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# CLINICAL OUTCOMES OF FRAGMENTECTOMY FOR CARRAGEE TYPE I AND III LUMBAR DISC HERNIATIONS: A SINGLE-CENTER EXPERIENCE

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ABSTRACT

**Objective:** Fragmentectomy represents a tissue-preserving alternative to conventional microdiscectomy. Evidence specifically stratifying outcomes by Carragee lumbar disc herniation type remains limited. To evaluate the clinical outcomes and safety of fragmentectomy in patients with Carragee type I and type III lumbar disc herniations at a single center.

**Materials and Methods:** This retrospective study included 32 consecutive patients who underwent fragmentectomy for Carragee type I (n=18) or type III (n=14) herniations at the L3-S1 levels between 2020 and 2023. The primary outcomes were visual analog scale (VAS) and Oswestry disability index (ODI) scores at 6 and 12 months. Normality was assessed with the Shapiro-Wilk test, and parametric or non-parametric tests were applied accordingly. Subgroup analyses compared outcomes among Carragee subtypes.

**Results:** The mean follow-up was 18 months. VAS scores decreased from 8.20±1.10 preoperatively to 0.90±0.54 at 12 months ($p<0.001$; Cohen's d =5.06). ODI improved from 69.33±12.78 to 9.70±5.18 ($p<0.001$; Cohen's d =4.27). No significant difference was observed between Carragee subtypes at 12 months (VAS: $p=0.065$; ODI: $p=0.607$). Three patients (9.4%) required revision surgery. No intraoperative or postoperative complications were recorded.

**Conclusion:** Fragmentectomy may be an effective, tissue-preserving surgical option for carefully selected patients with Carragee type I and type III lumbar disc herniations. Prospective controlled studies are required to establish superiority over conventional microdiscectomy.

**Keywords:** Fragmentectomy, lumbar disc herniation, Carragee classification, microdiscectomy, clinical outcomes

## INTRODUCTION

Lumbar disc herniation (LDH) constitutes one of the most prevalent causes of radiculopathy and remains the underlying pathology in one of the most performed spinal procedures worldwide[1]. Surgical management encompasses a spectrum of technical approaches, ranging from aggressive subtotal discectomy to more conservative fragment-targeted strategies. Fragmentectomy, defined as the selective removal of the extruded or sequestered disc fragment without disrupt the intervertebral disc space, and conventional microdiscectomy, which additionally involves curettage of intradiscal material, represent two ends of this spectrum[2].

Fragmentectomy has been recognized as a suitable option for patients with a small annular defect, in whom preservation of disc structure is both feasible and desirable[3]. By avoiding unnecessary violation of the disc space, this approach aims to preserve the structural and biomechanical integrity of the anterior column, which may reduce postoperative low back pain and promote faster functional recovery[4,5]. Recent studies indicate that this technique may reduce the risk of recurrent herniation in carefully selected cases, particularly in Carragee type I and type III herniations, characterized by small annular defects and an otherwise competent disc.

The Carragee classification system provides a reproducible framework for identifying surgical candidates most likely to benefit from a limited approach[6]. Patients with large annular tears (type II) or intact annuli without free fragments (type IV) are generally considered less suitable and may require more extensive disc removal or complementary stabilization[7,8].

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Despite growing interest in tissue-preserving discectomy, evidence specifically stratifying outcomes by Carragee herniation type remains limited. The aim of this study was to evaluate clinical outcomes and safety of fragmentectomy in patients with Carragee type I and type III LDHs and to compare results between the two subtypes.

## MATERIALS AND METHODS

### Patient Selection

This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki. The study was approved by the Atatürk University Faculty of Medicine Clinical Research Ethics Committee (approval no: B.30.2.ATA.0.01.00/110, date: 27.01.2022). All patients provided written informed consent prior to surgery.

Between 2020 and 2023, a total of 258 patients underwent surgery for LDH at our institution. Of these, 226 patients were excluded based on predefined criteria: herniation above the L3 level (n=41), previous spinal surgery (n=60), presence of spinal tumor or infection (n=11), Carragee type II or IV herniation morphology (n=89), and follow-up duration less than 6 months (n=25). The remaining 32 consecutive patients who met all inclusion criteria were enrolled, representing 12.4% of the overall surgical cohort.

Inclusion criteria were age ⩾18 years, minimum 6 months of follow-up, radiologically confirmed single-level Carragee type I or III LDH at L3-S1, and failure of conservative management for at least 6 weeks. Herniations above L3 were excluded to maintain homogeneity, as upper lumbar herniations present distinct anatomical and biomechanical characteristics.

### Classification and Imaging

Disc herniations were classified using the four-type system of Carragee et al.[6]: type I (fragment-fissure) minimal annular defect with a single extruded or sequestered fragment; type II (fragment-defect) extruded fragments with a wide annular tear ⩾6 mm; type III (fragment-contained) intact annulus with fragments accessed through an oblique annular incision; type IV (no-fragment-contained) intact annulus without subannular free fragments (Figure 1A-B).

Classification was independently assessed by two spine surgeons on preoperative magnetic resonance imaging (MRI), with attention to annular defect size, fragment morphology, and disc integrity. Intraoperative confirmation was performed by the senior surgeon in all cases. Discordances, occurring in 3 of 32 cases (9.4%), were resolved by consensus, with intraoperative findings considered definitive. Throughout this manuscript, "fragmentectomy" refers to selective fragment removal without disc space entry, the term "sequestrectomy" used in some literature describes the same procedure[3,5].

### Surgical Technique

All procedures were performed under general anesthesia in the prone position via a standard microsurgical approach with intraoperative fluoroscopic guidance. The decision to proceed with fragmentectomy followed a predefined two-stage algorithm. Preoperatively, candidates required MRI evidence of a Carragee type I or III herniation with an annular defect ⩽5 mm, absence of a wide annular tear, and a single well-defined fragment causing neural compression. Intraoperatively, fragmentectomy was confirmed when the defect was visually consistent with preoperative assessment and no residual loose material was identified after fragment removal and saline irrigation (Figure 1C). If a larger annular tear, multi-fragmented herniation, or residual fragments were encountered intraoperatively, the procedure was converted to limited microdiscectomy.

### Outcome Measures

Patients were evaluated at 6 and 12 months postoperatively, and annually thereafter. Clinical assessments included neurological examination and patient-reported outcome measures. Pain intensity was quantified using the visual analog

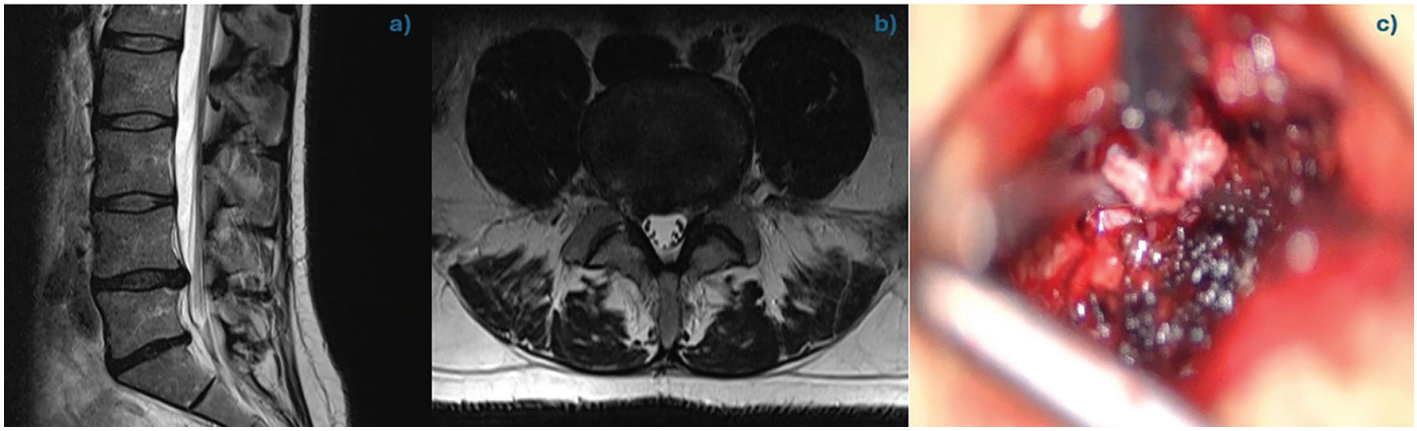


**Figure 1.** Sagittal T2-weighted MRI. **(a)** demonstrating L4-5 extruded disc fragment in a 47-year-old male patient with Carragee type III disc herniation. **(b)** Axial T2-weighted MRI showing the extruded fragment compressing the right L5 nerve root. **(c)** Intraoperative microscopic view of the fragmentectomy procedure. MRI: Magnetic resonance imaging

scale [(VAS); 0-10] and functional disability with the Oswestry disability index [(ODI); 0-100%]. MRI or computed tomography was performed when clinically indicated; routine postoperative imaging was not obtained in asymptomatic patients.

### Statistical Analysis

Prior to parametric testing, normality of all continuous variables was assessed with the Shapiro-Wilk test, appropriate for n≤50. Variables satisfying normality were analyzed using paired t-tests and reported as mean ± standard deviation. VAS scores at 12 months violated normality (W=0.896, p=0.005) and were analyzed using the Wilcoxon signed-rank test, reported as median with interquartile range (IQR). Categorical variables were reported as frequencies and percentages. For subgroup comparisons between Carragee type I and III at 12 months, the Mann-Whitney U test was used for VAS (non-normal) and the independent-samples t-test for ODI (normal), following Levene's test for homogeneity of variance. Statistical significance was set at p<0.05. A post-hoc power analysis was performed to assess the adequacy of the sample size. All analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Normality test results are summarized in Table 1.

## RESULTS

A total of 32 patients (14 women, 18 men; mean age: 48.6 years, range: 31-67) were included. Eighteen (56.3%) were classified as Carragee type I and 14 (43.7%) as Carragee type III. The most frequently affected level was L4-L5 (53.1%), followed by L5-S1 (34.4%) and L3-L4 (12.5%). Mean follow-up was 18 months (range 12-26). Baseline characteristics are presented in Table 2. Preoperatively, 7 patients (21.9%) presented with motor deficits, 4 with dorsiflexion weakness grade 3/5 and 3 with plantar flexion weakness, all accompanied by sensory loss in corresponding dermatomes. Eighteen patients (56.3%) had isolated sensory deficits, and 3 (9.4%) presented with severe refractory radicular pain unresponsive to at least 6 weeks of conservative treatment.

Most patients (29/32; 90.6%) achieved substantial or complete resolution of leg and low back pain within three weeks of surgery and returned to daily activities within a mean of two weeks. VAS scores decreased from 8.20±1.10 (median: 8.20; IQR: 7.63-8.42) preoperatively to 2.06±0.76 (median: 1.99; IQR: 1.39-2.47) at 6 months and to a median of 0.79 (IQR: 0.69-1.09) at 12 months. The preoperative-to-6-month reduction was significant (paired t-test, p<0.001; Cohen's d =4.29), as was the preoperative-to-12-month comparison (Wilcoxon signed-rank test, p<0.001). ODI scores improved from 69.33±12.78 preoperatively to 23.80±7.42 at 6 months and 9.70±5.18 at 12 months (both p<0.001; Cohen's d =3.10 and 4.34, respectively). Full outcome data are presented in Table 3.

Subgroup analysis revealed no statistically significant difference between Carragee type I (n=18) and type III (n=14) in VAS (Mann-Whitney U, p=0.065) or ODI (independent t-test, p=0.607) at 12 months, suggesting comparable outcomes across both subtypes. Subgroup data are presented in Table 4.

No intraoperative or postoperative complications were recorded. Three patients (9.4%) required revision surgery: one at 4 months due to a residual fragment causing persistent radiculopathy, and two at 7 and 11 months respectively due to recurrent herniation at the same level confirmed by MRI. All three achieved satisfactory recovery following revision. No clinically detected recurrence occurred among the remaining 29 patients; however, asymptomatic reherniations cannot be excluded given the absence of routine postoperative imaging.

Post-hoc power analysis confirmed >98% statistical power for both primary outcomes (VAS: Cohen's d =5.06, power=99.8%; ODI: Cohen's d =4.27, power=98.4%; $\alpha$=0.05, n=32), indicating adequate power despite the modest sample size.

**Table 1.** Shapiro-Wilk normality test results and applied statistical methods

| Variable | Shapiro-Wilk (W/p-value) |
|---|---|
| VAS-preoperative | W=0.975/p=0.648 |
| VAS-6 months | W=0.975/p=0.636 |
| VAS-12 months | W=0.896/p=0.005* |
| ODI-preoperative | W=0.977/p=0.703 |
| ODI-6 months | W=0.965/p=0.373 |
| ODI-12 months | W=0.958/p=0.236 |

*: Wilcoxon signed-rank test applied; data reported as median (IQR). VAS: Visual analog scale, ODI: Oswestry disability index, IQR: Interquartile range

**Table 2.** Patient demographics and baseline characteristics (n=32)

| Variable | Value |
|---|---|
| Sex-female/male | 14/18 (43.8%/56.3%) |
| Mean age (years) | 48.6 (range: 31-67) |
| Mean follow-up (months) | 18 (range: 12-26) |
| Carragee type I | 18 (56.3%) |
| Carragee type III | 14 (43.7%) |
| Herniation level-L3-L4/L4-L5/L5-S1 | 4 (12.5%)/17 (53.1%)/11 (34.4%) |
| Motor deficit | 7 (21.9%) |
| Sensory deficit only | 18 (56.3%) |
| Pain only | 3 (9.4%) |
| Revision surgery | 3 (9.4%) |
| Intraoperative complications | 0 (0%) |
| Postoperative complications | 0 (0%) |

**Table 3.** VAS and ODI scores at preoperative, 6-month, and 12-month time points

| Outcome measure | Preoperative | 6 months | 12 months |
|---|---|---|---|
| **VAS score (0-10)** | | | |
| Mean ± SD | 8.20±1.10 | 2.06±0.76 | 0.90±0.54 |
| Median (IQR) | 8.20 (7.63-8.42) | 1.99 (1.39-2.47) | 0.79 (0.69-1.09) |
| p-value vs. preoperative | - | <0.001* | <0.001† |
| **ODI score (0-100)** | | | |
| Mean ± SD | 69.33±12.78 | 23.80±7.42 | 9.70±5.18 |
| Median (IQR) | 69.07 (61.20-77.99) | 24.24 (20.72-28.44) | 9.68 (7.08-14.16) |
| p-value vs. preoperative | - | <0.001* | <0.001* |

*: Paired t-test (normality confirmed), †: Wilcoxon signed-rank test (non-normal distribution), VAS: Visual analog scale, ODI: Oswestry disability index, SD: Standard deviation, IQR: Interquartile range

**Table 4.** Subgroup analysis: clinical outcomes by Carragee herniation type at 12 months

| Outcome | Type I (n=18) | Type III (n=14) | p-value |
|---|---|---|---|
| VAS 12 months-median (IQR) | 0.88 (0.75-1.24) | 0.69 (0.56-0.94) | 0.065‡ |
| ODI 12 months-median (IQR) | 8.79 (6.67-11.28) | 11.20 (7.49-14.90) | 0.607‡ |
| VAS improvement (%) | 89.3% | 91.6% | 0.412 |
| ODI improvement (%) | 85.8% | 83.7% | 0.539 |
| Revision surgery-n (%) | 1 (5.6%) | 2 (14.3%) | 0.562§ |

‡: Mann-Whitney U test, §: Fisher's exact test, VAS: Visual analog scale, ODI: Oswestry disability index, IQR: Interquartile range

## DISCUSSION

This study evaluated clinical outcomes of fragmentectomy in 32 consecutive patients with Carragee type I and III LDHs. Both VAS and ODI scores demonstrated statistically significant and clinically large improvements sustained through 12 months of follow-up, with a zero-complication rate and a revision surgery rate of 9.4% consistent with the published fragmentectomy literature[3,9]. However, since no comparator group was included, it cannot be determined whether these outcomes reflect the efficacy of the technique itself or the favorable natural history of the selected patient population, which inherently comprised cases with smaller annular defects and more contained pathology.

The rationale for fragmentectomy lies in preserving the structural integrity of the intervertebral disc and segmental stability. In contrast to subtotal discectomy, which may compromise stability through extensive intradiscal material removal, fragmentectomy targets only the herniated fragment. Preserving annular competence is of particular importance, as the Carragee classification has demonstrated that annular defect morphology is a key determinant of recurrence risk and postoperative clinical course[6,10]. A historical shift toward conservative disc removal, exemplified by Williams'[11] early report of limited discectomy in over 500 patients, informed the contemporary practice of fragmentectomy. More recently, endoscopic approaches have reinforced the principle that limited exposure reduces tissue trauma; however, current evidence does not conclusively demonstrate superiority of endoscopic over open microsurgical techniques[12,13].

The subgroup analysis comparing type I and type III herniations revealed no statistically significant difference in VAS or ODI at 12 months. This finding suggests that both subtypes respond comparably to fragmentectomy, which is clinically relevant for patient selection. Type III herniations did not yield inferior outcomes. However, the limited subgroup sizes (n=18 and n=14) preclude definitive conclusions, and this observation requires validation in larger prospective cohorts.

For Carragee type II herniations recurrence risk following limited discectomy is higher[14]. While some advocate subtotal discectomy in such cases, extensive disc removal may paradoxically worsen long-term low back pain through accelerated disc height loss and facet joint overloading[15,16]. In our institution, type II cases requiring aggressive intervention are managed with discectomy and dynamic stabilization when appropriate. Fragmentectomy is reserved for type I and III herniations where smaller defects support a limited approach.

Preservation of disc height represents a further potential advantage of fragmentectomy. Maintaining disc height reduces facet joint loading and may delay posterior element degeneration[17]. Whether this biomechanical benefit translates into superior long-term outcomes compared with microdiscectomy remains to be demonstrated in prospective comparative studies.

### Study Limitations

This study has several limitations. First, its retrospective single-center design introduces selection bias and limits generalizability. Patients with more favorable pathological anatomy may have been preferentially selected for fragmentectomy. Second, the absence of a control group precludes direct comparison with conventional microdiscectomy; observed improvements cannot be definitively attributed to the surgical technique. Third, follow-up was limited to a mean of 18 months, precluding assessment of late recurrence or long-term durability. Fourth, the lack of routine postoperative MRI means asymptomatic reherniations may be underreported. Finally, subgroup sizes limit the power of subtype comparisons. Future multicenter prospective controlled studies with standardized imaging follow-up are needed to validate these findings.

## CONCLUSION

Fragmentectomy may represent an effective, tissue-preserving surgical option for carefully selected patients with Carragee type I and type III LDHs, with significant improvements in pain and functional outcomes and a low complication profile. No clinically significant difference was observed between the two Carragee subtypes. Whether these outcomes are superior to those of conventional microdiscectomy cannot be established without a prospective controlled design. Further comparative studies with larger cohorts and standardized follow-up are required.

### Ethics

**Ethics Committee Approval:** The study was approved by the Atatürk University Faculty of Medicine Clinical Research Ethics Committee (approval no: B.30.2.ATA.0.01.00/110, date: 27.01.2022).

**Informed Consent:** All patients provided written informed consent prior to surgery.

### Footnotes

### Authorship Contributions

Surgical and Medical Practices: C.G., İ.G., U.Ö., M.Y.A., Ö.A., B.T.Ö., A.F.Ö., Concept: M.Y.A., Ö.A., B.T.Ö., A.F.Ö., Design: M.Y.A., A.F.Ö., Data Collection or Processing: C.G., M.A.T., İ.G., M.K.K., Analysis or Interpretation: M.A.T., F.A., M.K.K., Literature Search: M.A.T., F.A., A.F.Ö., Writing: C.G., M.A.T., F.A., M.Y.A., A.F.Ö.

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