecting Studies for This Review

Types of Studies. Clinical evaluations of bracing and observation.

Types of Participants

1. AIS (no other musculoskeletal or neurologic conditions responsible for curvature, diagnosed at or after the age of 8 years)
2. Participants who meet current indications for brace initiation
   a. Cobb angle between 20° and 45°
   b. Age <15 years
   c. Risser 0, 1, 2
3. Follow-up to at least skeletal maturity

Types of Interventions. Observation or bracing (including TLSOs and bending braces, but not including Milwaukee, SpineCor, Triac) and without other prescribed interventions (*e.g.*, inpatient or outpatient physical therapy).[58,59]

Types of Outcome Measures

1. Surgery
2. Recommended surgery
3. Curve progression to >50°

Search Strategy for Identification of Studies

1. Medline
2. Web of Science
3. Cochrane Controlled Trials Registry
4. Clinical Evidence
5. Bibliography of all reviewed articles
6. Limited to English language, humans, children 0 to 18 years

The search strategy included the terms "adolescent idiopathic scoliosis," "idiopathic scoliosis," "natural history," "observation," "bracing," and "orthotics."

Study Selection. One reviewer (L.A.D.) conducted the electronic search and selected the studies based on title, abstract, and key words. The same reviewer then printed a full copy of the articles and determined whether or not they met the inclusion criteria. In addition, the bibliographies of all included ar-

Table 2. Continued

Weaning	Minimum Follow-up	Risk Factors	Main Conclusion
R4 females; R5 males	Skeletal maturity	Dose; Cobb	Full-time and part-time bracing are equally effective
0–1	1 yr	Curve type	Wilmington alters natural history
Stop at R4, no growth over 6 mo	2.1 yr	Cobb, maturity, rotation	Effective for curves <35° and larger with low apex
R4, no growth	1 yr	Cobb, maturity, rotation, correction, dose	Boston superior to natural history for curves <50°
SM	1 yr	Cobb, maturity, curve type	TLSO superior to natural history, especially in older patients and those with smaller Cobb angle
Not reported	Skeletal maturity	Gender, Cobb, curve type, maturity, correction, type of brace	Boston superior to Charleston
Not reported	2 yr	Rotation	TLSOs change natural history
Not reported	2.5 yr	Peak height velocity	Can predict surgical outcome based on Cobb angle at PHV
R4	Skeletal maturity	Weight, gender, maturity, dose	Overweight patients have less success; should be taken into account when making treatment decisions
SM	Skeletal maturity	Cobb, maturity, curve type	Charleston improves upon natural history
R4	1 yr	Maturity, gender, Cobb, rotation, correction, curve type	Overall failure rate similar to natural history studies; need to refine indications
Stop at R4, no growth over 6 mo	1 yr	Cobb, curve type, correction	Charleston improves upon natural history
R4 or 2 yr postmenarche	Skeletal maturity	Maturity, rotation, correction, dose	Brace does not alter natural history, especially in those older than 12 with Risser 2+
R4 females; R5 males, no growth over 6 mo	2 yr	Cobb, maturity, dose	Boston brace is effective when used 18+ hours/day
R4, no growth over 6 mo	1 yr	Type of brace, curve type	Providence recommended for curves <35° in lumbar/thoracolumbar curve
	Post-menarchal, "stable" over last two follow-ups		No advantage to bracing
	>15 yr at last follow-up		Nonintervention is equivalent to bracing in surgical rate
	1 yr	Cobb, maturity, curve type	TLSO superior to natural history, especially in older patients and those with smaller Cobb angle

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Table 3. Surgical Rate by Study, Pooled Over All Studies and by Treatment

Reference	No. of Surgeries	Total Sample	Surgical Rate	Confidence Interval
Braced				
Allington *et al*[18]	45	147	31	24–38
Bassett *et al*[19]	9	79	11	6–20
d'Amato *et al*[25]	18	102	18	11–26
Emans *et al*[26]	27	212	13	9–18
Fernandez-Feliberti *et al*[28]	14	54	26	16–39
Katz *et al*[37]	70	319	22	18–27
Korovessis *et al*[38]	3	24	13	4–31
Little *et al*[64]	51	120	43	34–51
O'Neill *et al*[60]	83	276	30	25–36
Price *et al*[47]	17	95	18	11–26
Spoonamore *et al*[61]	22	71	31	21–42
Trivedi *et al*[48]	3	42	7	2–19
Vijvermans *et al*[62]	19	151	13	9–21
Wiley *et al*[50]	15	50	30	26–52
Yrjonen *et al*[54]	1	72	1	0–7
Observation				
Goldberg *et al*[63]	2	15	13	4–39
Goldberg *et al*[57]	10	77	13	7–22
Fernandez-Feliberti *et al*[28]	18	47	38	26–53
Pooled braced	397	1814	23	20–24
Pooled Observation	30	139	22	16–29

ticles were checked for additional work that met the inclusion criteria. If 2 papers were found analyzing the same group of patients (*e.g.*, early and late results of the same clinical series), the most recent paper or the one with the largest sample size was included. If a study included participants or brace types that did not meet the inclusion criteria, the study was either not used or the only the data addressing the eligible patients/brace were subset out and included. The decision was made to include papers if the vast majority of participants met the inclusion criteria. These exceptions are noted in Results.

Data Extraction. One reviewer (L.A.D.) extracted data from the papers using a standardized format. Data extraction was then repeated a week later by the same reviewer. Discrepancies between the 2 extractions were corrected. The following data concerning the material and methods of the trials were extracted: year published, years of treatment included in the paper, research design, total sample size, number of surgeries, recommended surgeries, and/or curves that progressed to >50°, and minimum follow-up. Additional data concerning inclusion criteria and risk factors for surgery included; gender, Risser, age, and Cobb angle at diagnosis/treatment initiation; and curve type, brace type, and dose (hours of recommended brace wear). Attempts were made to contact the primary authors when questions concerning these variables arose.

Data Analysis. The pooled prevalence of surgery was calculated separately for both observation and surgery. This calculation involved dividing the number of surgeries summed over all studies by the number of participants summed over all studies. Pooled prevalence estimates for surgery by risk factor were also derived if there were comparable data reported in more than 1 study; 95% confidence intervals were calculated for the individual study rates and for the pooled estimates.

Results

Study Selection

A total of 152 studies concerning observation and/or bracing were located using the electronic databases. Sixty-three of these articles were not further reviewed because, based on their abstracts, they clearly did not meet 1 or more of the inclusion criteria. The full text of 85 articles was reviewed, as well as the full-text of 7 additional studies noted in the bibliographies. Of these 92 articles, 18 were found to meet inclusion criteria. Details of these studies are summarized in Tables 1 and 2. Minor exceptions were made to the inclusion criteria in order to include 2 observation studies and 5 bracing studies.

1. Maturity at diagnosis. d'Amato *et al*[25] and Wiley *et al*[50] included patients as old as 16, but all were Risser 0 to 2. O'Neill *et al*[60] included patients up to the age of 17, but all were Risser 0 to 2. Spoonamore *et al*[61] included patients up to the age of 16 (mean age, 12 years); 8 of 71 patients (6%) were Risser 2 or 3.
2. Age <8 years of age at diagnosis. Vijvermans *et al*[62] included "juvenile-onset" patients (29 of 132 patients, 19%). Emans *et al*[26] included patients who were initially treated before the age of 10; since the data were subset by age, we were able to include only those patients who were initially treated after the age of 10.

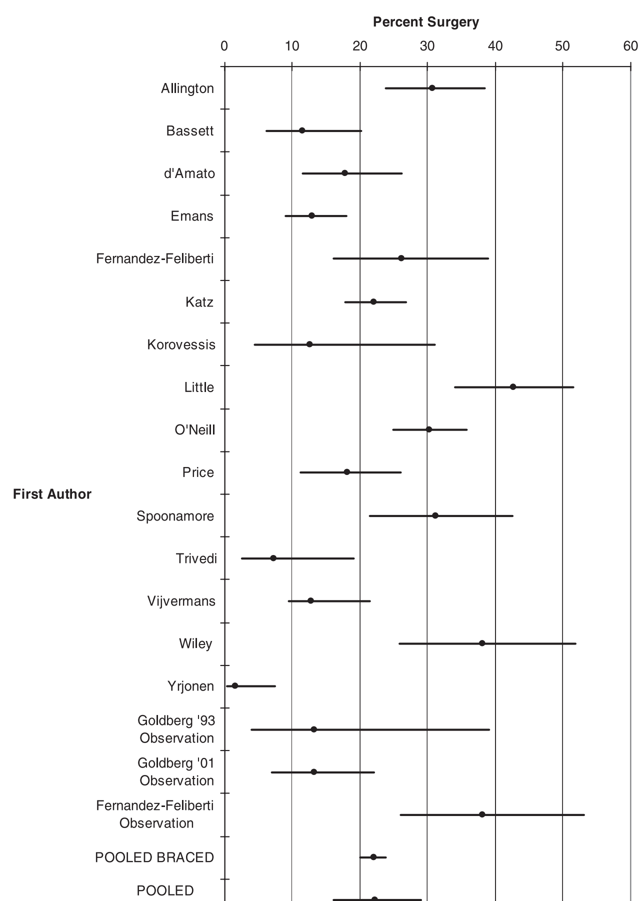

Figure 1. Surgery rates by individual study compared with pooled bracing and pooled observation rates.

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Table 4. Surgical Rate by Cobb Angle at Treatment Initiation

Cobb Angle	Reference	No. of Surgeries	Total Sample	Surgical Rate	Confidence Interval
<30°	Allington *et al*[18]	4	68	6	2–14
	Emans *et al*[26]	5	111	5	2–10
	Braced <30°	9	179	5	3–9
	Goldberg *et al*[63]	2	13	15	4–42
	Goldberg *et al*[57]	5	44	11	5–11
	Observation <30°	7	57	12	6–23
>30°	Allington *et al*[18]	41	79	52	41–63
	Emans *et al*[26]	22	101	22	15–31
	Wiley *et al*[50]	15	50	30	26–52
	Braced >30°	78	230	34	27–38
	Goldberg *et al*[63]	0	2	0	0–67
	Goldberg *et al*[57]	5	33	15	7–31
	Observation >30°	5	35	14	6–29
Pooled braced		397	1814	23	20–24
Pooled observation		30	139	22	16–29

3. Curve Size. Emans *et al*[26] and Price *et al*[47] both included curves up to 49° (10% between 40° and 49° in each study). Goldberg *et al*[57,63] included patients whose curves were <20° or >40°. The outcomes in the Emans *et al*[26] and 2 Goldberg *et al* studies[57,63] were broken down by Cobb angle; therefore, we were able to include only the subsets of eligible patients.

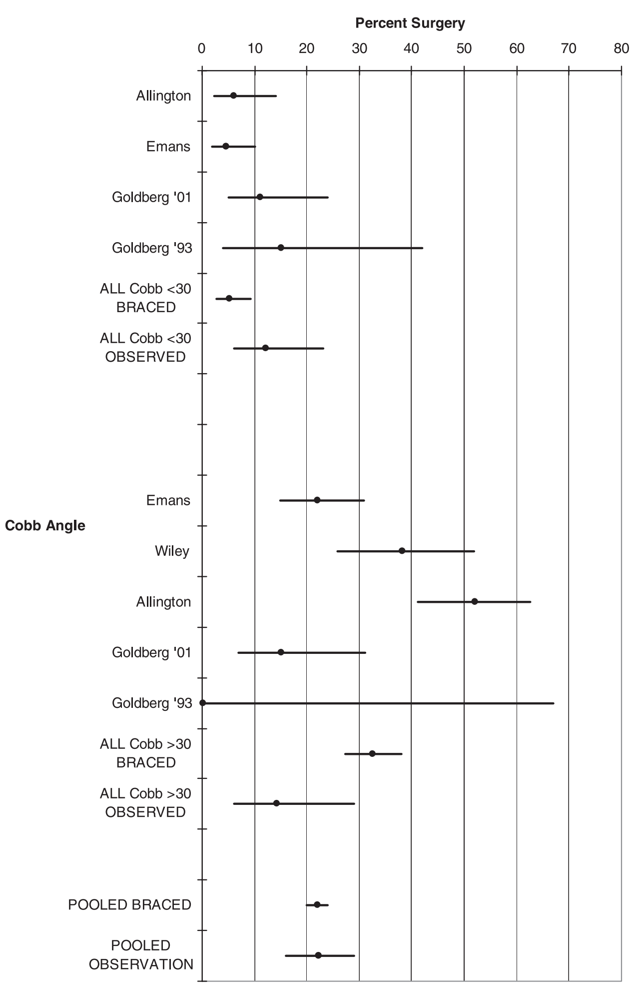

Figure 2. Surgery rates by Cobb angle (<30° or >30°) compared with pooled bracing and pooled observation rates.

Details of Studies

Design. In accordance with the inclusion criteria, all studies included information concerning the surgical rate in their series, although the main purpose of the studies differed. Seven studies used a retrospective comparison design (Level III[55]) to look at differences in outcomes between braced *versus* observed AIS patients;[28,57,63] full-time and part-time bracing and electrical stimulation;[18] Boston *versus* Charleston braces;[37] Providence *versus* Boston braces;[54] and normal weight *versus* overweight patients.[60] All other studies used a Level IV[55] case-series design. Korovessis *et al*[38] evaluated the effects of a TLSO on spinal, trunk, and rib cage deformities and the Little *et al*[64] study was designed to look at peak height velocity and other maturity indicators in relation to curve progression. The remaining Level IV studies were primarily designed to evaluate the effect of bracing on curve progression. The sample size of braced patients in the studies ranged from 15[63] to 319[37] (median number of patients per study, 78).

Patient Characteristics at Treatment Initiation

The studies included both boys and girls with the exception of some authors[25,38,48,54,63,64] who reviewed only female patients. All studies included skeletally immature patients (Risser 0–2), although some authors[26,54,61] included a small percentage of patients at Risser 3 or 4 who might be considered too skeletally mature according to current bracing indications. Little *et al*[64] and Vijvermans *et al*[62] did not supply specific Risser signs. In all studies, the smallest Cobb angle included was 20°. As noted, the largest Cobb angle at brace initiation included in this review was 49° in 2 studies.[26,47] The "dose" of full-time bracing was reported as 22 to 23 hours, except in the O'Neill *et al*[60] (18 hours) and Spoonamore *et al*[61] (16 hours) studies. Part-time bracing was defined as 12 to 16 hours[18]; nighttime-bracing was recommended for 8 hours.[25,37,47,54,64] Weaning from the brace generally occurred at Risser 4 or 5; some authors required a lack of

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Table 5. Surgical Rates by Type of Brace

Brace Type	Reference	No. of Surgeries	Total Sample	Surgical Rate	Confidence Interval
Boston	Emans *et al*[26]	27	212	13	9–18
	Katz *et al*[37]	24	153	16	11–23
	Vijvermans *et al*[62]	19	151	13	8–19
	Wiley *et al*[50]	15	50	30	19–44
	Yrjonen *et al*[54]	0	36	0	0–10
	Pooled	85	602	14	12–17
Boston/Charleston	Little *et al*[64]	51	120	43	34–51
	Trivedi *et al*[48]	3	42	7	2–19
	Pooled	54	162	33	27–41
Providence	d'Amato *et al*[25]	18	102	18	11–26
	Yrjonen *et al*[54]	1	36	3	0–14
Charleston	Katz *et al*[37]	46	166	28	21–35
	Price *et al*[47]	17	95	18	11–27
	Pooled	82	399	21	17–25
TLSO	Fernandez-Feliberti *et al*[28]	14	54	26	16–39
TLSO	Korovessis *et al*[38]	3	24	13	4–31
Boston/TLSO	O'Neill *et al*[60]	83	276	30	25–36
Rosenberger	Spoonamore *et al*[61]	22	71	31	21–42
	Pooled	122	425	29	25–33
Wilmington	Allington *et al*[18]	45	147	31	24–38
Wilmington	Bassett *et al*[19]	9	79	11	4–17
	Pooled	54	226	24	19–30
Pooled braced		397	1814	23	20–24
Pooled observation		30	139	22	16–29

change in height over 6 months before weaning was recommended.[25,26,48,54] The untreated patients in the Fernandez-Feliberti *et al* study[28] were selected from a larger cohort of patients who never received bracing treatment because either they or their parents refused. They were followed every 6 months with radiographs. Untreated patients in the 1993 Goldberg *et al* series[63] were chosen from those in a school screening program at a single hospital in Dublin and those in the 2001 study were from a dedicated research database at the same institution.[57]

Outcomes and Risk Factors

The patients in all studies were followed at least until skeletal maturity. This endpoint, although shorter than that advocated by many journals and by the Scoliosis Research Society, was chosen to include as many studies as possible. Because further progression and surgeries may occur after this endpoint, the surgical rates presented here should be considered minimum estimates from these series. Surgical indications included progression,[18,48] or specifically a curve of ≥45°[38,60,64] or ≥50°.[61] The patients in the Emans *et al* study[26] were indicated for surgery based on a wider range of outcomes, including a curve of ≥40°, pain, deformity, and/or thoracic lordosis. Similarly, surgery was indicated in the Fernandez-Feliberti *et al*[28] series if patients had a thoracic lordosis, a curve ≥40°, failed brace treatment, or felt their deformity was unacceptable. The indications for surgery at Goldberg's institution are worth noting.[57] Surgery is considered based on Cobb angle, cosmesis, the probability of future progression, maturity, and the wishes of the patient and family. As they state, ". . . 40° is not in itself an indication for surgery, neither is a lesser Cobb angle an absolute bar" (p. 44). The remainder of the papers did not report their specific indications for surgery.[19,25,37,50,54,62]

A wide variety of risk factors for progression/surgery were evaluated in the papers. We were able to extract surgery rates for different Cobb angles for a subset of the observation and bracing studies. We also were able to calculate surgical rates based on a subset of bracing studies for brace type, curve type, Risser sign, and bracing dose.

Pooled Estimates

Overall. Table 3 and Figure 1 summarize the individual study and pooled results for all patients combined. The surgical rates in the observational studies ranged from 13% in both Goldberg *et al* studies to 38% in the Fernandez-Feliberti *et al* study and in the bracing studies from 1%[54] to 43%.[64] The pooled rate for observation was 22% (95% confidence interval [CI], 16%–29%), which is very similar to the pooled rate after bracing of 23% (95% CI, 20%–24%).

Cobb Angle. Table 4 and Figure 2 summarize the surgical rate by Cobb angle at treatment initiation. The pooled surgical rate after observation for curves <30° was 12% (95% CI, 6%–23%) and 14% for those curves >30° (95% CI, 6%–29%). The rate after bracing for curves <30° was 5% (95% CI, 3%–9%) and 34% (95% CI, 27%–28%) in curves >30° at treatment initiation.

Brace Type. Table 5 and Figure 3 summarize the data as analyzed by the type of brace. Various types of TLSOs were used in the studies. The lowest pooled surgical rate was associated with the Boston brace (14%; 95% CI, 12%–17%) and the highest rate was associated with the

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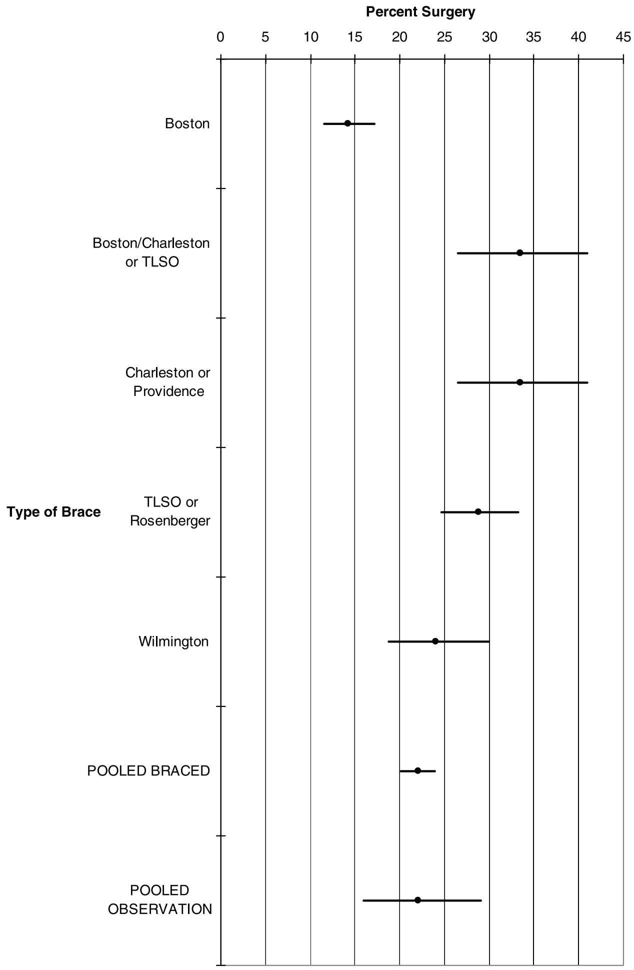

Figure 3. Surgery rates by type of brace compared with pooled bracing and pooled observation rates.

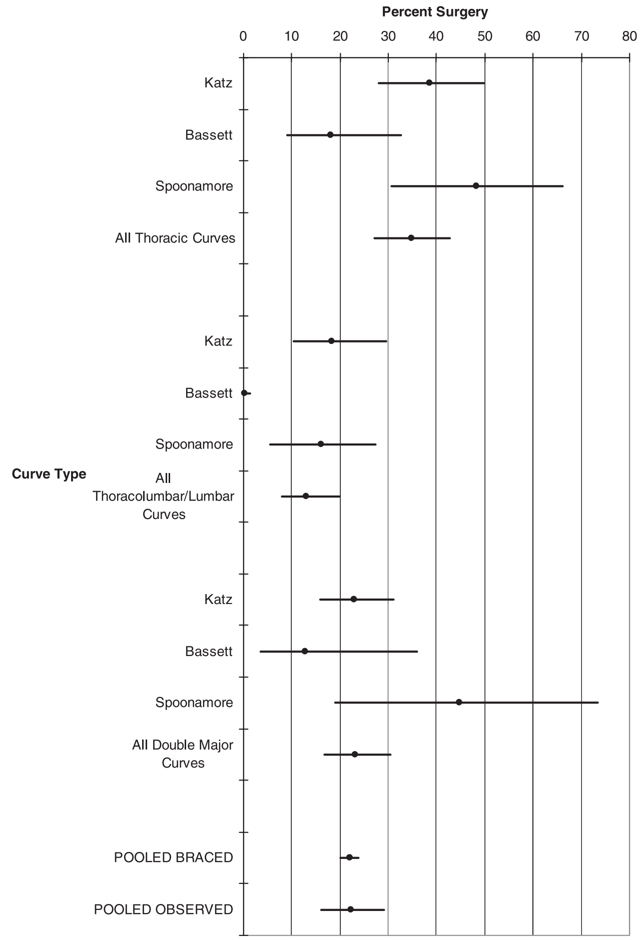

Figure 4. Surgery rates by curve type (thoracic, thoracolumbar/lumbar, or double major) compared with pooled bracing and pooled observation rates.

studies using a combination of generic TLSOs, the Boston, or the Rosenberger (29%; 95% CI, 25%–33%).

Curve Type. Table 6 and Figure 4 summarize the surgical rate by curve type. The highest pooled rate was associated with thoracic curves (35%; 95% CI, 27%–42%), followed by double major curves (23%; 95% CI, 17%–30%) and thoracolumbar/lumbar curves (13%; 95% CI, 8%–20%).

Risser Sign. Table 7 and Figure 5 summarize the surgical rate by Risser sign at brace initiation. Subjects who began bracing at Risser 0 or 1 had a higher rate of surgery (25%; 95% CI, 21%–30%) than those braced at Risser 2 (9%; 95% CI, 4%–18%).

Dose. Table 8 and Figure 6 summarize the surgical rate by the hours of recommended brace wear. Given that the dose (hours of recommended brace wear) is confounded

Table 6. Surgical Rate by Curve Type

Curve	Reference	No. of Surgeries	Total Sample	Surgical Rate	Confidence Interval
Thoracic	Katz *et al*[37]	28	73	38	28–50
	Bassett *et al*[19]	7	39	18	9–33
	Spoonamore *et al*[61]	13	27	48	31–66
	Pooled	48	139	35	27–42
Thoracolumbar/lumbar	Katz *et al*[37]	11	61	18	10–30
	Bassett *et al*[19]	0	24	0	0–14
	Spoonamore *et al*[61]	4	33	12	5–27
	Pooled	15	118	13	8–20
Double major	Katz *et al*[37]	26	115	23	16–31
	Bassett *et al*[19]	2	16	13	4–36
	Spoonamore *et al*[61]	4	9	44	19–73
	Pooled	32	140	23	17–30
Pooled braced		397	1814	23	20–24
Pooled observation		30	139	22	16–29

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Table 7. Surgical Rates by Risser Sign at Treatment Initiation

Risser	Reference	No. of Surgeries	Total Sample	Surgical Rate	Confidence Interval
0/1	Allington *et al*[18]	45	147	31	24–38
	Bassett *et al*[19]	9	79	11	6–20
	Katz *et al*[37]	68	268	25	21–31
	Trivedi *et al*[48]	3	42	7	2–19
	Wiley *et al*[50]	13	28	46	30–64
	Pooled	84	338	25	21–30
2	Katz *et al*[37]	2	51	4	1–13
	Wiley *et al*[50]	4	16	25	10–50
	Pooled	6	67	9	4–18
Pooled braced		397	1814	23	20–24
Pooled observation		30	139	22	16–29

with brace design in the papers evaluating Charleston and Providence braces,[25,47,48,54] these data were not considered in the pooled estimates of surgery associated with dose. The pooled estimate for full-time wear (22.91%; 95% CI, 21%–26%) was only slightly lower than that for part-time wear (26%; 95% CI, 19%–34%).

Discussion

This review presents pooled data from 3 studies reporting the rate of surgery after observation only and from 15 studies reporting the rate after bracing for AIS. Comparing the pooled rates for these 2 interventions shows no clear advantage of either approach; therefore, based on the evidence presented here, one cannot recommend one approach over the other to prevent the need for surgery in AIS. This recommendation carries a grade of D, indicating that the use of bracing relative to observation is supported by "troublingly inconsistent or inconclusive studies of any level."[55]

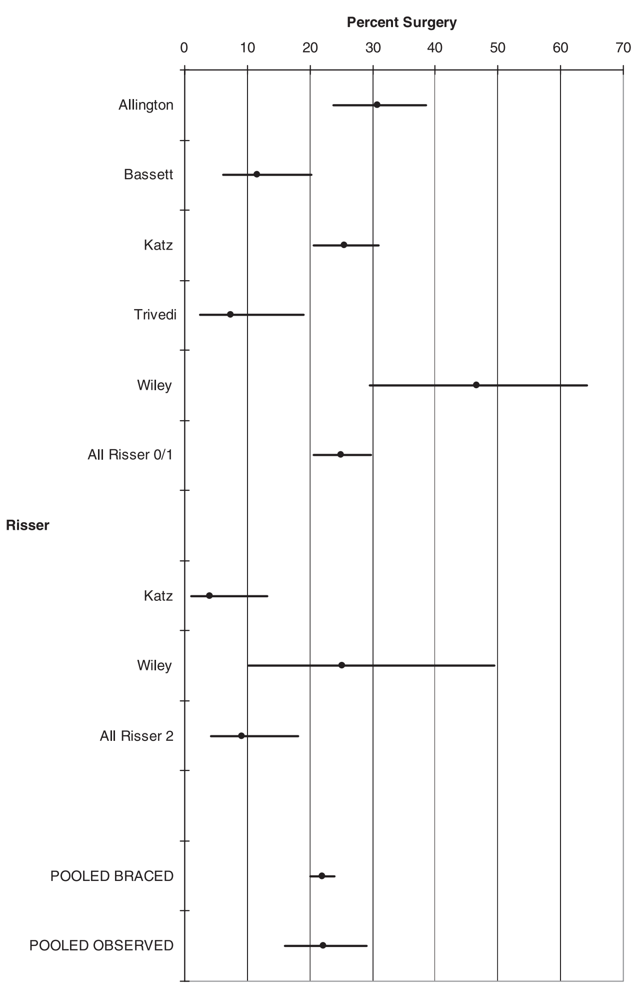

Figure 5. Surgery rates by Risser grade (0/1 or 2) compared with pooled bracing and pooled observation rates.

The inconsistent rates of surgery from the different papers, both within and between treatments, could stem from several factors. First, despite our attempts to create a homogenous pooled sample based on current indications for bracing, inclusion criteria still varied between studies, and the majority of studies did not present enough detail in their results to allow us to subset out patients for all of the risk-factor specific surgical rates. Also of note is the variation in surgical indications. Many reports were vague about their indications, mentioning only "progression" as the indication, whereas other reports were more specific. For example, some authors[38,47,61,64] required a Cobb angle of at least 45° before consideration of surgery, whereas other authors[25,37,50,62] did not report their specific indications. Very few reports mentioned how many patients were offered, but declined, surgery.

The fact that a large number (n = 1814) of braced patients from many different institutions were available for this review is evidence for the reliability of the pooled surgical rate of 22%. However, there is less evidence for the observation pooled rate since only 3 studies, representing just 2 institutions, were available for this review. This lack of confidence is amplified by the fact that the rates differ greatly between the studies. Without the Fernandez-Feliberti *et al* data,[28] the observation surgical rate would be 13%, which is significantly lower than that following bracing. An obviously erroneous conclusion would be that bracing causes an excess risk of surgery. A more nuanced conclusion would take into account the difference in approaches and surgical indications between Dublin and the rest of the centers. Perhaps not advocating treatment from the start, as has been the policy in Dublin since 1991, results in less anxiety on the part of the patient and family concerning AIS, which then might result in less patient demand for surgery. Future long-term studies are needed to determine whether this "patient-determined" rate of surgery is more

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Table 8. Surgical Rate by Recommended Hours of Brace Wear

Hours of Wear	Reference	No. of Surgeries	Total Sample	Surgical Rate	Confidence Interval
16–18	Allington *et al*[18]	8	49	16	9–29
	Spoonamore *et al*[61]	22	71	31	21–42
	Wiley *et al*[50]	5	14	36	16–61
	Pooled	35	134	26	19–34
18–23	Allington *et al*[18]	37	98	38	29–48
	Bassett *et al*[19]	9	79	11	6–20
	Emans *et al*[26]	27	212	13	9–18
	Fernandez-Feliberti *et al*[28]	14	54	26	16–39
	Korovessis *et al*[38]	3	24	13	4–31
	O'Neill *et al*[60]	83	276	30	25–36
	Vijvermans *et al*[62]	19	151	13	9–21
	Wiley *et al*[50]	35	50	30	26–52
	Yrjonen *et al*[54]	0	36	0	0–10
	Pooled	227	980	23	21–26
Pooled braced		397	1814	23	20–24
Pooled observation		30	139	22	16–29

appropriate than the more typical "clinically determined" rate of surgery in terms of health and function throughout adulthood.

Our patients should be informed that there is inconclusive and inconsistent evidence concerning the risk of surgery in AIS. Given that disclaimer, we may then counsel them that, despite our best efforts at bracing, between 20% and 24% of patients go on to surgery. Certain risk factors likely increase this rate, i.e., presenting at Risser 0 or 1, with a thoracic curve of >30° is associated with a risk of greater than 30%. They should also be aware that this review did not demonstrate an advantage to bracing over observation in terms of surgical rates. Given the fact that bracing can be an onerous regimen, in terms of time, social acceptance, and physical activity, and that surgery is not without significant risks, this information is essential as we allow patients and families to make their decision based on their own personal risk/benefit ratios.

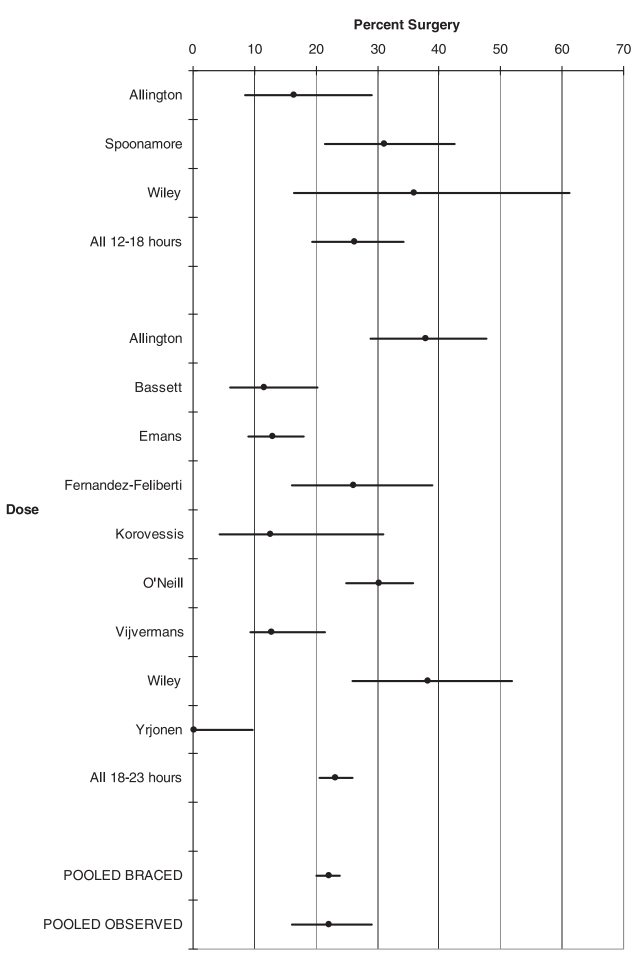

Figure 6. Surgery rates by prescribed dose (12–18 hours or 18–23 hours) compared with pooled bracing and pooled observation rates.

■ Key Points

- Data on surgical rates after observation and bracing were abstracted from 18 studies.
- The pooled surgical rate was 23% after bracing and 22% after observation.
- This review provides no evidence to recommend bracing over observation.
- This evidence-based review should be used to inform the decisions of clinicians, patients, and parents as they weigh the costs and benefits of bracing treatment.

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