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Review

Can Posterior Dynamic Stabilization Reduce the Risk of Adjacent Segment Deterioration?

Posterior Dinamik Stabilizasyon Komşu Segment Bozulmasını Önleyebilir mi?

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ABSTRACT

AIM: The aim of this study was to systematically review the relevant literature to develop a benchmark for the incidence of adjacent segment degeneration (ASDeg) and adjacent segment disease (ASDis) following the posterior dynamic stabilization (PDS) procedure and to investigate whether conclusions can be made with regard to the isolated PDS procedure in reducing the risk of ASDeg and ASDis compared with fusion, and with regard to the role of additional PDS devices implanted adjacent to fusion in protecting from ASDeg and ASDis caused by the neighboring fusion.

MATERIAL and METHODS: We retrieved electronic databases of Medline, Ovid and Cochrane Central Registry of Controlled Trials, combined with a supplemental hand search. Thirty-one articles met our inclusion criteria.

RESULTS: The pooled incidence of ASDeg and ASDis following PDS procedure was 16.4% and 5.5% respectively. Data from comparative studies showed a significantly lower incidence of ASDeg and nonsignificantly lower incidence of ASDis following PDS than following fusion surgery. Further, the additional PDS devices implanted adjacent to fusion could significantly reduce the risk of ASDeg and nonsignificantly decrease that of ASDis caused by fusion.

CONCLUSION: These results suggested relative success of the PDS procedure in protecting against ASDeg and ASDis.

KEYWORDS: Adjacent segment deterioration, Posterior dynamic stabilization, Lumbar fusion, Lumbar spine, Nonfusion instrumentation, Degenerative disc disease, Lumbar instability

ÖZ

AMAÇ: Bu çalışmanın amacı posterior dinamik stabilizasyon (PDS) işlemi sonrasında komşu segment dejenerasyonu (ASDeg) ve komşu segment hastalığı (ASDis) insidansı için bir referans işareti geliştirmek amacıyla ilgili literatürü sistematik olarak gözden geçirmek ve füzyonla karşılaştırıldığında ASDeg ve ASDis riskini azaltmak için izole PSD işlemi bakımından ve komşu füzyon nedeniyle ASDeg ve ASDis durumlarından korumada füzyona komşu implante edilen ek PDS cihazlarının rolü açısından bir sonuca varılıp varılamayacağını araştırmaktı.

YÖNTEM ve GEREÇLER: Medline, Ovid ve Cochrane Central Registry of Controlled Trials elektronik veri tabanlarını ve ayrıca ek olarak manuel bir aramayı kullandık. Otuz bir makale çalışmaya alma kriterlerimizi karşıladı.

BULGULAR: PDS işleminden sonra ASDeg ve ASDis'in birleştirilmiş insidansı sırasıyla %16,4 ve %5,5 bulundu. Karşılaştırmalı çalışmalardan veriler PDS'den sonra füzyon cerrahisine göre önemli ölçüde daha düşük ASDeg insidansı ve önemli olmayan ölçüde daha düşük ASDis insidansı gösterdi. Ayrıca füzyona komşu implante edilen ek PDS cihazları füzyonun neden olduğu ASDeg riskini önemli ölçüde ve ASDis riskini önemli olmayan ölçüde azaltabiliyordu.

SONUÇ: Bu sonuçlar PDS işleminin ASDeg ve ASDis durumlarına karşı koruma açısından relatif başarısına işaret etti.

ANAHTAR SÖZCÜKLER: Komşu segment bozulması, Posterior dinamik stabilizasyon, Lumber füzyon, Lumber omurga, Nonfüzyon enstrümentasyon, Dejeneratif disk hastalığı, Lumber instabilite

INTRODUCTION

The motion-sparing technique has been explored and developed alternative to lumbar spinal fusion to address the possible transitional problems following fusion surgery related to the increased mechanical stress on adjacent levels (29,40). Posterior dynamic stabilization (PDS) technique is such an alternative, which focuses on the concept of reducing the stiffness of the instrumentation to permit more physiological load transmission (44). It seeks to provide stabilization and eliminate pain while maintaining or restoring the mobility of the spinal motion segment, in an effort to prevent pathologic motion at both the stabilized and transitional levels (44). The concept of PDS, compared with fusion, is attractive particularly because it pays greater concern about the global

function of the spine and the negative effects of fusion on the adjacent levels (31). By replacing the whole fusion construct, or by "topping off" the rigidly instrumented fusion segment, the PDS devices avoid an abrupt transfer of stress from a rigid construct to the neighboring segments and potentially diminish the risk of adjacent segment deterioration (ASD).

Despite large numbers of publications, however, the advantage of PDS systems in decreasing the risk of ASD remains largely theoretical. No good quality randomized controlled trials have been performed to evaluate this potential superiority of the PDS systems. With the lack of high-level evidence, we attempted to perform a quantitative meta-analysis to develop benchmarks for the incidence of ASD following isolated PDS procedure. Further aims were to investigate whether conclusions can be made regarding the isolated PDS procedure in reducing the risk of ASD compared with fusion surgery, and regarding the role of additional PDS devices implanted adjacent to fusion in protecting from ASD related to the neighboring rigid construct.

METHODS

Search Strategy and Inclusion/Exclusion Criteria

An electronic retrieval of Medline, Ovid (BIOSIS Previews included) and Cochrane Central Registry of Controlled Trials was performed up to August 2011. A manual search of *Spine, European Spine Journal,* and the American and British versions of *Journal of Bone and Joint Surgery*, as well as the reference lists of the selected studies was conducted to identify further articles. Though Embase was not accessible, we assumed that there would be few additional references when a comprehensive search in the abovementioned databases combined with a hand search was conducted (35).

We used "(dynamic stabilization OR soft stabilization OR flexible stabilization OR nonrigid stabilization OR nonfusion stabilization OR interspinous devices OR posterior transpedicular stabilization OR pedicle screw based systems) AND (lumbar spine)" as our main search strategy. Retrievals using individual instrumentation were also performed to add further possible references (Appendix 1).

Studies were selected according to the following criteria: 1) the participants for surgical treatment were suffering from low back pain with or without radicular pain and a degenerative lumbar disease was diagnosed; 2) the PDS device was used for the surgical intervention, either alone or adjunctive to fusion; 3) at least one desirable outcome regarding ASD was reported. ASD was defined by each identified study rather than predefined by the authors, and it was classified into two categories: adjacent segment degeneration (ASDeg) and adjacent segment disease (ASDis), as suggested by Harrop et al. (8); 4) a minimum sample size of ten and follow-up of six months were demanded. Studies with patients who had spinal infection, acute facture, tumor, deformity, osteoporosis or rheumatoid arthritis were not included. Review articles, case reports, biomechanical and cadaveric studies and non-English literature were also excluded.

Two authors (Z.Z., Z.X.) selected the studies independently. Items that were not fit for inclusion on the basis of titles and abstracts were excluded at the first-round. The remaining trials were retrieved in full text version for final decision. A study was included for analysis when both authors considered that it met the inclusion criteria. Disagreement between investigators was discussed, and a consensus was attempted.

Data Extraction

Two authors (Z.Z., Z.X.) independently extracted data from the included studies, and again a consensus was attempted. The data extracted to describe the characteristics of the investigations were study design, characteristics of the participants, interventions, number of participants allocated to each intervention group, follow-up time and rate, and outcomes. Evaluation of evidence class was performed with the checklist used by Carney (4), which treats good quality RCTs as class I evidence, good quality cohort studies and case control studies as class II evidence, and case series as class III evidence.

Data Analysis

Studies applying the isolated PDS technique were used to analyze the incidence of ASD following the PDS procedure. Studies comparing the incidence of ASD between the PDS and fusion techniques were used to identify whether the former can produce less ASD than the latter. And studies that compared the incidence of ASD between isolated fusion and fusion plus adjacent PDS were used to investigate whether the additional PDS could reduce the risk of ASD related to the neighboring spinal arthrodesis.

Analysis was performed on the extracted data with RevMan 5.0 software (Cochrane IMS) and Meta-disc software (48). Because there were differences among the individual studies, such as study design, specific surgical techniques, and definition of ASD, we used a random-effects model rather than a fixed-effect model. Although the random-effects model could not explain or eliminate heterogeneity, it was considered more suitable for the statistical combination of low back pain trials than the fixed-effect model (7). In a random-effects model, event rate or odds ratio, 95% confidence interval, and probability value were calculated for dichotomous variables. $P < 0.05$ was considered statistically significant. Test for statistical heterogeneity was using the Q- and I^2-statistics (9,10,25). The Q-statistic tested the null hypothesis that all studies shared a common effect size with minimal dispersion of the effect size across studies. For I^2-statistics, an I^2 value lower than 25% was considered homogeneous, an I^2 value between 25% and 50% as low heterogeneity, an I^2 value between 50% and 75% as moderate heterogeneity, and an I^2 value above 75% as high heterogeneity (10).

RESULTS

Search Results & Description of Included Studies

A total of 663 possible articles were identified. After a two-round selection, 31 articles were considered to meet

inclusion criteria (2,3,6,11-17,19-23,26-30,33,34,36,37,41-43,45-47) (Figure 1). For the possible duplicate studies (31&40,14&23,13&15), only the data from the trial with the longest follow-up were used for estimating the incidence of ASD. The follow-up time varied form 6 months to more than 10 years, and the mean age ranged from 39 to 71.4 years. Totally nine types of PDS devices were involved, with the Dynesys system reported most frequently (by 11 articles).

Twenty-three articles referred to the isolated PDS procedure and eight referred to the PDS as adjuncts to fusion. Among the 23 articles with the PDS procedure only, twelve reported the incidence of ASDeg (Table I), and thirteen reported that of ASDis (Table II), with two articles investigating both rates. Four investigations compared the incidence of ASDeg/ASDis between the PDS and fusion procedures (13,16,17,29).

Among the eight articles that used PDS devices as adjuncts to fusion, PDS were implanted adjacent to fusion in four articles (12,22,27,33), as a component part of hybrid fusion in three (20,21,28), and both in one (41) (Table III). Three trials compared the incidence of ASDeg/ASDis between the sole fusion and fusion plus adjacent PDS (12,22,33).

After full consideration, all articles were classified as class III evidence according to the articles with the lowest evidence class.

Meta-Analysis Results

The pooled incidence of ASDeg was 16.4% (95% CI: 12.3%–21.2%, range: 0–47.4%, Figure 2), regardless of any other potential confounding factors. The pooled rate of ASDis was 5.5% (95% CI: 4.0%–7.4%), ranging from 0% to 9.6% (Figure 3).

When the incidence of ASDeg was compared between PDS and fusion procedures, there was a statistical difference with the PDS showing a lower rate (OR =0.29, 95% CI: 0.12–0.72; P =0.008; Figure 4). A tendency towards lower incidence of ASDis following PDS was also shown but this difference was not statistically significant (OR =0.52, 95% CI: 0.21–1.31, P =0.17; Figure 5).

The incidence of ASDeg was significantly lower when the additional adjacent PDS devices were implanted neighboring to fusion (OR =0.28, 95% CI: 0.10–0.74, P =0.01; Figure 6). And for ASDis, an insignificant trend of lower rate was shown (OR =0.19, 95% CI: 0.02–1.73, P =0.14; Figure 7).

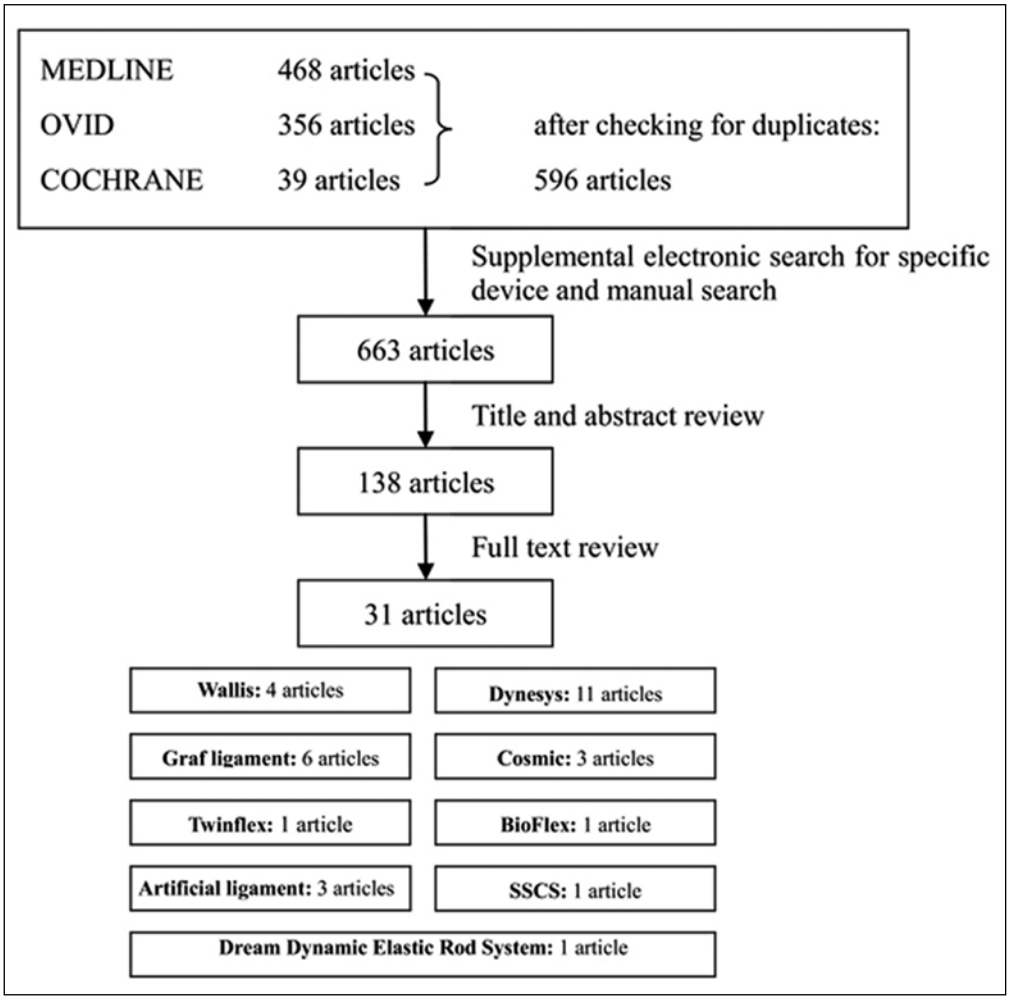

Figure 1: Flow diagram of literature search.

Other Results

Three articles reported hybrid fusion with PDS at the fused levels, of which two compared the incidence of ASDeg between hybrid fusion and non-hybrid fusion (Table III). Kim et al. (20) reported an ASDis rate of 1.8% using BioFlex system after an averaged follow-up of 10.6 months. Korovessis et al. (21) compared the short-term effect of rigid versus dynamic instrumentation, and found no case of ASDeg in either group. Similarly, Mochida et al. (28) revealed an insignificant lower rate of ASDeg following instrumented posterolateral fusion with LeedsKeio artificial ligament than with the rigid Steffee system.

One article (41) reported an incidence of ASDis of 6.5% following hybrid fusion with supplemental PDS at the adjacent segments 3.3 years after surgery (Table III).

DISCUSSION

The incidence of ASDeg and ASDis following spinal fusion reaches 34% and 14% respectively (8). In many cases, ASD destroys functional outcomes and may require further surgical interventions (24). PDS, as one of the nonfusion techniques, was introduced to address this issue. Yet the potential role of PDS in prevention of ASD has not been systematically evaluated. We performed this quantitative analysis, and revealed an incidence of 16.4% for ASDeg following the PDS

Table I: Characteristics of Articles Reporting Incidence Data of ASDeg Following PDS/fusion Procedure

Study ID	Study design	N	Male (%)	Mean age (yrs)	No. of fixed/ fused levels	% one-level fixation/ fusion	Mean FU time (yrs)	ASDeg (%)	Type of PDS / fusion
Kim 2011	Retrospective case series	21	28.6	61.3	1.9	33.3	2.4	19.0	Dynesys
Sandu 2011	Retrospective case series	15	26.7	67	1.5	60.0	≥ 1.0	0	Wallis
Morishita 2011	Cohort study: prospective? retrospective?	Group 1: 41	58.5	59.6	1.0	100	3.0	12.2	SSCS
		Group 2: 36	47.2	63.0	1.0	100	3.0	30.6	iTLIF
Cansever 2011	Retrospective case series	25	64.0	43.5	2.0	24.0	1.0	0	Dream Dynamic Elastic Rod System
Choi 2009	Retrospective case series	43	41.9	51.1	1.6	46.5	10.3	41.9	Graf ligament
Vaga 2009	Prospective case series	10	40.0	43.5	1.8	30.0	0.5	10.0	Dynesys
Kumar 2008	Prospective case series	20	–	–	2.1	–	2.0	20.0	Dynesys
Schaeren 2008	Prospective case series	19	26.3	70.8	1.0	100	4.3	47.4	Dynesys
Schnake 2006	Prospective case series	24	29.2	71.4	1.0	100	2.2	33.3	Dynesys
Putzier 2005	Prospective case series	35	62.9	39	1.1	94.3	2.8	0	Dynesys
Sénégas 2002	Prospective case series	40	72.5	42	1.0	100	3.3	7.5	Wallis
Kanayama 2001	Retrospective cohort study	Group 1: 18	44.4	55	1.0	100	5.9	16.7	Graf ligament
		Group 2: 27	51.9	58	1.0	100	6.3	44.4	iPLF

***FU**, follow-up; yrs, years; **SSCS,** segmental spinal correction system; **iPLF,** posterolateral fusion with rigid instrumentation; **iTLIF,** transforaminal lumbar interbody fusion with rigid instrumentation; **Group 1,** intervention group treated by PDS devices; **Group 2,** intervention group treated by fusion surgery.*

Table II: Characteristics of Articles Reporting Incidence Data of ASDis Following PDS/fusion Procedure

Study ID	Study design	N	Male (%)	Mean age (yrs)	No. of fixed/ fused levels	% one-level fixation/ fusion	Mean FU time (yrs)	ASDis (%)	Type of PDS/ fusion
Maleci 2011	Case series: prospective? retrospective?	139	44.6	54.5	1.5	–	≥ 2.0	2.2	Cosmic
Stoffel 2010	Prospective case series	100	36.9	65	1.6	45.6	1.3	6.0	Cosmic
Kaner 2010	Prospective cohort study	Group 1: 26	23.1	63.7	1.0	100	3.2	0	Cosmic
		Group 2: 20	35.0	58.1	1.0	100	3.7	5.0	iCF
Hong 2010	Case series: prospective? retrospective?	23	34.8	57.3	1.0	100	5.4	4.3	ILP
Choi 2009	Retrospective case series	43	41.9	51.1	1.6	46.5	10.3	2.3	Graf ligament
Kanayama 2009	Retrospective cohort study	Group 1: 65	33.8	63	1.0	100	3.4	9.2	Graf ligament
		Group 2: 78	48.7	60	1.0	100	3.1	14.1	iPLIF
		Group 3: 75	41.3	64	1.0	100	3.8	13.3	iPLF
Bothmann 2008	Prospective case series	40	51.9	56	1.4	59.3	1.3	5.0	Dynesys
Sénégas 2007	Retrospective case series	142	73.9	46.9	1.6	63.7	14	8.5	Wallis
Kanayama 2007	Retrospective case series	43	41.9	58	1.2	83.7	≥ 10	7.0	Graf ligament
Kanayama 2005	Retrospective case series	64	29.7	66	1.2	82.8	5.6	6.3	Graf ligament
Stoll 2002	Prospective case series	73	41.0	58.2	1.5	66.3	3.2	9.6	Dynesys
Kanayama 2001	Retrospective cohort study	Group 1: 18	44.4	55	1.0	100	5.9	5.6	Graf ligament
		Group 2: 27	51.9	58	1.0	100	6.3	18.5	iPLF
Moon 1999	Case series: prospective? retrospective?	51	–	–	1.2	78.4	5.3	0	Graf ligament

FU, *follow-up; yrs, years;* ***ILP,*** *interspinous ligamentoplasty;* ***iCF,*** *circumferential fusion with rigid instrumentation;* ***iPLF,*** *posterolateral fusion with rigid instrumentation;* ***iPLIF,*** *posterior lumbar interbody fusion with rigid instrumentation;* ***Group 1,*** *intervention group treated by PDS devices;* ***Group 2/3,*** *intervention group treated by fusion surgery;*

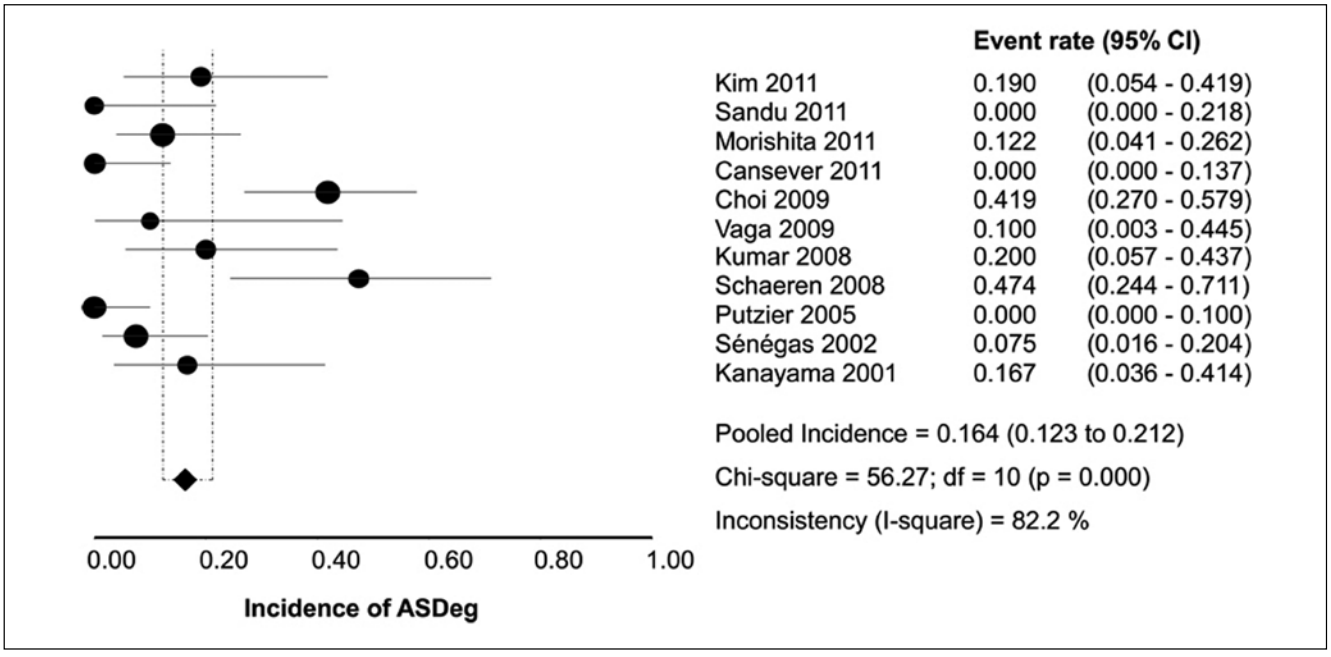

Figure 2: Pooled incidence of ASDeg.

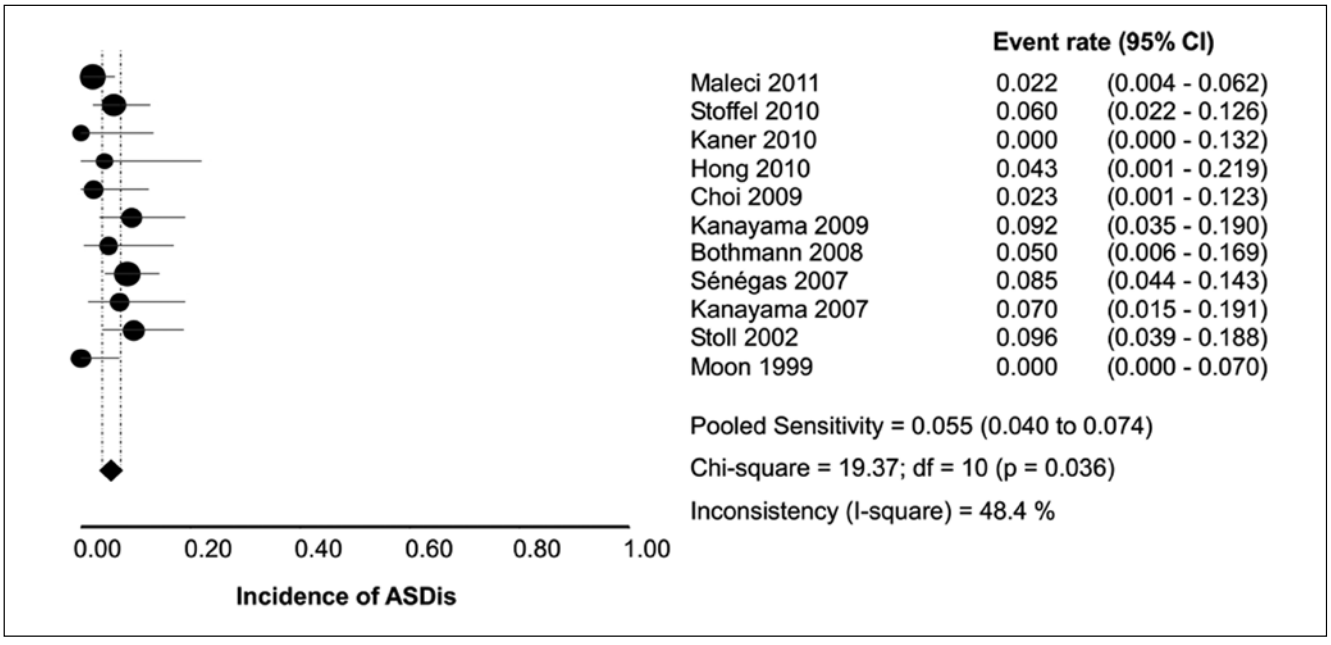

Figure 3: Pooled incidence of ASDis.

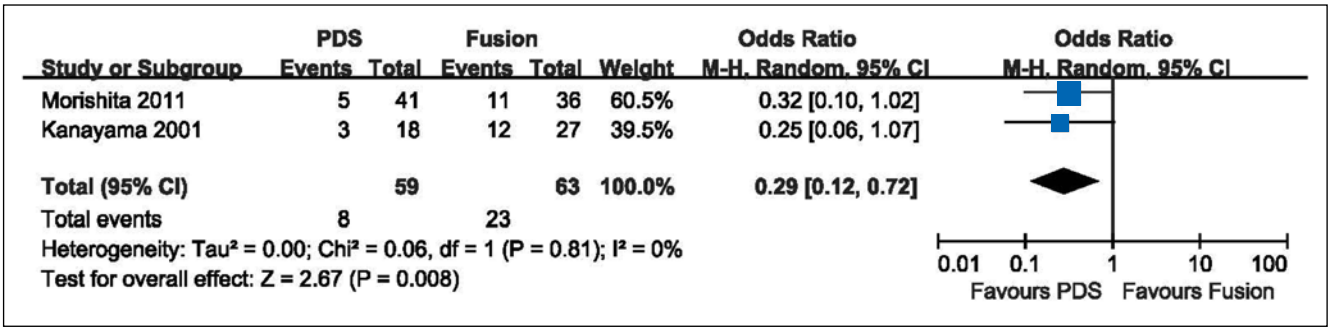

Figure 4: Forest plot for the comparison of the incidence of ASDeg between PDS and fusion procedures.

procedure, in contrast to a generally lower rate of 5.5% for ASDis. The incidence of ASDeg was significantly lower with PDS procedure than with spinal arthrodesis. A tendency toward lower incidence of ASDis following PDS was also shown though insignificant. Additionally, the PDS devices implanted adjacent to fusion could reduce the incidence of ASDeg significantly and that of ASDis insignificantly compared with isolated fusion surgery.

The pooled incidence of ASD should be treated with caution, because there may be incorporated heterogeneity due to different study designs, varied participant characteristics and preoperative conditions of adjacent segments, variations in specific types of PDS devices and degrees of decompression and number of fixed levels, inconsistent criteria used to measure ASD, or differing lengths of follow-up time. The wide range of ASDeg incidence (0–47.4%) was the reflection of the summary of the abovementioned factors besides the effect of PDS itself. And the value of I^2 for ASD in particular for ASDeg indicated high heterogeneity (I^2 =82.2%). Therefore, we only used the pooled rates to establish the benchmarks for the incidence of ASD following isolated PDS procedure.

Although there may be several risk factors associated with ASD following PDS procedure, it is difficult to perform a meta-regression analysis or subgroup analysis to identify them because of the relatively small number of included articles compared with so many potential risk factors. Despite all this, we made our efforts to find the clues of them. Age is known to affect ASD (32), and the association might be similarly applied to dynamic stabilization. The two articles with the largest mean age of patients showed a much higher incidence of ASDeg than the pooled rate (37,40). In contrast, none of the four studies with the smallest mean age exceeded a morbidity

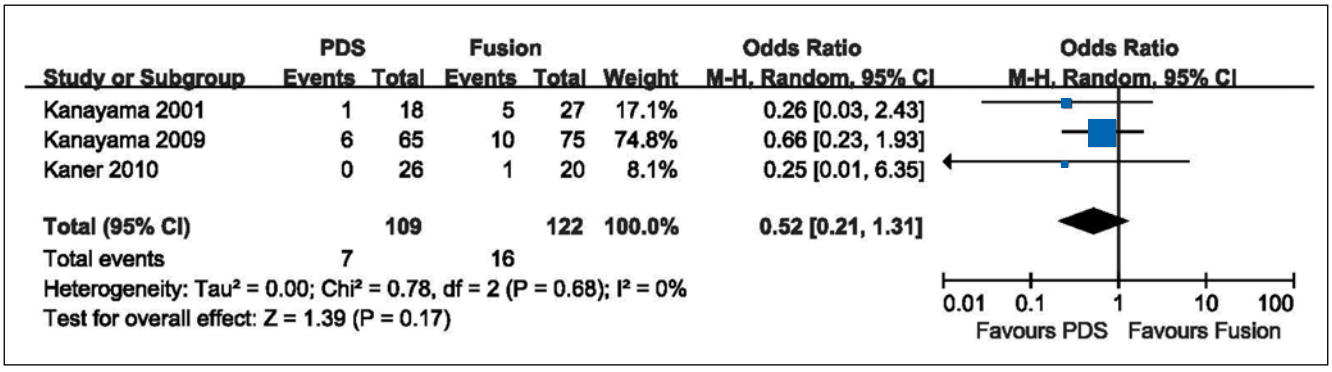

Figure 5: Forest plot for the comparison of the incidence of ASDis between PDS and fusion procedures.

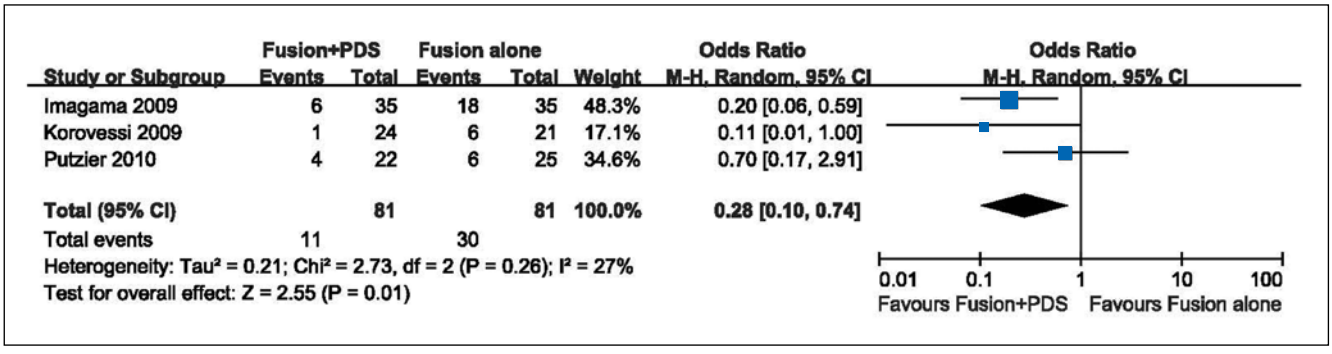

Figure 6: Forest plot for the comparison of the incidence of ASDeg between isolated fusion and fusion plus adjacent PDS devices.

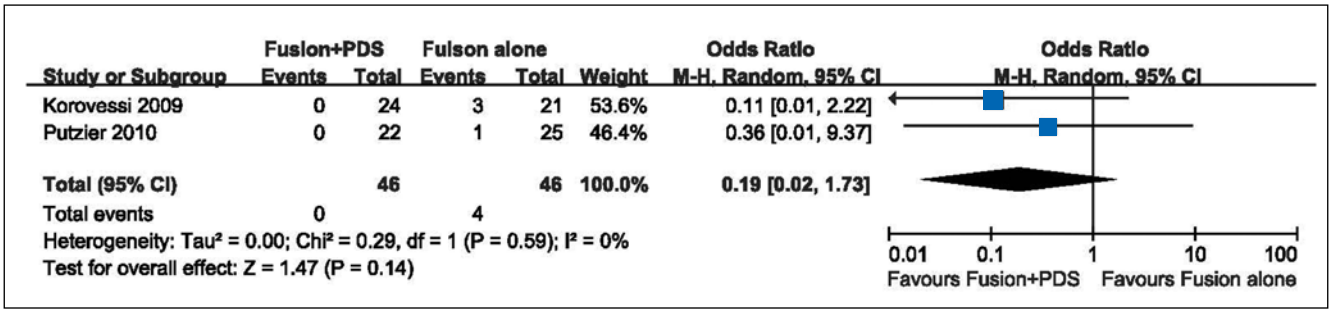

Figure 7: Forest plot for the comparison of the incidence of ASDis between isolated fusion and fusion plus adjacent PDS devices.

of 10.0% (3,34,42,47). The length of follow-up time appeared to affect ASDeg. The incidence of ASDeg was extremely high (41.9%) with the longest follow-up period of 10.3 years (6). On the contrary, when the follow-up was no longer than one year, the rates of ASDeg were all below the pooled incidence (3,47). More direct evidence was that a same study reported by two articles presented a trend towards higher rate of ASDeg with longer follow-up time (37,40). The impact of the number of fixed levels was contradictory, with Kim et al. (19) supporting a higher rate of ASDeg with multilevel than with single level stabilization but Choi et al. (6) demonstrating no such difference. Sex ratio appeared not to impact the incidence of ASDeg. With regard to the rate of ASDis, there seemed no evident effects from these potential risk factors. The narrow width of 95% CI (4.0%–7.4%) and the low heterogeneity (I^2=48.4%) indicate the small effect size of other confounding factors apart from PDS itself on the incidence of ASDis.

Considering the effects of potential risk factors, we did not choose to compare the ASD rates between PDS and fusion

Table III: Characteristics of Articles Reporting Incidence Data for Asdeg/Asdis with PDS Devices Used as Adjuncts to Fusion

Study ID	Study design	N	Male (%)	Mean age (yrs)	No. of fused levels	No. of PDS fixed levels	Mean FU time (yrs)	ASDeg/ ASDis (%)	Type of fusion & PDS
Adjacent to fusion									
Maserati 2010	Retrospective case series	24	50.0	49	1.0	1.0	0.7	12.5 (is)	iCF & Dynesys
Putzier 2010	Prospective randomized non-blind study	Group1: 22	56.7	44.9	1.0	1.0	6.4	18.2 (eg)/ 0 (is)	iCF & Dynesys
		Group 2: 25	46.7	44.6	1.0	0	6.4	24.0 (eg)/ 4.0 (is)	iCF
Korovessis 2009	Randomized controlled trial	Group 1: 24	–	65	2.5	1.0	5.0	4.1% (eg) 0 (is)	iPLF & Wallis
		Group 2: 21	–	64	2.5	0	5.0	28.6% (eg) 14.3 (is)	iPLF
Imagama 2009	Retrospective cohort study	Group1: 35	40.0	67.2	1.0	1.0	3.5	17.1 (eg)	iPLIF & Artificial ligament
		Group 2: 35	34.3	64.0	1.0	0	3.9	51.4 (eg)	iPLIF
Hybrid fusion									
Kim 2007	Retrospective case series	57	21.1	55.7	1.4	1.4	0.9	1.8 (is)	iPLIF & BioFlex
Korovessis 2004	Prospective randomized trial	Group1: 15	–	62	2.5	2.5	3.9	0 (eg)	iPLF & Twinflex
		Group 2: 15	–	65	2.8	2.8	3.9	0 (eg)	iPLF
Mochida 1999	Cohort study: prospective? retrospective?	Group1: 33	24.2	59.4	1.0	1.0	3.6	0 (eg)	iPLF & Leeds-Keio artificial ligament
		Group 2: 34	23.5	58.7	1.0	1.0	3.6	8.8 (eg)	iPLF
Hybrid fusion + Adjacent to fusion									
Schwarzenbach 2010	Retrospective case series	31	48.4	53.6	1.1	2.6	3.3	6.5 (is)	iPLIF & Dynesys

FU, *follow-up; yrs, years;* ***iCF,*** *circumferential fusion with rigid instrumentation;* ***iPLF,*** *posterolateral fusion with rigid instrumentation;* ***iPLIF,*** *posterior lumbar interbody fusion with rigid instrumentation;* ***Group 1,*** *intervention group treated by fusion with adjunctive PDS devices;* ***Group 2,*** *intervention group treated by fusion without adjunctive PDS devices.*

procedures and between the isolated fusion and fusion plus adjacent PDS devices by analyzing the data from two sets of case series. Rather, we performed the analyses by using data from comparative studies. Almost all of these studies attempted to balance the possibly important prognostic indicators between the intervention groups, including age, follow-up time, sex ratio and stabilization length, making surgery type the major factor to explain the difference in ASD rates. And the low value of I^2 indicated statistically homogenous among the individual studies.

Results from comparative studies demonstrated the advantage of PDS procedure in reducing the incidence of ASDeg over fusion surgery (OR =0.29, 95% CI: 0.12–0.72, P =0.008). Nevertheless, the theoretical foundation from biomechanical studies to support this disparity is weak. Schmoelz at al (38,39) found that both dynamic and rigid instrumentation had a minimal impact on the motion and intradiscal pressure in the adjacent segments. Castellvi et al. (5) revealed a reduction of only 5.5% of the adjacent segment peak stress by dynamic stabilization compared with rigid instrumentation. However, Barrey et al. (1) argued that this negligible reduction of disc stress at adjacent level might reach clinical significance due to the cumulative effect after repeated loading cycles.

The difference in the rate of ASDis was however not statistically significant between the PDS and fusion surgery (OR =0.52, 95% CI: 0.21–1.31, P =0.17). One possible explanation for the significant difference in ASDeg rate but not in ASDis rate is that not all degenerative cases necessarily convert into symptomatic conditions.

Recently there has been increasing enthusiasm in the application of PDS devices implanted adjacent to fusion for the prevention of ASD. Superiority in a certain degree was demonstrated in the current study following this application than fusion alone. Generally, this adjunctive implant is intended for gross instability or multilevel degeneration where one or more segments are not severe enough to warrant fusion (27). With the aid of additional PDS devices, the level adjacent to fusion can be protected from hyper-mobility by load sharing and restricting its range of motion (1). Furthermore, compared with multilevel fusion, this technique can potentially avoid overstress of the segment superior to dynamic stabilization (33). However, something should be noted. First, the hyper-mobility caused by adjacent fusion can be over-compensated by the supplemental PDS devices. Second, multilevel fixation regardless of rigid or dynamic stabilization would increase the mobility of the level above it and may accelerate ASD at the level neighboring to instrumentation. Putzier et al. (33) found that the adjunctive Dynesys implant lowered the incidence of ASDeg at the level immediately adjacent to fusion to 9.1% compared with 24.0% in the isolated fusion group, meanwhile it resulted in 9.1% more degeneration in the more distant levels. Moreover, the reoperations related to implant failure might increase. Therefore, the benefits of additional PDS devices in reducing the risk of ASD at the immediately neighboring segment and its related harms should be weighed.

Although some trials adopted hybrid fusion (20,21,28) or hybrid fusion plus adjacent PDS devices (41), we did not suppose such application of PDS at the fused segment was mainly for protecting from ASD. Rather, it is considered to promote better fusion and avoid implant failure for its better load sharing with the fusion mass (18). As expected, the two comparative studies (21,28) that compared the incidence of ASDeg between the hybrid fusion and fusion with rigid fixation did not identify superiority of the former procedure (0% versus 0%; 0% versus 8.8%, P =0.239; respectively).

CONCLUSIONS

These results demonstrated relative success of the PDS systems in protecting against ASD. Studies of high quality are required to strengthen the quality of evidence and contribute information to complement these findings.

Appendix 1:

Individual instrumentations used for retrievals were "Graf ligament", "Dynesys", "FASS", "DSS", "Accuflex", "Bioflex", "Twinflex", "FlexPLUS", "Stabilimax NZ", "Isobar", "Cosmic", "TOPS", "TFAS", "ARFS", "artificial ligament", "Leeds-Keio ligament", "X-STOP", "DIAM", "Wallis", "Coflex", "elastic ligament", "LOOP", "Minns", "Flexus" and "Superion Spacer".

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