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REVIEW ARTICLE

Do Modic changes have an impact on clinical outcome in lumbar spine surgery? A systematic literature review

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Abstract
Purpose To provide a systematic literature review of the impact of preoperative Modic changes (MCs) on the clinical outcome following lumbar spine surgery for degenerative lumbar spine disease.
Methods A PubMed search until 31 October 2015 was performed to identify publications correlating preoperative MC with clinical outcome in patients undergoing spine surgery.
Results Inclusion criteria were met by 14 articles (7 prospective and 7 retrospective studies) representing a total of 1652 surgical patients, of which at least 804 (>49 %) showed MC. Of the 14 publications, 6 concerned discectomy ($n = 607$), 1 fusion versus discectomy ($n = 91$), 3 fusion surgery ($n = 454$), and 4 total disc replacement (TDR, $n = 500$). A trend toward less improvement in low back pain or Oswestry Disability Index score was found in the discectomy studies, and a trend toward increased improvement was demonstrated in the TDR studies when MC was present preoperatively. The fusion studies were of low evidence, and showed conflicting results.
Conclusion Preoperative MC showed a trend toward a negative correlation with clinical improvement in patients undergoing discectomy for LDH and a positive correlation with clinical improvement in patients undergoing TDR for degenerative disc disease. However, it is questionable whether the differences surpass the minimal clinically important difference (MCID). In patients undergoing fusion surgery, there was insufficient evidence to draw any conclusions. Future studies should include a larger patient material, focus on MCID, and include known confounding factors of the clinical outcome of spine surgery in the analysis.

Keywords Modic changes · VESC · Low back pain · Clinical outcome · Surgery · Fusion

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Introduction

Vertebral end-plate signal changes (VESCs) are common MRI-findings in patients with non-specific low back pain (LBP), describing signal intensity changes in the corpora of the vertebrae. However, the correlation of VESC with clinical outcome in spine surgery is debated.

VESCs are also known as Modic changes (MCs) and are subdivided into Modic type 1 changes (MC1) referring to oedema-like signal intensity changes, Modic type 2 changes (MC2) referring to fat-like signal intensity changes, and the less common Modic type 3 changes (MC3) referring to sclerosis-like signal changes thought to be late stages of MC1 or MC2 [1–3].

Surgery on the lumbar discus for herniated disc has been shown to accelerate the development of MC1 [4], especially when comparing discectomy to sequestrectomy [5, 6], although conflicting results have been published as well [7–11].

Several studies have demonstrated a correlation between VESC and LBP [12–17]. Jensen et al. showed a prevalence of VESC in 43 % of patients with non-specific LBP and/or sciatica and a prevalence of VESC in 6 % of the general population [13]. Ohtori et al. associated LBP with MC through a TNF-α induced nerve in-growth of sensory fibres in the endplate [18].

The aetiology of MC largely remains unknown, although the prevailing hypothesis suggests that a degeneration of the discus results in greater axial loading and increased mechanical stress on the vertebral endplate bodies leading to inflammation and oedema [1]. Some studies support an alternative hypothesis of MC being caused by bacterial infection, most frequently Propionibacterium acnes [12, 19–21].

Lumbar disc herniation (LDH) is also considered a risk factor for developing MC, especially MC1 [22, 23]. Patients with lumbar disc herniation (LDH) have significant improvement in leg pain after surgery when conservative treatment fails. However, the type of surgical procedure performed in a patient with LDH and preoperative MC1 is up for discussion, as MC1 may influence the outcome on back pain and MC1 has been reported to be associated with spinal instability and hypermobility [10, 24]. Thus, the preoperative presence of MC1 may indicate the need of additional stabilising surgery, such as fusion surgery [10, 25–30]. In accordance, some studies even suggest that fusion increases the conversion of MC1 to MC2, probably by correcting the mechanical instability, and these changes appear to be a good indicator of satisfactory outcome after fusion surgery [26, 31]. However, one should also consider that the natural course of MC usually is a development to MC2, MC3, or normal bone marrow over time [1, 32].

The purpose of the present systematic literature review was to investigate whether there is a correlation between preoperative MC and clinical outcome in patients undergoing lumbar spine surgery, including simple discectomy procedures, instrumented fusion surgery, and total disc replacement (TDR).

Methods

A PubMed literature search until October 31, 2015 was performed using the search term “Modic Changes OR VESC”, which generated 297 articles. Adding language “English” along with “AND (surgery OR fusion)” to the search criteria yielded 119 articles.

Inclusion in the present review required the following: (1) the presence of MC on preoperative MRI was reported, (2) the included patients, or part of them, underwent lumbar surgery, and (3) the presence of preoperative MC was correlated with the clinical outcome of surgery.

All titles and abstracts—and when relevant, the full article—were reviewed by the two authors independently, identifying 14 articles fulfilling the inclusion criteria. Cross-checking the references from the included studies revealed no additional relevant articles.

Results

Table 1 summarises the objectives and findings of the included 14 publications concerning discectomy ($n = 6$), fusion versus discectomy ($n = 1$), fusion surgery ($n = 3$), and total disc replacement (TDR) ($n = 4$). The 14 articles comprised a total of 1652 surgical patients of which at least 804 (>49 %) showed some type of MC. However, the actual number of patients with MC is higher, as one article [33] did not report the number of patients showing MC. Predominant clinical outcome measures involved ODI and VAS for LBP across the studies (Fig. 1).

Patient inclusion criteria were generally based on failed conservative treatment, presentation of chronic LBP and/or radicular pain and radiological recognition of herniated lumbar disc and/or degenerative changes.

Studies of discectomy for LDH

A total of 607 patients were evaluated in the 6 articles, of which 3 were prospective studies. Approximately 325 (54 %) patients showed MC. In general, no significant difference was found preoperatively between patients with or without MC. The number of patients in the 6 articles is subgrouped according to MC types in Fig. 2 showing for each article, the number of patients and the trend toward no impact or negative impact of MC on the clinical outcome following discectomy for LDH.

Chin et al. [11] performed a prospective pilot study including 30 patients undergoing microdiscectomy. Their main objective was to determine if MC had an impact on postoperative LBP and concordant sciatica.

All patients reported leg pain greater than back pain and presented with LBP for an average of 25.6 months. Group 1 contained 15 patients with MC1 ($n = 8$) or MC2 ($n = 7$), while group 2 contained 15 patients without MC. Follow-up was only 6 months. No significant difference was demonstrated in VAS for LBP and sciatica postoperatively in the two groups. ODI was similar in both groups preoperatively but approached a significant difference at follow-up ($P = 0.09$) with best improvement in the patient group without MC. The difference in VAS or ODI between patients with MC1 and MC2 was not examined.

Sørlie et al. [8] investigated if preoperative MC1 correlated with clinical outcome in a prospective study of 178 patients undergoing microdiscectomy for LDH. The patients were divided into a group with preoperative MC1 or mixed MC1/2 ($n = 36$) and a group ($n = 142$) without MC ($n = 74$) or MC2 ($n = 68$). At 12-months follow-up,

Table 1 Summary of objectives and findings of the 14 included studies

Study	Design	Main objective	Patients (=*n*)	Patients with Modic changes *n* (%)	Modic type 1 *n* (type 2/3)	Surgical procedure	Predominant clinical outcome measures	Final follow-up (months)	Did preoperative MC correlate with clinical outcome?
Chin et al. [11]	Prospective	To examine outcome after discectomy in patients with and without Modic 1 or 2	30	15 (50 %)	8 (7/0)	Microscopic discectomy	VAS and ODI	6	Trend toward less improvement in ODI score among patients with preop. MC ($P = 0.09$)
Sørlie et al. [8]	Retrospective	To investigate if preop. MC represents a risk factor for persistent LBP after lumbar microdiscectomy	178	104 (58 %)	36[a] (68/0)	Microscopic discectomy	EQ-5D, VAS and ODI	12	Trend toward less improvement among patients with preop. MC1 compared to patients without these lesions (VAS $P = 0.06$)
Rahme et al. [34]	Retrospective	To examine the impact of MC on clinical outcome following lumbar discectomy	41	32 (78 %)	6 (26/0)	Microscopic discectomy	VAS and ODI (*P* value not available)	41	Neither the presence nor the type of preop. MC had an effect on clinical outcome
Ohtori et al. [10]	Prospective	To examine the relationship between LBP and MC1 following discectomy for lumbar disc herniation	45	23 (51 %)	23 (0/0)	Discectomy	VAS, ODI and JOAS	24	No significant difference in clinical outcome in patients with preop. MC1 compared to patients without these lesions (VAS, JOAS and ODI $P > 0.05$)
Schistad et al. [35]	Retrospective	To examine the impact of Modic Changes in pain during 1-year-follow-up in patients with lumbar radicular pain	126	100 (79 %)	10 (90[b])	Microscopic or standard discectomy	McGill, VAS and ODI	12	MC1 seemed to imply a slower recovery in patients with lumbar radicular pain (McGill $P = 0.003$[c]/0.018[d])
Lurie et al. [7]	Retrospective	To determine which baseline imaging characteristics are associated with surgical treatment effect	187	51 (27 %)[e]	17 (34/0)[e]	Discectomy	ODI	24	Preop. MC1 predicted worse outcome (ODI $P = 0.002$) and smaller treatment effect (ODI $P = 0.003$) in patients undergoing discectomy
Cao et al. [25]	Retrospective	To compare surgical outcomes of simple discectomy and IPLIF[f] in patients with LDH-MC[g]	91	91 (100 %)	42 (60/0)[a]	Discectomy iPLIF	VAS and JOAS	18	Better improvement of LBP among patients with preop. MC undergoing iPLIF compared with discectomy (VAS and JOAS: $P < 0.05$)
Ghodsi et al. [29]	Prospective	To investigate the frequency of MC and their association with clinical outcome after lumbar spinal fusion	70	52 (73 %)	31 (20/1)	Posterolateral fusion	VAS and ODI (*P* value not available)	12	Preop. MC did not correlate significantly with clinical outcome regardless of Modic type
Ohtori et al. [27]	Prospective	To investigate the change of Modic type 1 to type 2 after postero-lateral fusion surgery	33	33 (100 %)	21 (12/0)	Posterolateral fusion	VAS, ODI, and JOAS	24	No significant difference in clinical outcome in patients with preop. MC of any type (VAS, ODI and JOAS $P > 0.05$)

Table 1 continued

Study	Design	Main objective	Patients (=*n*)	Patients with Modic changes *n* (%)	Modic type 1 *n* (type 2/3)	Surgical procedure	Predominant clinical outcome measures	Final follow-up (months)	Did preoperative MC correlate with clinical outcome?
Kwon et al. [30]	Retrospective	To investigate the efficacy of PLIF with cages in patients with degenerative disc disease and MC	351	92 (26 %)	26 (55/11)	PLIF with cage	VAS	60	PLIF was found to be an effective treatment in patients with LBP even in the presence of MC. MC3 correlated with worse outcome ($P > 0.05$)
Siepe et al. [36]	Prospective	To asses clinical outcome in patients with varying baseline characteristics treated with TDR[h]	92	23 (25 %)	NA (NA/NA)	Total disc replacement	SF-36, VAS, and ODI	34	The preoperative presence of MC did not have a significant influence on clinical outcome in patients treated with TDR ($P > 0.05$)
Gornet et al. [33]	Retrospective	To determine which variables predicted clinical outcome following TDR[h]	99	NA	NA (NA/NA)	Total disc replacement	ODI and SF-36	60	Preop. MC2 predicted better clinical outcome compared to MC1 and no MC ($P = 0.037$)
Blondel et al. [37]	Prospective	To analyse the impact of MC on clinical outcome in patients undergoing TDR	221	114 (52 %)	65 (49/0)	Total disc replacement	VAS and ODI	30	Patients showing preoperative MC1 had significantly better surgical outcome compared to no MC and MC2 (VAS for radicular pain $P = 0.009$, ODI $P = 0.021$)
Hellum et al. [38]	Prospective	To evaluate if baseline characteristics predicted outcome in patients treated with TDR prosthesis or rehabilitation	88	74 (84 %)	41 (48/NA)[a]	Total disc replacement	ODI and FABQ-W[i]	24	LBP with the presence of MC is an indicator of treatment with disc prosthesis (ODI $P = 0.008$)

[a] MCI/MCII includes patients with both single type and mixed type I/II

[b] Patients with Modic type II and III were merged into one group

[c] *P* value between MC1 and MC2/3

[d] *P* value between MC1 and non-MC

[e] The amount of patients with MC undergoing surgery was not clear, which means that the numbers are based on the fraction of MC in the total cohort

[f] Instrumented posterior lumbar interbody fusion

[g] Lumbar disc herniation and Modic changes

[h] Total disc replacement

[i] Fear Avoidance Beliefs of Working Questionnaire

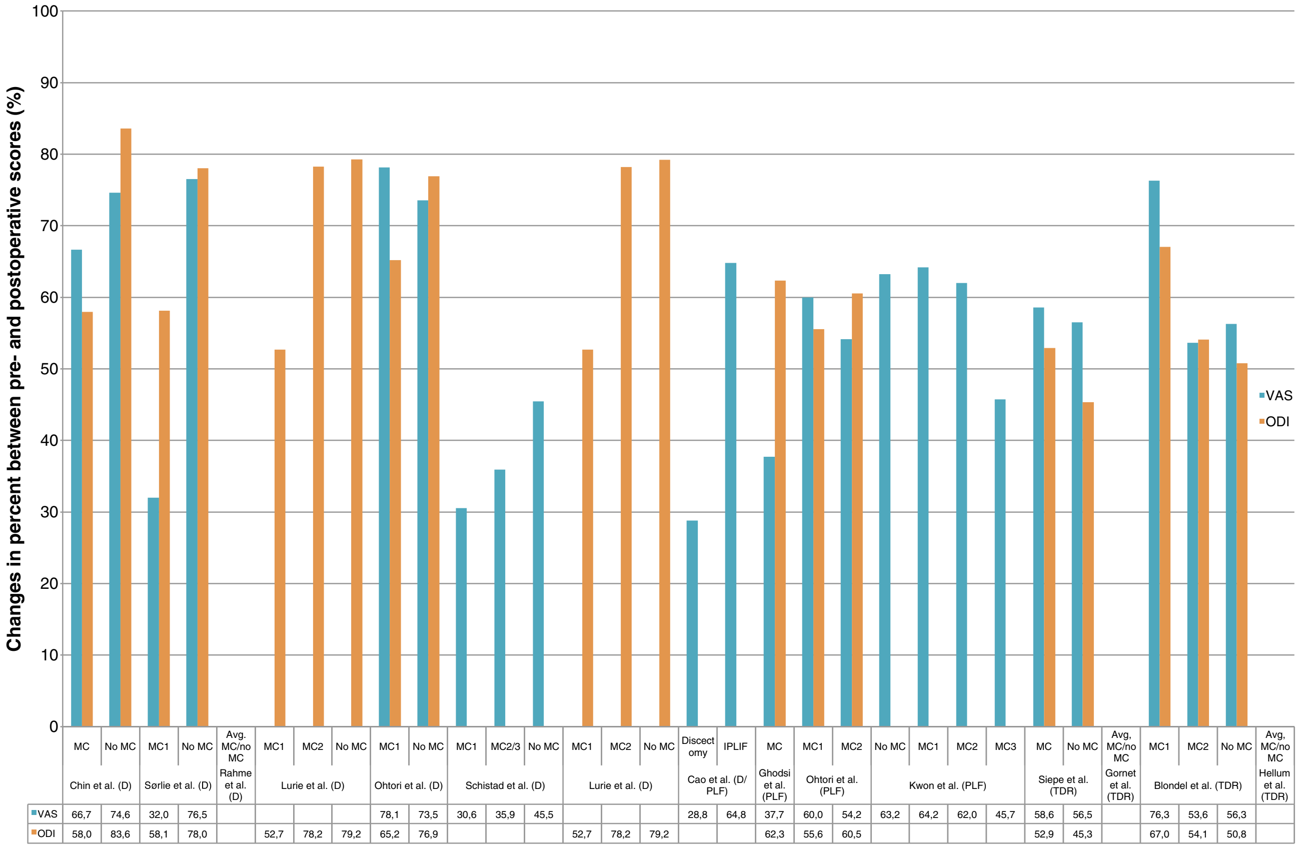

Fig. 1 Graphical representation of reported percentage change from preoperative to last follow-up in VAS for LBP and ODI. Avg. MC/no MC indicates that data on differences in MC/no MC subgroups were unavailable. *D* discectomy, *PLF* posterior lumbar (interbody) fusion, and *TDR* total disc replacement

the two groups had improved significantly in all of the outcome measures, including VAS, ODI, and EQ-5D. A clear trend toward less improvement of LBP and ODI was demonstrated in the group with MC1 compared with the no-MC/MC2 group, but statistical significance was not reached ($P = 0.06$).

A logistic regression analysis showed that smoking was the only statistical significant independent predictor of less improvement of VAS for LBP postoperatively. The authors commented that there might be synergistic effect between smoking and MC1 resulting in a significant negative impact on patient improvement of LBP. They concluded that patients with MC1 can expect less but still significant improvement of LBP after 12 months but not if they smoke.

Ohtori et al. [10] prospectively examined the relationship between preoperative MC1 and postoperative LBP in 45 patients undergoing discectomy for LDH. Patients were divided into group 1 ($n = 23$) with preoperative MC1 and group 2 ($n = 22$) without MC. Patients without MC were selected randomly from a cohort of 115 patients. Both groups had equally significant improvement of VAS for LBP after discectomy, and no significant difference was found in postoperative VAS for LBP or leg pain, Japanese Orthopaedic Association Score (JOAS) or ODI between the two groups at 24-months follow-up ($P > 0.05$, exact value not available). The authors concluded that discectomy was an equally effective treatment for LDH among patients with and without MC1.

Rahme et al. [34] retrospectively studied if lumbar microdiscectomy for LDH had an impact on preoperative MC in a cohort of 41 patients. They found an increase in the prevalence of MC from 46 to 78 % at the operated level. Comparing the groups with preoperative MC ($n = 32$, 6 MC1 and 26 MC2) and without preoperative MC ($n = 9$) showed no difference in improvement of ODI or VAS for low back and leg pain at a median follow-up of 41 months (range 32–59 months). As to the changes in MC, they concluded that following lumbar discectomy, most patients develop MC (type 2 in particular) at the operated level, possibly resulting from an acceleration of the degenerative process.

Schistad et al. [35] retrospectively examined the correlation between MC and clinical recovery in patients with

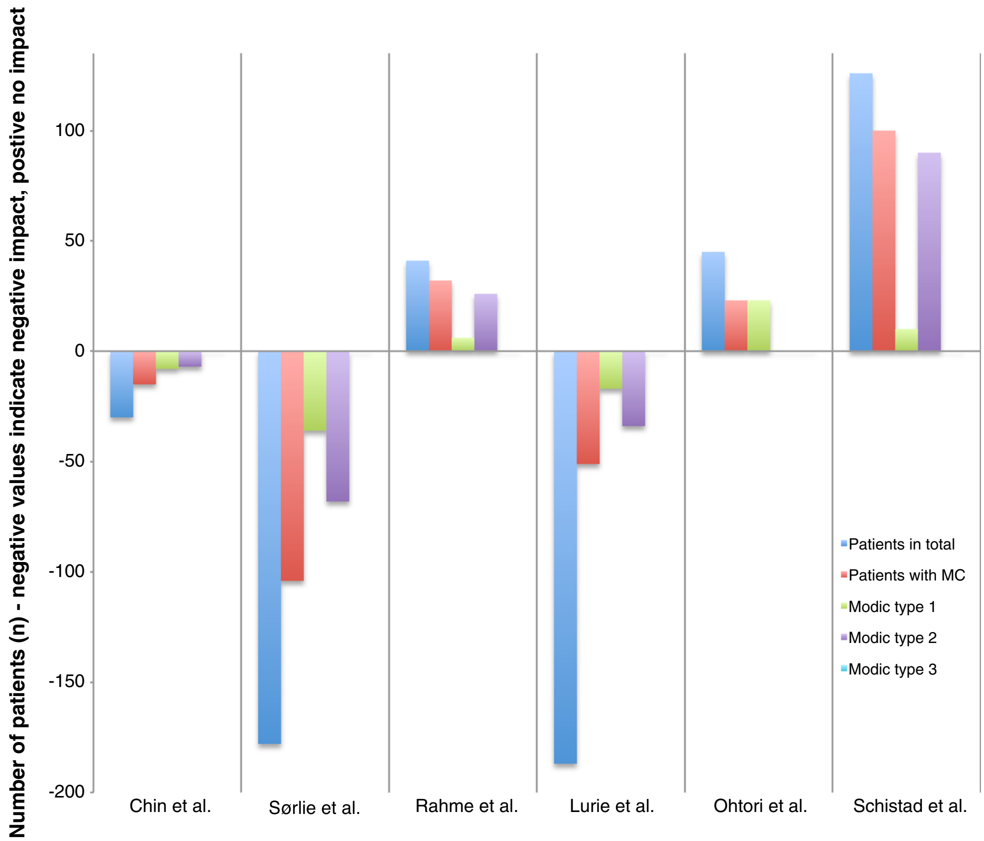

Fig. 2 *Graphical* representation of the impact of preoperative MC1 on clinical outcome at final follow-up among studies of discectomy. Positive values represent no impact and negative values represent a trend toward or a statistical significant impact of preoperative MC1 on clinical outcome at final follow-up. Lengths of the *bars* represent the number of patients in the study

lumbar radicular pain. Of the 243 participants, 30 showed MC1, 147 showed MC2, and 7 showed MC3. Patients were divided into a surgical group ($n = 126$), and a conservative group ($n = 117$) based on neurological deficits or lack of improvement from previous conservative treatment. Surgical treatment involved microdiscectomy or standard discectomy (the surgical procedure of 35 patients was not known). The authors found no statistical significant difference in clinical outcome between the surgical and conservative groups and divided all patients into three groups: no MC ($n = 59$), MC1 ($n = 30$), and MC2/3 ($n = 154$). Patients with MC1 showed significantly worse recovery in McGill sensory pain score after 6 weeks in both treatment groups ($P = 0.007$). When adjusted for, smoking correlated with VAS for LBP at baseline ($P < 0.05$) and McGill sensory pain at 6 months ($P < 0.05$). At final follow-up, there was no statistical significant difference in McGill, VAS for LBP or leg pain between the groups. They concluded that both surgically and non-surgically treated patients with lumbar radicular pain and MC1 may have a slower recovery of sensory pain.

Lurie et al. [7] performed a retrospective cohort study to determine which baseline MRI characteristics, including MC, are associated with surgical treatment effect. The study included 307 patients, of which 61 % ($n = 187$) were treated with discectomy and the remaining 39 % ($n = 120$) with conservative treatment. 27 % showed MC (MC1 accounted for 9 % and MC2 accounted for 18 %). For the present review, these percentages were used to extract an estimated number of surgically treated patients showing MC (Table 1), as this number was not mentioned in the study. The authors found that patients undergoing surgery with MC1 had worse outcome ($P = 0.002$) measured in ODI score and smaller treatment effect ($P = 0.003$) at 24 months follow-up and suggested that MC1 could be a risk factor of radicular pain distinct from the disc herniation and predict worse outcome following discectomy compared with similar patients without MC1. They concluded that patients with intervertebral disc herniation had worse surgical treatment effect if they presented with small disc herniation and MC1 compared with those with thecal sac compression $\geq 1/3$.

Based on the reported numbers in each article, we calculated the percentage change in VAS for LBP and/or ODI from preoperative to postoperative follow-up. The difference in the percentage change among patients with or without MC ranged from 8 to 20 % and is shown in Fig. 1. It was not possible to calculate the corresponding standard deviations as they were not reported in the published data.

Studies of discectomy versus fusion

Cao et al. [25] performed a retrospective study of 91 patients with LDH and MC on a single level and predominant LBP undergoing discectomy ($n = 47$) or instrumented posterior lumbar interbody fusion (iPLIF, $n = 44$). All patients were offered iPLIF but those concerned with the financial costs and operation-/implant-related complications of the iPLIF procedure underwent discectomy instead. Preoperative clinical scores were equal in the two groups. At 18 months follow-up, JOAS was significantly increased ($P < 0.05$) and VAS for LBP was significantly decreased ($P < 0.05$) in patients treated with iPLIF compared with the patients undergoing discectomy. Accordingly, LBP was similar to preoperative severity in 23.4 % of the discectomy patients and in 4.5 % of the iPLIF patients. The authors concluded that iPLIF should be recommended as surgical procedure in patients suffering from LDH and MC with LBP greater than radicular pain.

Studies of lumbar spinal fusion

In the included three studies, a total of 454 patients were evaluated, of which 39 % ($n = 177$) showed preoperative MC. Two studies were prospective and one study retrospective.

To evaluate the impact of MC on posterolateral fusion, Ghodsi et al. [29] subgrouped a prospective cohort of 70 patients with degenerative lumbar instability into no MC ($n = 18$), MC1 ($n = 31$), MC2 ($n = 20$), and MC3 ($n = 1$ patient). Segmental instability was defined as translation $\geq$3 mm or angulation $\geq$10° on lateral radiographs at flexion and extension positions. At 1 year follow-up, no differences were found in ODI and VAS for LBP (P value not available). The authors concluded that posterolateral fusion was an effective procedure in patients showing spinal instability regardless of Modic changes or type.

Ohtori et al. [27] did a prospective cohort study of patients with MC1 ($n = 21$) or MC2 ($n = 12$) with the primary objective of examining changes in MC following posterolateral fusion surgery. The two groups presented no preoperative differences in VAS, ODI, or JOAS, and no statistical significant difference in postoperative LBP was demonstrated at 2 years follow-up ($P > 0.05$, exact value not available). Based on postoperative MRI, they concluded that MC1 could be expected to convert into MC2, possibly due to a regeneration of degenerated bone marrow following the surgical stabilization.

Kwon et al. [30] retrospectively investigated the efficacy of PLIF with stand alone cages in 351 patients with degenerative disc disease (DDD) and MC. The patients were grouped into four categories: no MC ($n = 259$), MC1 ($n = 26$), MC2 ($n = 55$), or MC3 ($n = 11$). At final follow-up (mean 60 months), VAS for LBP was significantly decreased in all four groups, but MC3 patients showed less improvement compared with the other groups ($P < 0.05$, exact value not available). They concluded that stand alone PLIF with cage was an effective treatment for patients suffering from LBP and DDD with or without MC1/2, but preoperative MC3 predicted lower clinical success and fusion rate.

Studies of total disc replacement

A total of 500 surgical patients were evaluated across the four studies of which three were prospective. More than 211 patients (>42 %) showed MC.

Siepe et al. [36] prospectively assessed clinical outcome in 92 patients treated with TDR. The patients were according to MRI findings subgrouped into group 1 with DDD ($n = 40$), group 2 with DDD and nucleus pulposus prolapse ($n = 12$), group 3 with post discectomy ($n = 17$), and group 4 with DDD and MC ($n = 23$). No statistical significant difference in ODI and VAS for LBP between the control group (group 1) and group 4 was demonstrated ($P > 0.05$, exact value not available) at the mean follow-up of 34 months. They concluded that predominant LBP and DDD with or without MC could be considered as an acceptable indication for lumbar TDR.

Gornet et al. [33] aimed to determine variables that may prove useful in predicting clinical outcome following TDR in their retrospective study of 99 patients. At baseline, the authors found no difference in ODI score regardless of Modic type, but at the 5-year follow-up, a lower ODI score was present in patients showing preoperative MC2 compared with patients showing MC1 or no MC ($P = 0.037$). They concluded that many factors could contribute toward an optimal outcome of TDR and that preoperative MC2 increased the treatment effect compared with MC1 or no MC.

Blondel et al. [37] prospectively analysed the influence of MC on clinical outcome in 221 patients undergoing TDR, of which 65 presented MC1 (30 %) and 49 MC2 (22 %) on preoperative MRI. ODI and VAS for low back and radicular pain were used, and the mean final follow-up was 30 months (range 24–72). Statistical significance was reached when a univariate analysis of ODI was performed at 12 months follow-up in the patient group with MC1 compared with the non-Modic group and MC2 group (but not at final follow-up). The MC1 group had the lowest mean ODI score ($P = 0.03$). Statistical significance was also reached in VAS for radicular pain ($P = 0.009$) and ODI ($P = 0.021$) in patients with MC1 in the multivariate analysis with the non-Modic group used as reference. The authors concluded that patients with preoperative MC1 had better improvement of TDR compared with patients with MC2 or no MC.

Hellum et al. [38] evaluated if certain baseline characteristics could predict worse clinical outcome in patients treated with either rehabilitation or TDR in their prospective cohort study of 154 patients. They were randomized into a surgical ($n = 88$) group and a non-surgical group ($n = 66$). Of the 88 surgical patients, MC1 were present in 26, MC2 were present in 33, and mixed MC1 and MC2 were present in 15. Patients showing MC treated with TDR had better improvement in ODI (at least 15 points improvement) at 2-year follow-up ($P = 0.04$) compared with patients without MC. The authors concluded that shorter duration of LBP, low Fear-Avoidance Beliefs for work and MC1 or MC2 predicted better clinical outcome after treatment with disc prosthesis.

Discussion

Persisting LBP after simple discectomy for LDH is a well-known complication with a reported prevalence of 15–25 % at 2-years follow-up in a recent review [39]. An association of MC1 with LBP and unfavourable results of conservative treatment has been reported in several studies [40–44], although not in all [45]. Thus, MC1 may also influence the outcome of lumbar surgery. To the best of our knowledge, this is the first systematic literature review examining the impact of preoperative Modic changes on clinical outcome in lumbar spine surgery.

When confronted with a patient presenting lumbar disc herniation, leg and/or low back pain and MC on a preoperative MRI, results from the present review may be relevant when informing the patient of expected improvement in LBP after surgery, and when deciding upon type of surgical procedure.

A PubMed search identified 14 relevant studies (Table 1), including a total of 1652 operated patients, of which at least 804 patients (>49 %) showed preoperative MC.

The majority of the studies ($n = 607$) [7, 8, 10, 11, 34, 35] encompassed discectomy for LDH as surgical procedure. The two studies with the largest patient material found that preoperative MC1 was significantly correlated with worse outcome in ODI and smaller treatment effect ($n = 187$) [7] and significant worse outcome in LBP ($n = 178$) [8]. The findings were supported by a small pilot study [11] ($n = 30$), which was further limited by a short follow-up of 6 months and by the fact that the Modic group included both patients with MC1 or MC2. Likewise, it was limiting for the conclusions that one of the two studies with large patient material [7] was retrospective, and the other [8] actually found that only smoking was the single-independent risk factor of less improvement in LBP following discectomy. A synergistic interaction between smoking and MC1 was suggested, leading to less favourable clinical outcome. The study was further limited by the fact that 42 % of the original cohort was excluded because of unavailable or missing preoperative MRI scans, which may have introduced a selection bias. No correlation between preoperative MC1 and clinical outcome was found in two smaller studies [10, 34] ($n = 45$ and $n = 41$), of which one did not differentiate between the subtypes of MC, as the subgroups were too small to conduct a meaningful analysis. A significant association between MC1 and slower recovery of radicular pain was found in one study [35] ($n = 126$), although no difference was seen at final follow-up. However, the study was not designed to assess the effect of surgery.

Conclusively, the majority of the included patients across the discectomy studies showed a trend toward less improvement in LBP or ODI following discectomy for LDH in the presence of MC1. However, none of the studies commented on whether the difference in improvement in ODI or VAS for LBP surpassed a minimal clinically important difference (MCID). In general, for patients with chronic LBP, the MCID for improvement is typically around a 32 % reduction from baseline values [46] and the noise or imprecision of the measurement around 15–20 % of the full-scale range [47, 48]. Based on data from the articles, we calculated the percentage change in VAS for LBP and/or ODI from preoperative to postoperative follow-up. The difference in the percentage change between patients with or without MC ranged from only 8 to 20 %. It is thus very questionable whether the observed differences in clinical outcome in the present articles were of any clinically detectable level for the patients.

Is discectomy then still the optimal surgical approach in LDH patients with MC1 and primary leg symptoms, or should fusion also be contemplated? The published studies do not present sufficient evidence to answer this question. One may also argue that fusion based primarily on the preoperative presence of MC1 would be unnecessary due to the dynamic nature of MC [32]. Conversely, if MC1 are considered to be signs of mechanical instability [10, 24] and possibly corrected by fusion surgery, then an improved clinical outcome in LBP may ultimately be achieved. Ohtori et al. [27] and Vital et al. [31] supported the theory of fusion surgery leading to an acceleration of the conversion of MC1 to MC2, based on their comparison of preoperative and postoperative prevalence of MC subtypes in patients undergoing lumbar fusion surgery. Likewise, the presence of MC1, possibly implying weakening of the adjacent disc, has been suggested as a risk factor for reoperation for recurrent LDH after microendoscopic discectomy, based on an MC1 prevalence of 17.2 % in reoperated patients compared with 1.5 % in patients not undergoing additional surgery [49].

Only one study specifically aimed at comparing clinical outcome of discectomy versus fusion in the presence of MC. Cao et al. ($n = 91$) retrospectively found a significant improvement in LBP in patients undergoing iPLIF compared with patients undergoing simple discectomy [25]. However, conclusions drawn from the study were seriously restricted by (1) the included patients presented predominant LBP, thus many spine surgeons would contemplate to fuse irrespectively of the presence of MC; (2) the selection of the patients to each treatment method was biased: Concerns of the patient about cost or implant failure lead to discectomy as opposed to fusion; and (3) lack of analysis of outcome for the different subgroups of MC.

Only three fusion studies [27, 29, 30] ($n = 454$) have reported on the correlation between preoperative MC and clinical outcome. In all, the indication of fusion surgery was independent of the presence of preoperative MC, and the overall success rate of clinical improvement was acceptable. Two of the studies were prospective [27, 29] ($n = 133$), showing no correlation between clinical outcome of posterolateral fusion and preoperative MC. However, one presented a very selected material, including only patients with segmental lumbar instability [29] and the other only compared the outcome of 21 patients with MC1 with 11 patients with MC2 [27]. The third study retrospectively analysed the outcome of a more controversial treatment for LBP—stand alone PLIF—in 351 patients with DDD, and likewise found no correlation with preoperative MC1 or MC2 [30]. Thus, it may seem that preoperative MC does not influence the clinical outcome of fusion surgery. But in reality, in the context of preoperative MC, a study has yet to be published, including a significant number of patients fulfilling the prevailing criteria for fusion surgery—that is LBP refractory for conservative treatment and radiologically diagnosed lumbar degeneration, but not necessarily instability.

In four studies of patients with LBP undergoing TDR [33, 36–38] ($n = 500$), clinical outcome was correlated with the presence of preoperative MC (>42 %) and the MC subtypes, reporting conflicting results. In only one study ($n = 221$) [37], the primary aim was to test, whether MC had an impact on clinical outcome of TDR. A statistically significant higher improvement in patients with MC1 was demonstrated in two prospective studies [37, 38] ($n = 309$) and with MC2 in one retrospective study [33] ($n = 99$), but, as for the discectomy studies, it is questionable, whether the observed difference in the percentage change, ranging from 13 to 20 % (Fig. 1), surpassed the MCID. The fourth and prospective study [36] ($n = 92$) found no correlation with MC and clinical outcome but did not subgroup according to type of MC. In general, the patient populations of the TDR studies were highly selective, and a satisfactory clinical improvement was observed among patients both with and without MC. Based on the presented studies, it cannot be concluded whether MC or a certain subtype predicts better outcome when TDR is performed in patients fulfilling the reigning inclusion criteria. However, the prevailing possible correlation was between MC1 and improved clinical outcome.

In the context of MC, it could be interesting to evaluate differences in clinical outcome, when comparing surgery leaving the discus intact and surgery involving the intradiscal space. Barth et al. [6] found a correlation between postoperative developments of MC in patients with LDH undergoing standard discectomy compared with sequestrectomy. However, the surgical procedure of the included discectomy studies in the present review, either involved entering the intradiscal space [7, 9–11], or it was not described whether the disc space was entered [8, 35]. Thus, the analysis could not be made, based on the present patient material. Likewise, a comparison across the fusion studies was not possible, as the fusion procedures varied, and only one study [29] left the disc space intact.

In general, the level of evidence of the studies included in the present review was low, primarily due to small patient cohorts, affecting the possible demonstration of the impact of preoperative MC on postoperative clinical outcome. Combined with the fact that the possible difference in clinical outcome does not seem to be major, most studies were underpowered, and in accordance concluded that their findings needed confirmation in larger cohort studies. Furthermore, data known to influence the clinical outcome of spine surgery, such as smoking, comorbidities, co-interventions, educational level, compensation, and psychosocial factors [50, 51], were generally not evaluated. Only two studies looked at smoking as a confounding factor. Smoking is well acknowledged as a risk factor for less improvement following spine surgery [52–54].

Conclusion

Overall, there is currently a low quality of evidence available on the impact of preoperative Modic changes on clinical outcome of lumbar spine surgery. However, the larger the cohort examined in the individual study, the greater the tendency was toward preoperative MC1 showing a statistical significant impact on clinical outcome.

In the presence of preoperative MC1, patients undergoing discectomy for lumbar disc herniation seem to present equal improvement in leg pain, but less improvement in low back pain. However, it is questionable whether the difference surpasses a minimal clinically important difference. So far, preoperative MC alone does not seem to justify adding fusion surgery to a discectomy in patients with a herniated disc and predominant leg pain.

In patients undergoing fusion surgery for predominant LBP and radiologically diagnosed lumbar degeneration, the level of evidence of the published articles does not allow any conclusions on the impact of MC alone on postoperative clinical outcome.

In patients undergoing total disc replacement for degenerative disc disease, the published articles do not allow any conclusions on the impact of MC subtypes alone on the postoperative clinical outcome, but MC1 may be correlated with improved clinical outcome.

Future studies should include a larger patient material, state whether the observed differences in clinical outcome surpass the minimal clinically important difference, as well as include an analysis of known confounding factors with potential influence on the clinical outcome of spine surgery.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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