ORIGINAL REPORT

Results of Milwaukee and Boston Braces with or without Metal Marker Around Pads in Patients with Idiopathic Scoliosis

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Received: 23 Oct. 2010; Received in revised form: 10 Dec. 2010; Accepted: 8 Jan. 2011

Abstract- Bracing is the non-operative treatment of choice for adolescent idiopathic scoliosis (AIS) and careful application of pads on apical segment of curve is very important for correction. Control of pads` appropriate site in brace is not easy by clinical evaluation. Therefore, we decided to compare results of braces which for better control of pads by radiographs, metal marker inserted around pads with those without metal marker. We evaluated 215 consecutive cases (182 female, 33 male) of AIS with 342 major curves from 1993 to 2003. Mean initial age was, 13.2±1.8 years (9-16) and mean duration of follow-up was, 16.1±16.4 months (0-114) that treated by 4 type of brace; 89 with type 1(Milwaukee with metal pads), 87 with type 2 (Milwaukee with simple pads), 17 with type 3 (Boston with metal pads) and 22 with type 4(Boston with simple pads). Cobb angle recorded at 5 stages (initial, best, wean, stop and final follow-up). Mean initial Cobb was 36.2˚, at stop stage, 35.2˚ and reached 38˚ at final follow-up. Overall, 21.3% improved, 42.2% were the same and 36.5% failed. Failure for braces type 1 to 4 were, 40.5%, 34%, 38% and 24% at final follow-up. A total of 59 patients (27.4%) underwent spinal fusion that for brace type 1 to 4 , was, 33, 21, 2 and 3 patients respectively. From 16 cases with initial Cobb of 50˚, at follow-up, 12 were ≥50˚ or had spinal fusion. Correction of lumbar (P=0.008) and main thoracic curves (P=0.002) was better by Boston than Milwaukee, however, in general difference between 4 types of braces was not significant and metal marker had no significant effect on results. Two important predictors of brace failure were, initial curve magnitude and brace type, but using metal marker around pads had no effect in results. It seems that bracing did not alter the natural history of scoliosis in early Risser stages with large magnitude of initial curves. Insertion of metal marker around pads is easy and cheap way that facilitate control of pad sites well, so, we recommend to use.

Acta Medica Iranica, 2011; 49(9): 598-605.

Keywords: Adolescent Idiopathic Scoliosis, Milwaukee brace; Boston brace; Metal marked Pads

Introduction

The aim of non-operative treatment of adolescent idiopathic scoliosis (AIS) is to control the curve, prevent from progressing and also prevent the need for surgical stabilization, in addition, the cosmesis of the child should be improved whenever possible (1-7). Orthotic treatment has been proven to be the only treatment effective in altering the natural history, and thus is the non-operative treatment of choice (5,7-9).

Historically the Milwaukee brace was used for thoracic and double curves, while the TLSO (such as Boston brace) was prescribed for single lumbar and thoracolumbar (TL) curves (1-11).

The reported success of non-operative treatment is variable. The most common parameter used to assess the effectiveness of brace treatment is the amount of curve progression that occurs, usually with success defined by curve progression of ≤5˚ at maturity and the other parameter used to assess the success of brace treatment is the prevention of surgery (1,4,5,9,10,12).

The purpose of the study was to assess whether it is more efficacy and better correction of scoliosis by application of metallic marker (wire) around pads. We thought that use of metallic marker around pads facilitate better adjustment of pads on correct position in apical segment of curves according to roentgenogram. As far as we know, there is no study to exactly determine the site of brace pads on radiographs only by

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clinical evaluation.We also reported the incidence of failure particularly by brace type used and also analyzed the results according to age, sex, curve types and curve magnitude.

Patients and Methods

A total of 460 patients for whom a Milwaukee or Boston brace was prescribed over the period from 1993 to 2003 were identified. From these cases, 215 patients (182 female, 33 male) with initial age of 13.2±1.8 years (9-16) met the 9 criteria for inclusion in this study, which were: 1) A diagnosis of AIS; 2) A chronological age of 9 years until 16 years at the time that treatment had begun; 3) No other form of non-operative treatment had been tried; 4) The brace had been worn until it was discontinued by the treating physician or underwent spinal fusion; 5) Adequate clinical records were available for review; (6) A primary curve of 24° or more till 50°; 7) A minimum of one year wear of brace before an arthrodesis had been done; 8) Using only one type of brace and 9) Patients had no thoracic hypokyphosis or lordosis during treatment.

We obtained data from office charts. Information such as; sex, age, joint laxity, age of menarche, period of brace wearing, type of bracing, the need for surgical fusion, whether the brace type or pads changed or adjusted. Scoliosis Cobb angles that were measured from standing postero-anterior and lateral radiographs at five stages of treatment: 1) At initiation of bracing 2) At stage of maximum correction in brace, (Best stage) 3) at time of weaning, 4) at time of discontinuing of brace (Stop stage) and 5-at final follow-up also recorded.

Senior author from 1993 to 1998, prescribed Milwaukee brace with simple pads (brace type 2) in 87 patients, and Boston brace with simple pads (brace type 4) in 22 patients. But from 1998 and thereafter prescribed braces with application of metal wire marker around pads, that there was 89 cases who wore Milwaukee brace with metal marker(brace type 1) and 17 cases who wore Boston brace with metal marker (brace type 3). Metal wire inserted around pads by clinical orthopaedist after brace completely prepared.

All patients wore the brace for 23 hours a day, until they were weaned or they had operative intervention. The patients were seen every 4 months with requesting standing radiographs in the brace at every visits, so that the brace could be evaluated and if necessary pads adjusted. Weaning from the brace occurred at the end of growth as evidenced by no height increase or at Risser 4 or 5 as seen on spine films, or for girls when 18 to 24 months from the beginning of menarche. Once start weaning, a standing postero-anterior (PA) radiograph was done four hours out of the brace and if in compare to the last recent radiograph in the brace, the curve maintained , the patients allowed to be out of brace four hours daily. This is repeated every four months, with an additional 4 hours out of the brace, till wearing at night. After 6 months of night wearing, radiograph obtained out of the brace one week and the bracing discontinued.

Results were classified as successful (improved) if the Cobb angle corrected more than 5° from the time of brace wearing to the final radiograph, progression of ≥ 6° was considered failure of treatment and results were the same if Cobb angle was in range of ±5° in relation to initial value. Also progression of scoliosis to ≥50° and to surgical fusion was noted as failure of treatment (10).

Statistical analysis were performed using SPSS 11.5, All probability (P) values in this study were calculated within a confidence interval of 95%. Independent t-test was used for analysis between the groups. Pearson correlation analysis were used to identify linear relations between the continuous variables, paired *t*-test used for comparison of curves in different stages and if there was more than one group, ANOVA used.

Results

General

General results indicated that of major curves, 21.3% showed correction in excess of 5° (Improved), 42.2% were the same (±5°) and 36.5% showed increase in excess of 5° (failed) as compared with pre-brace values at follow-up. A total of 23.2% (50 cases) of patients underwent surgery during the period they used the brace and 4.2% (9 cases) required surgery during the follow-up period (Table 1).

In this study, 51% of cases were double major curves, 19.5%, single main thoracic MT) and 14.4%, single major thoracolumbar (TL). In surgical group, 66.1% were double major, 16.9% single MT and 10.1% were triple major. Overall results indicate a typical pattern of initial correction in brace, gradual loss, and a final follow-up value that approaches the pre-brace value for major curves. Mean pre-brace values was 36.2° in 215 patients, mean correction at stage best in brace was 34%, which declined to 32% at stage wean, was 3% at stage stop and mean loss of correction was 4.9% at follow-up as compared with pre-brace values.

Table 1. Comparison of patients in four type of brace, Entire group and surgical cases

	Surgical patients	Entire group	Brace type			
			1	2	3	4
Number (F/M)	**59(51/8)**	**215(182/33)**	**89(76/13)**	**87(76/11)**	**17(14/3)**	**22(16/6)**
Mean age at:						
initial	12.3±1.7	13.2±1.8	13±1.8	13.5±1.6	13.2±2.2	13.4±1.9
Best stage	12.9±1.7	14.3±1.8	14±1.9	14.6±1.7	14.4±2.2	14.6±1.6
Surgery	15.8±2.6	15.9±2.6	15.2±2	16.7±3.2	15.7±1.7	17.5±1.8
Cobb change: to						
stop stage	16.8˚↓	1˚↓	0/6˚↓	0	2.4˚↓	8.3˚↓
to final F/U	-	1.8˚↑	1.4˚↑	3˚↑	2.2˚↑	2.6˚↓
Mean length of treatment (yr)	3.5 ± 1.2	3 ± 1.1	3.2 ± 1	2.7 ± 1.1	3.3 ± 1.4	3.3 ± 1.2
Initial mean angle	41.8˚	36.2˚	37.2˚	35.5˚	33.6˚	36.6˚
Follow up (mo	8.4 ± 19	16.1 ± 16.4	9 ± 9.6	22 ± 23	17 ± 19	21 ± 18
Curves(no of pts)						
Single :PT	1 (100%)	1	0	1	0	0
MT	10 (24%)	42 (19.5%)	23	17	0	2
TL	3 (9.6%)	31 (14.4%)	2	15	6	8
L	0	23 (10.7%)	3	3	8	9
Double major	39 (35%)	111(51%)	55	50	3	3
Triple major	6 (86%)	7 (3.2%)	6	1	0	0

Table 2. Correlation between initial curve magnitude (degrees) and the rates of failure and surgery for brace type 1,2, No(number)

Initial curve	No of curves	Failure		Surgery	
		No	%	No	%
24-29	79	28	35	13	16
30-39	116	55	47	34	29
40-50	101	44	43	41	40
Total	296	127	43	88	29.7

Table 3. Correlation between initial curve magnitude (degrees) and the rates of failure and surgery for brace type 3,4

Initial curve	No of curves	Failure		Surgery	
		No	%	No	%
24-29	16	8	50	3	18.8
30-39	18	2	11	1	5
40-50	12	4	33	3	25
Total	46	14	30	7	15

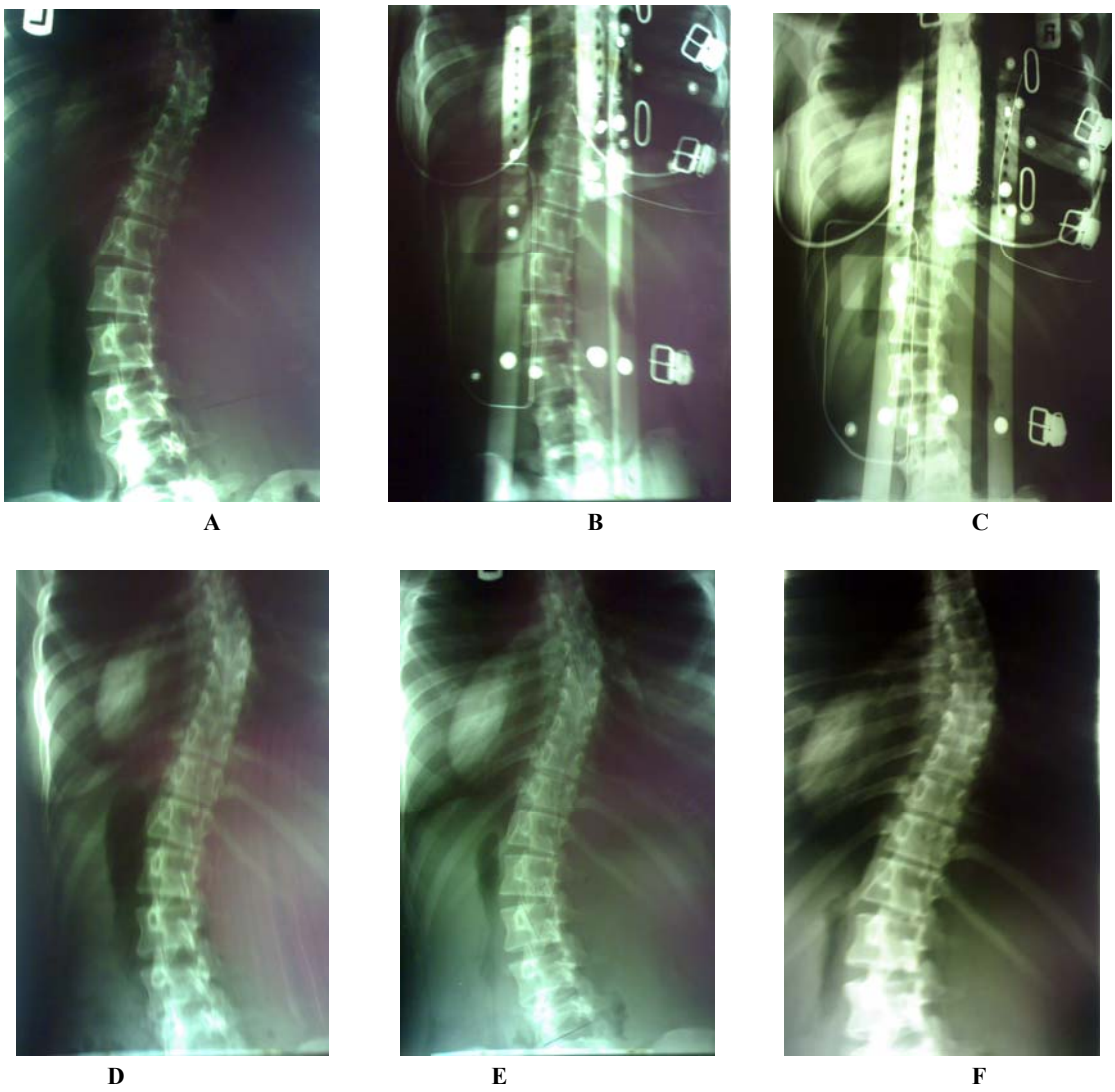

Figure 1. Radiographs of a 13 year-old female with 4 year full-time and 1 year part-time in brace.(A) Anteroposterior prebrace spinal radiograph with right main thoracic (T4-T10) of 40˚ and left lumbar(T11-L3) of 40˚. (B) Radiograph, one year after Milwaukee brace with metal wire around thoracic and lumbar pads, MT in brace was, 30˚ and L, 24˚. (C) Radiograph at 4 year in brace, MT was 34˚ and L, 30˚. (D) At stop stage, out of brace, MT, 40˚ and L, 44˚. (E) 1 year after stop of brace with MT, 40˚ and L, 45˚. (F) 2 year after stop of brace, MT decreased to 30˚ and L to 32˚.

In overall there was 342 major curves: PT; 19, MT; 162, T/L; 50, (L); 111, from these, initial curve value was 24-29° in 95 major curves (PT; 6, MT; 37, T/L; 15, L; 37), 30 to 39 degrees in 134 major curves (PT; 6, MT; 66, T/L; 16, L; 46) and 113 major curves with initial value of 40 to 50° (PT; 7, MT; 59, T/L; 19, L; 28) (Table 2,3).

Effect of brace type

A total of 158 major curves treated by brace type 1, 138 by type 2, 21 by type 3 and 25 by type 4.Table 1. At stage stop, a total of 35.5% failure detected in brace type 1, 24.2% in type 2, 28.6% in type 3 and 24% in brace type 4. Failure at final follow-up for brace type 1 to 4 were, 40.5%, 34%, 38% and 24%.Table 4, 5.

Mean correction at stage best in brace for type 1 to 4 of brace, was, 35%, 30%, 42% and 51%.Mean correction declined to 1.7%, 0%, 7.5% and 33% at stage stop. Mean loss of correction at final follow-up for brace type 1 to 3 was, 3.7%, 8.4% and 6.5% and mean correction for brace type 4, was, 7.1%.Table 6.

There was need to change and adjust the site of pads in brace for brace 1 to 4, in 18 cases (27 major curves), 12 cases (14 major curves), in 6 cases (8 major curves) and in 1 cases.

Table 4. Results of curve correction achieved by brace type 1,2

Curve type	Type 1						Type 2					
	Stop stage			Final Follow-up			Stop stage			Final follow-up		
	Improve	Same	Fail	Improve	Same	Fail	Improve	Same	Fail	Improve	Same	Fail
PT	1	2	8	0	3	8	3	5	0	1	5	2
MT	16	36	34	12	33	39	19	33	15	13	28	26
TL	7	2	2	5	5	1	8	10	5	5	10	8
L	15	22	13	11	19	22	8	21	11	7	20	13
Total(%)	39(25)	62(39)	57(36)	28(18)	60(38)	70(44)	38(27.6)	69(50)	31(22)	26(19)	63(45)	49(35)

Table 5. Results of curve correction achieved by brace type 3,4

Curve type	Type 3						Type 4					
	Stop stage			Final Follow-up			Stop stage			Final follow-up		
	Improve	Same	Fail	Improve	Same	Fail	Improve	Same	Fail	Improve	Same	Fail
	0	1	3	0	1	3	3	0	2	0	3	2
MT	6	1	0	4	1	2	5	1	3	4	2	3
TL	5	2	3	4	3	3	9	1	1	4	6	1
L	11(52.4)	4(19)	6(28)	8(38)	5(24)	8(38)	17(68)	2(8)	6(24)	8(32)	11(44)	6(24)

Table 6. Magnitude of all curve types by degrees for four types of brace in five stages of brace treatment. No (number)

Curve type (no)	Initial	Best	Wean	Stop	Final
Brace 1 : PT(11)	34	29	27.5	41	42
MT(86)	40	24.5	24.2	38.7	41.4
TL(11)	35	20.3	22.3	27	29.4
L(50)	33.7	23.8	24.2	34.2	35.2
Total	37.2	24.2	24.3	36.6	38.6
Brace 2: PT(8)	34.6	26.2	24.7	33	36
MT(67)	36.6	26.8	27.7	37.1	40.7
TL(26)	35.6	23.5	24.9	35	37.5
L(37)	33.7	22.6	23	34	35.7
Total	35.5	25	25.7	35.6	38.5
Brace 3:MT(4)	28	19	24	34	34.6
TL(7)	34	16.3	19	22	30.8
L(10) Total	35.1	23	27	36.9	39.8
	33.6	19.5	23.7	31.2	35.8
Brace 4: MT(5)	30.4	20.6	16.5	30.4	37
TL(9)	37.7	20.3	19.7	33.3	38.3
L(11)	31	15.1	22	23.3	29
Total	36.6	18	20	28.3	34
All (Total)	36.2	23.8	24.5	35.2	38

Table 7. Number of patients according to Risser sign for four types of Braces and number of surgery in each Risser

Brace type \ Risser	1	2	3	4	5
1	6	10	53	20	0
2	6	12	32	36	1
3	1	1	12	3	0
4	0	4	7	10	1
Total	13	27	104	69	2
Surgery (%)	8(61%)	13(48%)	34(32%)	4(5.8%)	0

In brace type 1, there were 6 triples major curves that all were progressive and required surgery. In 41 double major (MT+L), mean correction in MT was 4° and mean increase in L was 1.7° till stop stage. For 6 double major(PT+MT), mean increase in both was 5-6°.Mean correction in single major T/L and L was 4-5°, but single MT increased 5.5°.

In brace type 2, for single major MT, mean increase was 5° till stop stage, T/L not changed and L corrected 12°, but in double major curves, MT increased 4-7°, T/L 4.8° and L 3°.In 6 cases with double major (PT+MT) mean correction for PT was 3.5° and for MT was 2.7° till stop stage.

In brace type 3, mean correction of single T/L was 2.3°, L increased 2.4°, in double major(MT+TL), MT not changed but TL 7° corrected and in double (MT+L),both increased ,MT, 9.5° and L, 17.5°.

In brace type 4,for single curves, L decreased 1.6° and TL 1.5°, but MT increased 15° till stop stage .in double (MT+TL) both increased, MT, 7°,TL, 17° and in double(MT+L), both 2-4° corrected.

Surgical patients

From a total of 59 patients underwent surgery, 33 were in brace type 1(28 during brace used and 5 at follow-up ,that in single MT, 8 of 23, in double MT+L, 15 of 41 underwent surgery.), 21 in brace type2,(17 during brace used and 4 at follow-up), 2 in brace type 3(both in double major with MT+L) and 3 in brace type 4(2 in single TL and 1 in double major MT+TL), which all during period of brace used. From cases who underwent surgery, only in 5, there was need to adjust pad during period brace used, so difference was not significant with those who need no surgery .There was 16 cases with initial curve of 50° that during follow-up, 12 were ≥50° or underwent surgery (8 for brace 1 and 4 for brace 2, that 10 were MT, 1 TL and 1 L).

In comparison of brace 1 and 2, correction of PT at stop stage (P=0.015) and at final follow-up (P=0.05) was better by brace 2.Correction of TL was better by brace 1(stop stage P=0.045 and final P=0.033) but for correction of MT and L curves, difference was not significant .According to sex, only correction of MT at stop and final follow-up was better in female (P=0.012), also correction of MT was better in these stages for age ≥13 years/ old (P=0.012), but not significant in other curves for sex and age .There was no significant correlation between joint laxity and increase of surgery (P=0.14).

The results at Risser 4, was better for MT (P=0.000), TL (P=0.045) and L (P=0.032), but not for PT curves. Frequency of Risser and surgery are in table 7.

There was correlation between correction in best stage in brace with correction at stop and final follow-up for MT (P =0.000), TL (P=0.001) and L (P=0.000) but not for PT (P=0.6).In overall there was no difference between two types of Milwaukee brace in correction of curves.

In comparison of brace type 3 and 4, correction for MT and TL at stop stage was better (MT, P=0.045, TL, P=0.04)) in type 3, but no difference at final follow-up for MT but Correction of TL was better (P=0.047), correction of L curve was better by brace 4(stop stage, P=0.03 and final follow-up, P=0.048)

In comparison with Milwaukee, Boston was better for L (P=0.008) and MT (P=0.002), but no significant difference for PT and TL curves.

Discussion

The Milwaukee brace was the first non-operative treatment of scoliosis that could successfully abort progression of the scoliosis (1,11,13,14). In some studies, Boston brace showed better correction in all sizes of curves and better tolerated by the patients (1-3,6,7,11).

This is the first reported study, to our knowledge that with insertion of metallic marker (wire) around pads, it

is easy to detect ideal site of corrective pads in relation to apical segment of scoliotic curve by radiographs. However in majority of cases, there was not need to adjust pad in brace because pads were in appropriate sites .This means that if technical orthopaedist was expert in design of braces, insertion of metal marker has no effect in radiographic evaluation and conclusively no significant effect in final correction of curves .The two important factors in these patients, were, management in a standardized manner on an established protocol and high rate of compliance in this population, especially in initial curves of 45-50˚ that did not accept surgery (7,14,15).

Results showed that in spite of more correction in best stage with brace type 1(Milwaukee with metal marker), failure was more with metal marked braces(Milwaukee and Boston) (8,15). However initial in-brace correction is a way to determine if marginal curves for bracing(40-50), will be successfully treated by brace or not (4).

In comparison of brace type 1 and 2, according to the curve types, although correction of PT curve was better by brace type 2 and correction of TL curve by brace type 1, but in overall there was no significant difference in correction based on curve types.

Weaker results in brace type 1, may be due to several factors, such as; lower initial age, more initial curve magnitude, majority of patients in low Risser sign(Risser 1-3), more frequent single MT curve and triple curves, which are more progressive. Also lower age at surgery time in this group than brace type 2, may be result of more progression in this group .In brace type 2, with large number of patients in Risser 4, risk of failure and surgery was less than brace type 1 (13-17).

In Milwaukee brace groups, percent of failure based on initial curve value of, 24-29; 30-39; and 40-50 were, 35%, 47% and 43%, but percent of surgery increased with increase in initial curve value (13,15,16).

Weaker results in type 3 brace(Boston with metal marker) may be due to progressive nature of curves in this group since majority were in Risser of 1-3, but the initial age and curve value was the same as brace type 4, but, in group with brace type 4, which 11 were in Risser of 4-5, progression was less (11).

In Boston brace groups, percent of failure based on initial curve value of, 24-29; 30-39 and 40-50; were 50%, 11% and 33% but percent of surgery was least (5%) for 30-39˚ and high (25%) for 40-50 , that shows, risk of surgery was less than Milwaukee group and there is need to brace treatment in initial curves of below 30˚ due to high risk of progression (8,11).

Better correction of TL curves by metal marked braces, may not be related to good control of pad sites, but better correction of MT and L curves by Boston than Milwaukee, may be related to good compliance for Boston brace.

In all ranges of initial curve magnitude, the Milwaukee brace was responsible for a large number of failures (2,4). Young children had a worse outcome of brace treatment (2-4), and primary correction in best stage in brace correlated with the final improvement (3,4).

Failure of initial curves of 45-50˚ was high, since majority of these were those who rejected surgery for social and economic factors and asked physician to treat with bracing, so high percentage of surgery in this study, is related to these unresponsive curves. We found the worst final results in double major curves, which may be due to insufficient flexibility of these curves in brace (3). 40% of cases in our series with initial curves of 40-50 required surgery (4,6) and curve type seemed to have little predictive value in failure although triple curves were less well and single TL and L curves were better than double major curves (4). Few curves with apex above T6 (PT) were treated, but majority showed failure at follow-up (6).

In this study, correction of MT curve was better in female than male, but for other type of curves, difference between sex was not significant (14). In males, a total of 46% of curves progressed at least 6 and a total of 31% of curves progressed to ≥50˚ or spinal fusion surgery (10,15-18).

A coordinated exercise program may be a significant factor against the stiffness and weakness induced by brace wear, but in this study in spite of prescription of exercise by treating physician, patients had no exercise program (4).

Some aspects of our study are; not all patients were followed to skeletal maturity ,some had no follow-up after discontinuing of brace, there was no documented way to carefully determine compliance of cases, we were unable to study the role of thoracic kyphosis and lumbar lordosis in brace treatment, (because data were not recorded for all patients) and as in other studies, possible progression of curves can be seen after several years (3,4), follow-up is short and there may be greater loss of correction with the passage of time. In conclusion, we found that the most important single predictor of brace failure was initial curve magnitude and second factor of importance was the brace type, but using metal marker around pads, had no effect in increasing efficacy of braces. It seems that bracing did

not alter the natural history of scoliosis in early Risser stages with large magnitude of initial curves .Insertion of metal marker around pads is simple and cheap way that facilitate control of pad sites well and we recommend to use.

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