

COMPARATIVE RESULTS BETWEEN OPEN AND MINIMALLY INVASIVE FUSION IN LUMBAR DEGENERATIVE DISEASE

RESULTADOS COMPARATIVOS ENTRE A FUSÃO ABERTA E MINIMAMENTE INVASIVA NA DOENÇA DEGENERATIVA LOMBAR

RESULTADOS COMPARATIVOS ENTRE FUSIÓN ABIERTA Y MÍNIMAMENTE INVASIVA EN ENFERMEDAD DEGENERATIVA LUMBAR

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ABSTRACT

Objective: Lumbar spine fusion is indicated in patients who are refractory to traditional treatment for degenerative disc disease. The aim of this study was to compare the perioperative and postoperative results of conventional open surgery versus minimally invasive surgery (MIS) in posterior 360° lumbar fusion with pedicle screw instrumentation. **Methods:** A total of 25 patients underwent MIS and 40 underwent open surgery between 2015 and 2017. Perioperative variables and lumbar and radicular pain values were compared using a visual analogue scale (VAS) and the Oswestry disability index (ODI) until 12 months after surgery. **Results:** The MIS cohort presented less blood loss (140 vs 345 ml; $p=0.001$), shorter hospital stay (1.1 vs 2.2 days; $p=0.001$), longer operative time (113 vs 94 minutes; $p=0.001$) and greater X-ray exposure (80 vs 6 seconds; $p=0.001$), compared to the open surgery group. The MIS cohort showed better results in the ODI and lumbar VAS scores. No significant differences were observed in radicular VAS. **Conclusion:** MIS surgery showed advantages over the open surgery technique; however, the learning curve should be improved in order to reduce operative time. **Level of Evidence III; Retrospective descriptive observational study.**

Keywords: Intervertebral Disc Degeneration; Discectomy, Percutaneous; Spinal Fusion.

RESUMO

Objetivo: A fusão espinhal lombar é indicada para pacientes refratários ao tratamento tradicional da doença degenerativa do disco. O objetivo do presente estudo consistia em comparar os resultados peri- e pós-operatórios da cirurgia aberta convencional versus a cirurgia minimamente invasiva (MIS) na fusão lombar de 360° por via posterior com instrumentação de parafuso pedicular. **Métodos:** Foram estudados 25 pacientes submetidos à técnica de MIS e 40 submetidos à cirurgia aberta entre 2015 e 2017. As variáveis perioperatórias e os valores da dor lombar e dor radicular foram comparados com a escala visual analógica (EVA) e Oswestry Disability Index (ODI) até 12 meses após a cirurgia. **Resultados:** O grupo MIS apresentou menores índices de perda sanguínea (140 vs 345 ml; $p = 0,001$) e menor permanência hospitalar (1,1 vs. 2,2 dias; $p = 0,001$), maior tempo de cirurgia (113 vs. 94 minutos; $p = 0,001$) e maior exposição às radiografias (80 vs 6 seg; $p = 0,001$) em relação ao grupo de cirurgia aberta. O grupo MIS apresentou melhores resultados nos escores de ODI e EVA lombar. Na EVA radicular não foram observadas diferenças significativas. **Conclusão:** A cirurgia minimamente invasiva apresentou vantagens em relação à técnica da cirurgia aberta, embora a curva de aprendizagem deva ser otimizada para reduzir o tempo de cirurgia. **Nível de Evidência III; Estudo retrospectivo descritivo observacional.**

Descritores: Degeneração do Disco Intervertebral; Discotomia Percutânea; Fusão vertebral.

RESUMEN

Objetivo: La fusión espinal lumbar es indicada para pacientes refractarios al tratamiento tradicional de la enfermedad degenerativa del disco. El objetivo del presente estudio consistía en comparar los resultados peri y postoperatorios de la cirugía abierta convencional versus la cirugía mínimamente invasiva (MIS) en la fusión lumbar de 360° por vía posterior con instrumentación de tornillo pedicular. **Métodos:** Se estudiaron 25 pacientes sometidos a la técnica MIS y 40 sometidos a la cirugía abierta entre 2015 y 2017. Se compararon las variables perioperatorias y los valores del dolor lumbar y dolor radicular con la escala visual analógica (EVA) e índice de incapacidad de Oswestry (ODI) hasta los 12 meses post cirugía. **Resultados:** El grupo MIS presentó menores índices de pérdida sanguínea (140 vs 345 ml; $p=0,001$) y menor permanencia hospitalaria (1,1 vs 2,2 días; $p=0,001$), mayor tiempo de cirugía (113 vs 94 minutos; $p=0,001$) y exposición a las radiografías (80 vs 6 seg; $p=0,001$) con relación al grupo de cirugía abierta. El grupo MIS presentó mejores resultados en las puntuaciones de ODI y EVA lumbar. En la EVA radicular no se observaron diferencias significativas. **Conclusión:** La cirugía mínimamente invasiva presentó ventajas con relación a la técnica de la cirugía abierta, aunque la curva de aprendizaje deba ser optimizada para reducir el tiempo de cirugía. **Nivel de Evidencia III; Estudio retrospectivo descritivo observacional.**

Descriptor: Degeneración del Disco Intervertebral; Discectomía Percutánea; Fusión vertebral.

Study conducted at Sanatorio Modelo de Caseros, Buenos Aires, Argentina.

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INTRODUCTION

Lumbar spine fusion is an established technique for the treatment of different spinal pathologies.¹ As the number of adults in the general population increases,² demand for such procedures, especially those indicated to treat degenerative conditions, is also on the rise. Conventional spinal fusion techniques may expose these patients to an increase in perioperative morbidity secondary to the main rates of complications,³ such as significant blood loss⁴ and prolonged hospital stay.⁵ Thus, there is a current trend towards the development of surgical techniques that can minimize perioperative and postoperative risks.

During the initial phase of the transpedicular instrumentation, King⁶ described an approach using small facet screws as a spinal fixation method in order to achieve the fusion of the segments involved. Later, Boucher⁷ modified this technique using a longer screw driven through the pedicle with additional spongy bone grafting, which resulted in a reduction of the pseudoarthrosis rate.

This system with transpedicular screws provides greater fixation of the spine, since it involves the three spinal structures (anterior, medium and posterior), which spine to resist movements in every plane. Gaines⁸ specified, in a subsequent study, that these screws can be used for short segments of the lumbar spine, where segmental fusion should be enhanced, with effective and safe results following specific placement instructions.

In recent years, minimally invasive surgical procedures have shown optimal clinical outcome and a reduction in perioperative morbidity, especially in the fields of general surgery, gynecology and urology.^{9,10} In the treatment of degenerative disc pathologies, although the conventional open surgical approach still remains the gold standard, MIS techniques have increased in popularity.

Magerl¹¹ first published a study describing the technique of percutaneous screw fixation using an external fixation device to treat fractures and infections of the spine. Later, Mathews and Long¹² described the use of plates as external longitudinal connectors that were fixed with transpedicular screws placed percutaneously.

Wiltse et al.¹³ were pioneers in describing the paraspinous-splitting approach to the lumbar spine. They found out that this technique reduced bleeding and enabled more direct access to the pedicles. This method has been used in minimally invasive transforaminal lumbar interbody fusion (TLIF) surgeries as the only procedure.

This advance in techniques, together with the advent of new surgical instruments for this type of surgery has led to the application of minimally invasive surgery (MIS) approaches to spinal fusion. Nevertheless, before using this technique as the first choice, further studies should be conducted to assess its efficacy, and to compare spinal fusion with conventional techniques.

The aim of the present study was to determine whether there are differences in perioperative results, pain scale scores, functional postoperative findings and complications between minimally invasive surgery and conventional open surgery used for posterolateral 360° spinal arthrodesis (posterolateral TLIF) in patients with lumbar degenerative disc disease.

METHODS

This is an observational, comparative, prospective study for all the variables analyzed. For the assessment of the perioperative results, a cross-sectional approach was used, and for the functional results a longitudinal analysis of repeated measures was performed.

All the patients were notified of this study prior to the surgery, and signed an Informed Consent Form.

This study was approved by the Ethics Committee of Sanatorio Modelo de Caseros, Buenos Aires, Argentina.

Consecutive non-probability sampling was used to collect data on patients who underwent surgery in 2016 and 2017 at two surgical centers. Both surgical techniques – MIS and open surgery – were performed by the same surgical team.

The inclusion criteria were:

1. Age: 25 to 70 years; 2. Presence of recurrent lumbar disc herniation

with neurologic compromise; 3. Presence of only one level of lumbar degenerative disc disease with discogenic low back pain that did not respond to conservative treatment (after 4-8 weeks) including rest, painkillers (nonsteroidal anti-inflammatory drugs (NSAIDs) and opioids) and physical therapy; 4. Neurologic deficit related to the level of degenerative disc disease; 5. Presence of grades I and II spondylolisthesis, with instability; 6. Monosegmental degenerative lumbar spinal stenosis.

The exclusion criteria were:

1. Age: younger than 25 or older than 70 years old; 2. Patients who did not complete all of the data collection tools used; 3. Presence of multiple levels of lumbar degenerative disc disease; 4. Presence of grades III and IV spondylolisthesis; 5. Presence of associated vertebral fracture; 6. Presence of infection; 7. History of previous lumbar surgery.

The patients were divided into two groups: one group underwent a MIS technique (posterior transpedicular screw fixation) and the other, a conventional open technique (posterior lumbar surgery for arthrodesis).

In relation to the MIS technique, the ROMEO MIS[®] system of transforaminal interbody fusion (PLIF/TLIF) was used (Figures 1 and 2). In the case of the conventional open surgery, transpedicular screws with interbody cages (PLIF/TLIF) were used.

Prior to surgery, the patients' data including sex, age and level of fusion segment were collected. During the preoperative period, lumbar and radicular pain were evaluated using the visual analogue scale (VAS) of pain intensity, reported by the patient. The resulting score was expressed as 0 to 10, where 0 corresponded to "no pain at all" and 10 to "maximum intensity pain". In addition, an objective post-surgery score of ≤ 3 points was proposed. The lumbar and radicular VAS measurements were repeated 24 hours after surgery and during the follow-up controls at 1 month, 3 months, 6 months and 12 months postoperatively.

The Oswestry disability index (ODI) score was also determined. In this study the current version, 2.1a, was used. This validated tool consists of giving the patients 10 questions with 6 possible answers each. The questions refer to intensity of pain, sexual activity, social life and capacity to remain standing, carry out personal care, sleep, lift weight, walk, remain seated, and travel, all of which the patients reported. The resulting value was expressed as a percentage of disability. The American Food and Drug Administration has proposed



Figure 1. Case I fusion L4 L5 MIS + PLIF.

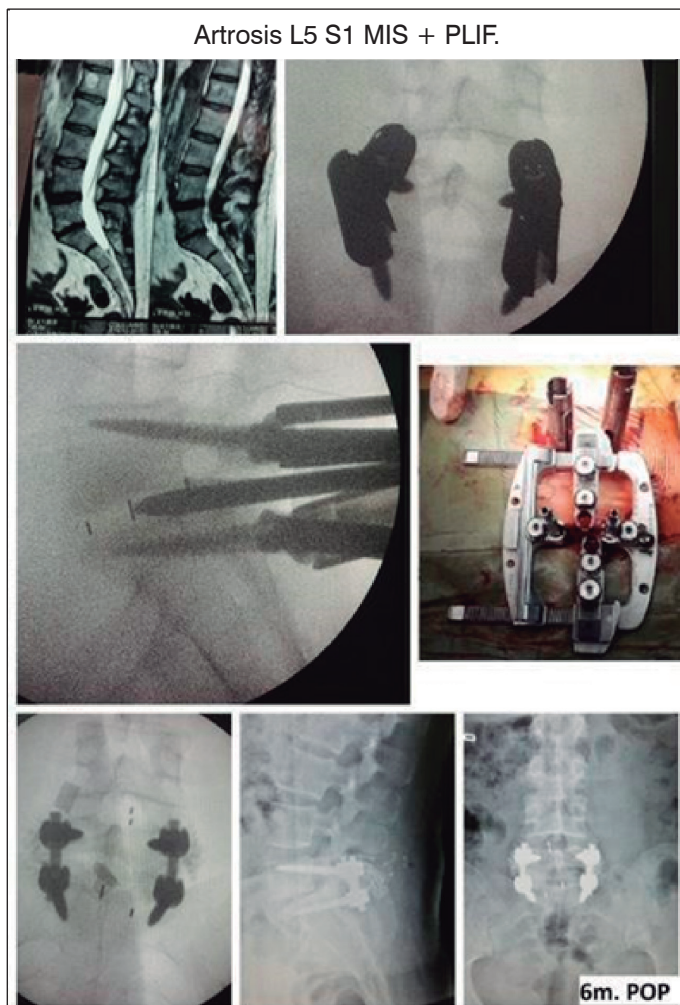


Figure 2. Case II fusion L5 S1 MIS + PLIF.

a minimal difference of 15 points between the preoperative and postoperative evaluations as an indicator of clinical change. In the present series, ODI measurements were also repeated during the follow-up controls at 1 month, 6 months and 12 months after surgery.

During the perioperative stage, data on operative time, hospital stay, time of exposure to X-rays and estimated blood loss were collected. In the case of the conventional open surgery, blood loss during surgery was determined together with the loss recorded during drainage. In the MIS approach, blood loss was only recorded during surgery, since this technique does not require the placement of drainage in patients after surgery.

Statistical Analysis

The data were analyzed using the statistics package SPSS version 24.0 (Armonk, NY, IBM Corp.). For the categorical variables of patients' characteristics (sex, surgical technique, level of fusion segment) the distribution of frequencies was calculated considering the number of cases and the percentage in relation to the total number of patients.

In order to report the results of numerical variables, the mean value and standard deviation were calculated for those variables with normal distribution, and the median value and interquartile range (IQR) were calculated for those variables that did not present normal distribution. The minimum and maximum values recorded were also reported. The variables sex and age were analyzed by surgical technique using Pearson's Chi-squared test and the student's t-test, respectively.

To determine whether there were any differences between hospital stay and operative time for the surgical techniques used, the student's t-test was used, since these variables presented normal

distribution. To analyze the differences in relation to blood loss and time of exposure to X-rays by the surgical technique, the non-parametric Mann-Whitney test was used.

The size of the sample population was calculated taking into account the four repeated measurements of the variable "ODI scores" for both groups of surgical techniques, considering a power value of 80% and effect size of 0.3. A minimum of 48 total cases, and 24 cases in each cohort (MIS versus open) was required. The value considered for statistical significance was $\alpha = 0.05$.

Furthermore, the student's t-test was used to compare the scores obtained from the visual analogue scales of lumbar and radicular pain (lumbar VAS and radicular VAS, respectively) for each surgical technique at six moments (preoperative, and at 24 hours, 1 month, 3 months, 6 months and 12 months postoperative). Finally, the ANOVA test was used with repeated measures to determine whether there were any differences in the values of ODI at different times: preoperative, at 1 month, 6 months and 12 months postoperative, by surgical approach.

RESULTS

Sample characteristics

A total of 65 patients were included in the sample: 38% (n=25) underwent minimally invasive surgery (MIS) and 62% (n=40) underwent conventional open surgery. Concerning the demographic variables, the MIS group had a mean age of 49 years (SD 5.6) and the open surgery cohort had a similar mean age: 51 years (SD 7.9). The sex distribution was as follows: 41% (n=17) female patients and 33% (n=8) male patients underwent MIS (Table 1).

Only 1 patient underwent MIS technique for L3-L4 and 2 patients underwent open surgery for the same segment. For level L4-L5, the technique used was MIS in 46% of patients (n=11), and for L5-S1, 34% (n=13) underwent the same technique (Table 1).

No statistically significant differences were observed between surgical groups in relation to age or sex (Table 2).

Perioperative results

The mean operative time for MIS was 113 minutes (SD 18); CI 95%: 106-120, minimum 90 and maximum 150 minutes. In the case of the open surgery, the mean operating time was 94 minutes (SD 11); CI 95%: 91-98, minimum 70 and maximum 120 minutes. A statistically significant difference between groups was observed (t= 5.256; p=0.0000) (Figure 3).

In relation to hospitalization time, the patients who underwent the MIS technique presented a mean hospital stay of 1.1 days (SD

Table 1. Variables of Patients' Characteristics by Surgical Technique.

	MIS	OPEN
Number of patients (%)	25 (38%)	40 (62%)
Mean age (SD)	49 (5.6)	51 (7.9)
Sex N (%)		
Female	17(41%)	24 (59%)
Male	8 (33%)	16 (67%)
Level of fusion segment N (%)		
L3-L4	1 (33%)	2 (67%)
L4-L5	11 (46%)	13 (54%)
L5-S1	13 (34%)	25 (66%)

SD=standard deviation.

Table 2. Sex and Age by Surgical Technique.

Variable	MIS	OPEN	Statistical test	p Value
Age (years)	49 (SD 5.6) CI 95%: 47-51	51 (SD 7.9) CI 95%: 49-54	t=-1.228	0.2
Sex (F/M)	41% vs 33%	59% vs 67%	Pearson's Chi2= 0.4228	0.516

SD= standard deviation. CI= confidence interval.

0.3); CI 95%: 0.9-1.2, minimum 1 and maximum 2 days, which was significantly lower than that of the patients who underwent open surgery: mean hospitalization time: 2.2 days (SD 0.4); CI 95%: 2.1-2.4, minimum 2 and maximum 3 days ($t=-11.04$; $p=0.0000$) (Figure 4).

In the case of blood loss, the median value for the individuals who underwent the MIS technique was 140 ml (IQR 120–150 ml), minimum 100 and maximum 200 ml; for the patients who underwent the open surgery, blood loss was significantly greater, with a median value of 345 ml (IQR 300–380 ml), minimum 240 and maximum 500 ml ($z=6.782$; $p=0.0000$) (Figure 5).

Regarding exposure to X-rays, the subjects who received MIS surgery presented a median exposure time of 80 seconds (IQR 76–96 seconds), minimum 60 and maximum 120 seconds, and those who underwent open surgery had a median exposure value significantly lower: 6 seconds (IQR 5–8 seconds), minimum 4 and maximum 10 seconds ($z=6.782$; $p=0.0000$) (Figure 6).

Summary of the Perioperative Results is show in Table 3.

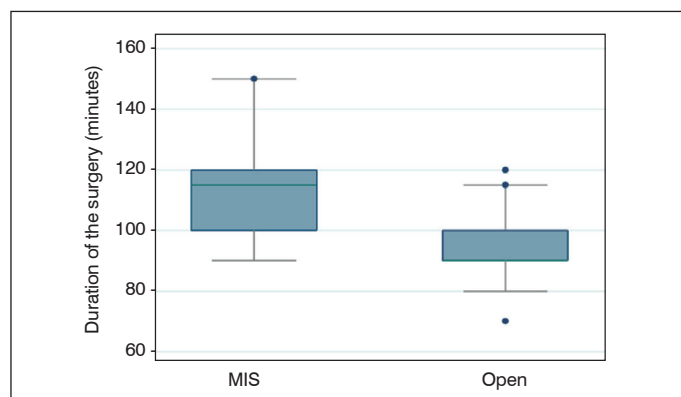


Figure 3. Operative Time by Surgical Technique.

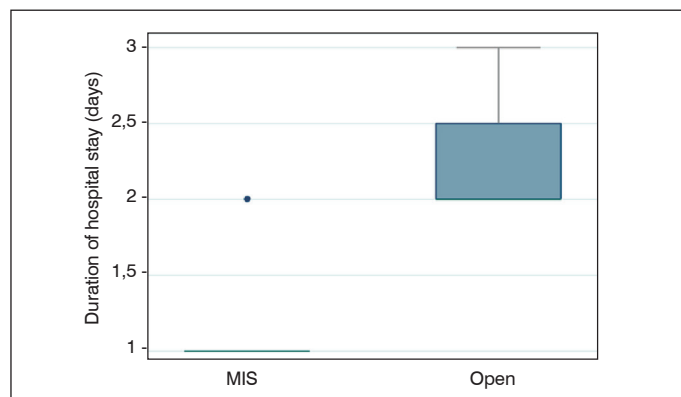


Figure 4. Hospitalization time by Surgical Technique.

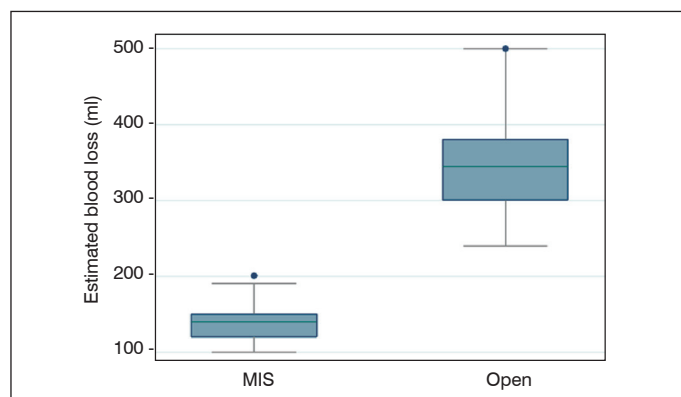


Figure 5. Blood Loss by Surgical Technique.

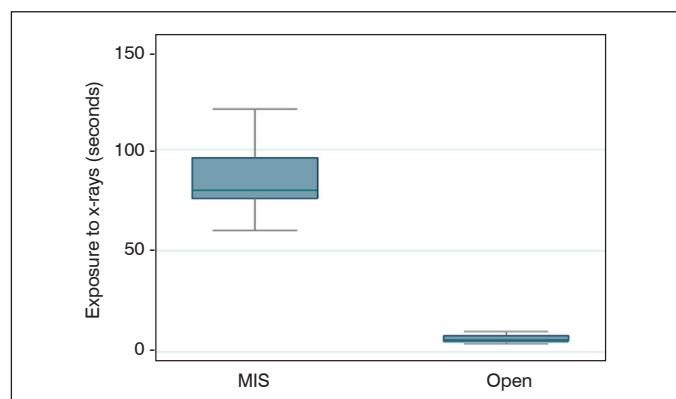


Figure 6. Exposure to X-rays by Surgical Technique.

Table 3. Summary of the Perioperative Results.

	MIS	OPEN	p Value
Operative time (minutes)			
Mean value (SD)	113 (18)	94 (11)	<0.001*
Hospitalization time (days)			
Mean value (SD)	1.1 (0.3)	2.2 (0.4)	<0.001*
Estimated blood loss (ml) Median value (IQR)	140 (120-150)	345 (300-380)	<0.001†
X-ray exposure (seconds) Median value (IQR)	80 (76-96)	6 (5-8)	<0.001†

*Student's t-test. †Mann-Whitney test.

Results of the visual analogue scale for lumbar pain (lumbar VAS)

No statistically significant differences were observed in the pre-operative lumbar VAS scores obtained for each surgical technique. In the MIS group the mean value was 6 points (SD 1.5); (CI 95%: 5.4–6.7), and in the open surgery cohort the mean value was 6.3 points (SD 1); (CI 95%: 6–6.6) ($t= -0.862$; $p=0.39$).

Twenty-four hours after surgery, the MIS cohort presented a mean lumbar VAS value of 2.3 points (SD 0.7); (CI 95%: 1.9–2.5), and the open surgery group had a mean value of 3 points (SD 0.7); (CI 95%: 2.8–3.2). We observed a statistically significant difference between both groups, with a lower value for lumbar pain in the MIS cohort ($t= -4.055$; $p=0.0001$).

One month after surgery, the MIS group showed a significantly lower lumbar VAS value compared to the patients in the open surgery group: mean value: 1.4 points (SD 0.5); (CI 95%: 1.2–1.6), versus mean value of 2 points (SD 0.8); (CI 95%: 1.7–2.2) ($t=- 3.264$; $p=0.0018$).

At month 3 postoperative, the same findings were observed, with significantly lower values in the MIS cohort compared to the values for the open surgery cohort: mean value 1 point (SD 0.7); (CI 95%: 0.7–1.3) versus mean value of 1.9 points (SD 0.6); (CI 95%: 1.7–2.1) ($t= -4.873$; $p=0.0000$).

Finally, the lumbar VAS scores were significantly different between the surgical groups at 6 and 12 months postoperative, with lower values in the MIS group: at 6 months the MIS cohort showed a mean value of 1 point (SD 0.5); (CI 95%: 0.7–1.2) versus the open surgery cohort, which presented 1.8 points (SD 0.6); (CI 95%: 1.6–2) ($t= -4.847$; $p=0.0000$). Twelve months after surgery the values were: for the MIS group, mean of 0.8 points (SD 0.8); (CI 95%: 0.5–1.1), and for the open surgery cohort, 1.4 points (SD 0.5); (CI 95%: 1.2–1.5) ($t= -3.433$; $p=0.001$).

Results of the visual analogue scale for radicular pain (radicular VAS)

No statistically significant differences were observed in the radicular VAS scores obtained before the surgery, considering each surgical technique. In the MIS cohort we observed a mean value of 6.5 points (SD 1.5); (CI 95%: 5.8–7.1), and in the open surgery group, the mean value was 6.7 points (SD 1); (CI 95%: 6.4–7) ($t= -0.859$; $p=0.393$).

At 24 hours after surgery, no significant differences were found

between the groups: the MIS group showed a mean value of 1.6 points (SD 0.6); (CI 95%: 1.3–1.8), and the mean value for the open surgery cohort was 1.3 points (SD 0.9); (CI 95%: 1–1.5) ($t = 1.434$; $p=0.15$).

One month and 3 months after surgery, we did not find any significant differences either with regard to the radicular VAS scores: at 1 month, the MIS group showed a mean value of 1.2 points (SD 0.7); (CI 95%: 0.9–1.4), and the open cohort presented 1.1 points (SD 0.8); (CI 95%: 0.8–1.3) ($t = 0.507$; $p=0.61$). Three months after surgery, the mean value was 0.72 points (SD 0.6); (CI 95%: 0.5–0.9) in the MIS cohort, and 0.87 points (SD 0.7), (CI 95%: 0.6–1.1) in the open surgery cohort.

Conversely, 6 months after surgery, there were significant differences between both groups: the MIS cohort presented a mean of 0.4 points (SD 0.5); (CI 95%: 0.2–0.6), and the open group presented 0.8 points (SD 0.6); (CI 95%: 0.6–1) ($t = -2.631$; $p=0.01$).

Finally, we did not find any significant differences between the MIS and the open surgery cohorts at 12 months after surgery: 0.4 points (SD 0.2–0.6), (CI 95%: 0.2–0.6), and 0.6 points (SD 0.6), (CI 95%: 0.4–0.8), respectively ($t = 1.355$; $p=0.18$).

Although it was not possible to perform a statistical analysis of the differences between the scores over time, since the variables did not meet the necessary statistical requirements, in Figure 5 and 6 the pattern of the lumbar and radicular pain scale scores by surgical technique can be seen: there is a trend towards a greater reduction in the lumbar pain score with the MIS approach. In contrast, the lines showing intensity of radicular pain by technique meet at several time points, except for 6 months after surgery, when a difference in favor of the MIS technique can be observed; however, this difference decreases at 12 months after surgery, although the scores for the MIS approach continue to be lower than those of the open surgery (Figure 7 and 8).

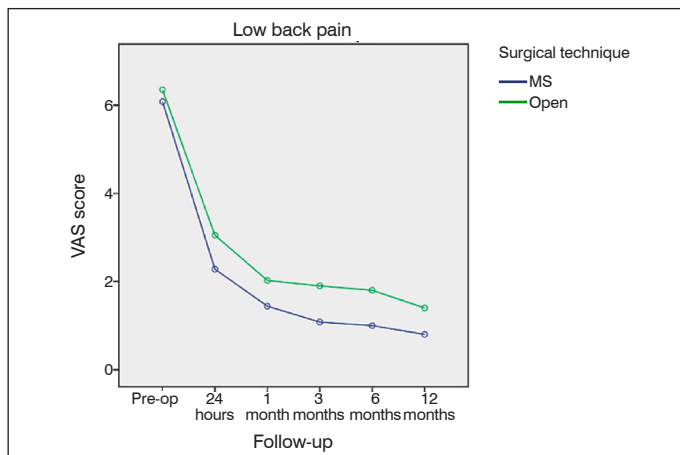


Figure 7. Lumbar VAS Pattern.

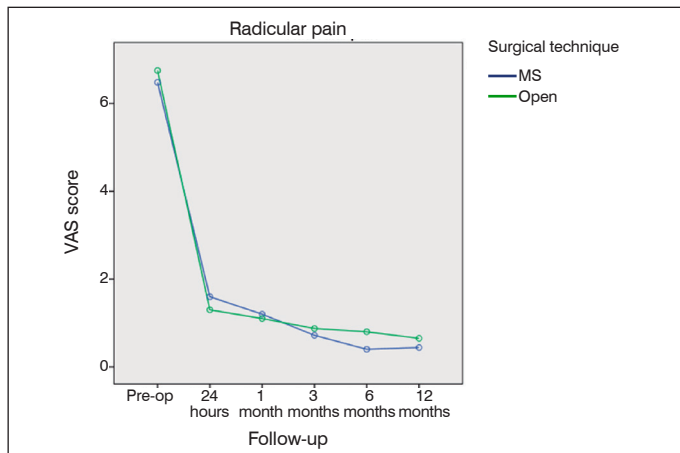


Figure 8. Radicular VAS Pattern.

Results of the Oswestry disability index (ODI)

The following conclusion was based on the multivariate analysis carried out to contrast the null hypotheses related to the effects where the within-subject factor is involved (ODI scores) without assuming sphericity, since the sphericity assumption was not met, according to the Mauchly's test ($W=0.392$; $p=0.000$).

Thus, after applying the repeated measures ANOVA test, we observed that although the mean values of the disability indices decreased over time with both surgical techniques, this reduction proved to be significantly greater in the MIS cohort ($F=7.111$; $p=0.01$) (Figure 7). The latter group of patients presented an average reduction in the disability index of 23.8 points 1 month after surgery, 27 points 6 months after surgery, and 30.1 points 12 months after surgery, exceeding the expected difference of 15 points between the pre- and post-surgery evaluations. In the case of the open surgery cohort, we also observed a decrease in the disability scores, albeit smaller, with an average reduction of 16.4 points at month 1, 21 points 6 months after surgery and 22.6 points 12 months after surgery (Figure 9).

Lastly, multiple comparisons were performed to evaluate the within-subject effects, and adjustments to the P-values, and the confidence intervals were determined using Bonferroni correction (Table 4).

It can be observed that prior to surgery, the differences in mean ODI scores between the two techniques did not reach statistical significance ($p=0.224$). Conversely, at 1, 6 and 12 months after surgery, significant differences were found, with lower ODI values in the MIS cohort ($p=0.000$; $p=0.004$ and $p=0.000$, respectively) (Table 4).

Complications

One case of implant displacement (PLIF) was observed in the MIS group, and one case of malpositioned implant was found in the open surgery cohort.

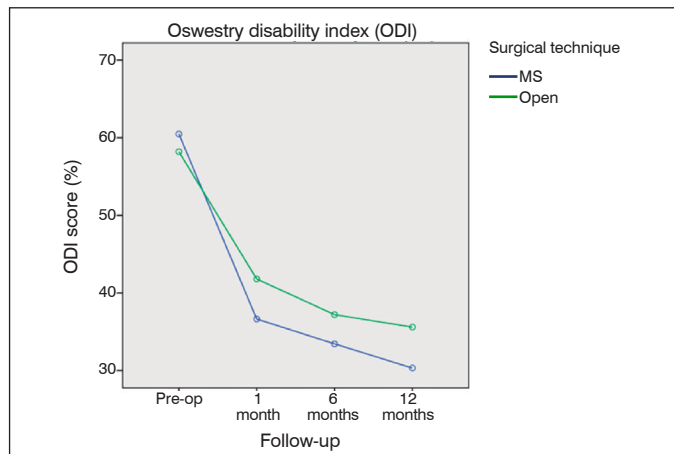


Figure 9. ODI Pattern by Surgical Technique.

Table 4. ODI Statistical Values.

ODI (%)	Surgical technique	N	Mean	SD	CI 95%	p value
Preoperative	Mis	25	60.4	5.2	57.5–63.3	0.224
	Open	40	58.2	8.3	55.8–60.0	
1 month after surgery	Mis	25	36.6	3.6	34.4–38.7	0.000
	Open	40	41.8	6.2	40–43.5	
6 months after surgery	Mis	25	33.4	6	31.4–35.4	0.004
	Open	40	37.2	4.1	35.6–38.7	
12 months after surgery	Mis	25	30.3	5.1	28.4–32.2	0.000
	Open	40	35.6	4.4	34.1–37	

DISCUSSION

Lumbar spine fusion is an effective method for the treatment of spondylolisthesis, lumbar degenerative disc disease and lumbar spinal stenosis. There are several surgical approaches to spinal fusion, such as posterior lumbar fusion, posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), and anterior lumbar interbody fusion (ALIF). At present, the use of MIS surgeries applied to lumbar fusion is increasing. Among its benefits, a reduction in blood loss and duration of hospital stay has been observed. However, the MIS procedures have a steep learning curve for surgeons.

In literature reviews on the perioperative results of MIS TLIF and transpedicular fusion with TLIF using conventional open surgery, different authors found significantly better outcomes in patients who underwent MIS TLIF compared to those who underwent open surgery. In a retrospective study that included 139 patients (76 in the MIS cohort and 63 in the open surgery cohort), Villavicencio et al.¹⁴ found a reduced estimated blood loss rate and shorter hospitalization times in the MIS group (163 ml; 3 days), compared to the cohort who received open fusion with TLIF (366.8 ml; 4.2 days). Nevertheless, the operative time was shorter in the conventional open surgery cohort.

Dhall et al.¹⁵ published a retrospective study with 21 patients in the MIS cohort and 21 in the open surgery cohort and compared lumbar fusion using both techniques. They observed a lower blood loss rate (194 vs 505 ml; $p=0.000$) and shorter hospital stay (3 vs 5.5 days; $p=0.000$) in the MIS TLIF group, compared to the results with fusion and TLIF using open surgery.

Schizas et al.¹⁶ studied 18 patients undergoing a MIS technique and 18 patients undergoing conventional open surgery. They also found that the MIS TLIF group presented shorter hospital stay (6.1 vs 8.2 days; $p < 0.05$), less blood loss (550 vs 1,400 ml; $p < 0.01$), and a reduction in pain, but a steeper learning curve.

In the present series, in concordance with the findings of Villavicencio et al. and Dhall et al., the results of the comparison between the MIS and the open surgery cohorts were more favorable in the former group with regard to the estimated blood loss (140 vs 345 ml; $p=0.001$) and hospitalization time (1.1 vs 2.2 days; $p=0.001$).

Peng et al.¹⁷ compared the clinical and radiological results of patients who underwent a MIS technique ($n=29$) with patients who underwent a conventional open surgery ($n=29$). They observed that the MIS cohort presented a longer operating time (216 vs 170 min; $p < 0.05$), shorter hospitalization time (4 vs 6.7 days; $p < 0.005$) and reduced blood loss (150 vs 681 ml; $p < 0.05$).

In short, the results for hospitalization time and rates of blood loss were more optimal in the MIS group in all the above mentioned studies, including the present series. In relation to operative time, our study, similar to that of Peng et al., showed shorter duration in the MIS cohort compared to the open surgery group (113 vs 94 min, respectively; $p = 0.000$). Conversely, in a study including 53 patients, Scheufler et al.¹⁸ found that operating time was equivalent in the MIS and open surgery cohorts, with no significant differences (132 vs 104 min, respectively; $p = < 0.05$).

Wong et al.¹⁹ were the first to describe the MIS TLIF technique, in early 2002, in 100 procedures. They found that operative time was longer in comparison to the group of open surgery. In a series published between 2006 and 2008, where 144 MIS TLIF procedures and 54 open surgeries were analyzed, the same authors observed that the patients who underwent MIS TLIF presented shorter operative time (2.5 hs) than the cohort undergoing open surgery (3.5 hs). This was due to the fact that the surgeons who performed the procedures had already overcome the initial learning curve required for the MIS TLIF technique.

In the same study, Wong et al. also observed that the MIS TLIF procedures were associated with a significant increase in X-ray exposure for patients, the surgeon, and the operating room staff. There was a 2.5-fold increase in millisievert (mSv) in the MIS TLIF group: 1.90 versus 0.75 mSv for the open TLIF surgery cohort ($p = < 0.01$). Even though in the present series, the surgical team's exposure to

X-ray was measured in seconds, not in millisieverts, our findings are in agreement with those of Wong; the subjects involved in the MIS procedure were subjected to greater X-ray exposure than those involved in the conventional open surgery (80 vs 6 seconds; $P = 0.001$).

Concerning postoperative pain, Jang and Lee²⁰ published a study showing a significant reduction in ODI scores (33 to 7.6; $p=0.0001$) in a sample population of 23 patients undergoing MIS TLIF without a control group.

Wong et al.¹⁹ found an average preoperative lumbar VAS of 6.3 in the MIS cohort and 6.72 in the open surgery cohort. These scores decreased one year after surgery, to 1.05 in the MIS group and 1.7 in the open surgery cohort, but the difference was not significant ($p = < 0.01$). The authors did not find any significant differences between both groups in the radicular VAS scores either, since the MIS cohort presented a preoperative score of 8.9, which decreased to 1.15, and in the case of the open surgery group, the preoperative value was 8.82 points which decreased to 1.3 one year after surgery ($p = < 0.01$). One year after surgery both techniques showed a reduction in the VAS scores below the 3 points initially proposed as a postoperative goal.

In our series, lumbar pain was significantly reduced one year after surgery, compared to the preoperative values: the preoperative scores were 6 points for the MIS cohort and 6.5 points for the open surgery group. The after surgery lumbar pain values one year later dropped to 0.8 points in the MIS cohort and 1.4 points in the open surgery cohort, which shows that for both surgical techniques, lumbar pain scores are significantly reduced below the 3 points initially set. Furthermore, pain reduction was significantly greater in the MIS group in our series ($p = 0.001$).

It is worth noting that the pain reduction was observed early in our series, because 24 hours after surgery, the pain decreased to a mean value of 2.3 (CI 95%: 1.9–2.5) in the MIS group, with lesser decrease in the open surgery cohort, reaching 3 points (CI 95%: 2.8–3.2), and this reduction continued during the follow-up period.

Villavicencio et al.¹⁴ did not find any significant differences in the lumbar VAS scores between both techniques 24 months after surgery: 3.4 points in the MIS cohort versus 3.2 points in the open surgery group ($p = 0.8$).

In relation to the functional results evaluated through the ODI scores, in the present series the preoperative value for the MIS cohort was 60.4, decreasing to 30.3 one year after surgery. In the conventional open group, the preoperative ODI score was 58.2, which dropped to 35.6 one year after surgery. The reduction in the ODI value in the MIS cohort was significantly greater compared to that of the open surgery value during the 12 month follow-up ($p=0.01$). In a prospective study of 23 patients, Jang and Lee²⁰ also observed a significant reduction in the mean ODI score from 33.1 to 7.6 in patients who had undergone MIS TLIF.

In Wong et al.'s study,¹⁹ the preoperative ODI values for the MIS and open surgery cohorts (52.8 and 51.2, respectively) presented reduction to 18 and 21 in a year, respectively without statistically significant difference between the groups ($p = > 0.05$).

In agreement with these findings, Deutsch and Musacchio²¹ found, in a prospective study of 20 subjects, that 85% of patients undergoing MIS TLIF presented a reduction of 20 points in the ODI score. In our study, the mean reduction was 30.3 points for the MIS group and 22.6 for the open surgery cohort. The difference between MIS and open fixation was more than the 15 expected points, following the recommendations. This may be due to a shorter hospital stay in the case of the patients who underwent the MIS technique, which leads to earlier recovery, thus affecting this score.

CONCLUSION

The aim of the present study was to study the functional results of lumbar fusion as a treatment for degenerative disc disease using 360° MIS arthrodesis compared to the conventional open surgery. These findings were assessed by means of the VAS pain and ODI scales. The perioperative results were also evaluated considering

estimated blood loss, hospital stay, operative time and complications, with the following conclusions:

The use of a MIS technique presented less blood loss and a shorter hospital stay, compared to the group that underwent conventional open surgery; however, we observed longer operating times and greater X-ray exposure associated with a steeper learning curve than in the conventional surgery.

Both surgical techniques showed a significant reduction in lumbar and radicular pain scores, and in the case of the MIS cohort, the reduction in lumbar pain was significantly greater.

The ODI score was significantly lower in the MIS cohort compared

to the open surgery group during the 12-month follow-up.

Immediate complications (dural tear, excessive bleeding), infection and postoperative neurologic lesion were not related to the type of surgery used.

There was 1 case of implant displacement in the MIS group (PLIF) and 1 case of implant malpositioning in the open surgery group.

All authors declare no potential conflict of interest related to this article.

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