Are abductor muscle quality and previous revision surgery predictors of constrained liner failure in hip arthroplasty?

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Abstract Dislocation is one of the most common complications of total hip arthroplasty. The use of constrained liners is an option for the management of chronic hip instability, typically used after other methods have failed. The purposes of this study were to evaluate the overall clinical outcomes and failure rates of a tripolar constrained liner design, to assess the radiographic outcomes of its use, and to examine whether various factors such as abductor mechanism quality and history of previous revision surgeries were associated with an increased risk of failure. Forty-three hips in 39 patients who had a mean follow-up of 51 months (range, 24–110 months) were reviewed. Ninety-one percent of the hips (39 of 43 hips) did not need any revisions over the study period. A new liner was implanted in all four failed hips with concurrent revision of the acetabular cup in three cases. No further dislocations occurred in this group. The mean hip score for surviving hips was 82 points (range, 38–100 points) at final follow-up. Radiographic evaluation revealed stable, well-fixed

acetabular components in all surviving hips without progressive radiolucencies. No association was found between abductor muscle quality and the incidence of failure, but patients who experienced a constrained liner failure were more likely to have undergone at least one previous hip revision operation. Tripolar constrained acetabular liners can provide successful outcomes in patients with hip instability, although it is important not to rely on the use of a constrained liner alone in an attempt to compensate for other correctable factors such as component positioning.

Introduction

Total hip arthroplasty (THA) has been extremely successful at restoring mobility and improving quality of life in patients who have degenerative diseases of the hip. However, this intervention is not without occasional postoperative complications, the most common of which is joint instability with reported dislocation rates ranging from 0.5 to 10% following primary THA [10, 22, 26], and sometimes surpassing 20% following revision total hip arthroplasty [11, 24]. Single dislocations, especially those occurring early in the postoperative period, can often be treated nonoperatively using closed reduction and a period of bracing. However, nonoperative treatment has limited success in patients with chronic and recurrent dislocations [28], and surgical intervention may be necessary [21]. One surgical option for reducing joint instability is the implantation of a constrained acetabular liner that provides an interference fit with the prosthetic head while maintaining articulating contact between the two components. Other indications for their use include marked abductor deficiency, multidirectional intraoperative instability, and patients who have neuromuscular diseases [3, 27].

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Controversy remains about the indications for and value of constrained liners in the management of recurrent hip dislocation, largely because of the variable results reported. While some authors have reported low failure rates of 6–7% at a mean of ten years follow-up [5, 12], others have reported failure rates as high as 40% at similar follow-up [3]. Some variability in the results can be attributed to differences between component designs [29]. Additionally, it has been suggested that an increased incidence of failure may be attributed to the increased constraint inherent in the prosthetic design [25], or to suboptimal implant positioning [4].

The major purposes of this study were to review the survival rate of one type of constrained liner, and to evaluate its radiographic outcomes in terms of any progressive radiolucencies or loosening. We additionally attempted to assess whether failure was associated with the quality of the abductor muscles or the number of revision operations prior to constrained liner implantation.

Patients and methods

Prospectively-collected databases at two institutions were reviewed to identify all patients who had received a Trident constrained acetabular liner (Stryker Orthopaedics, Mahwah, New Jersey) as part of a revision total hip arthroplasty and who had a minimum of 24 months of follow-up following this procedure. Any patients who had been treated for a periprosthetic infection of the ipsilateral hip prior to constrained liner implantation were excluded. In-patient and outpatient records were reviewed to assess patient demographics, history of previous arthroplasty surgery on the ipsilateral hip, intraoperative abductor muscle status, incidence of postoperative implant failure, as well as clinical and radiographic outcomes. An institutional review board waiver was granted for the study of these patients.

The study group included 43 hips (39 patients) in 11 men and 28 women who had a mean age of 64 years (range, 19–87 years) at the time of the index surgery. Thirty-three hips had a previous history of prosthesis dislocation (between one and 13 documented dislocations), whereas the remaining ten hips were revised with a constrained liner because of intraoperative instability. The previous skin incision was used for the revision procedure whenever possible to improve cosmesis and reduce the likelihood of postoperative skin hypoperfusion or denervation. In patients who had a posterior skin incision, a posterior approach was used. In cases where a more anterior skin incision was present, an anterolateral approach (modified Hardinge) with detachment of the anterior 40% of the gluteus medius and minimus muscles was used for the revision procedure.

Details of constrained liner

The liner used has a constrained design with two nested bearing surfaces meant to maximise the range of motion of the prosthesis while minimising the risk of dislocation. It is supplied as a pre-assembled unit consisting of a polyethylene acetabular liner with a built-in flange (see Fig. 1). Inside the liner is a hollow hemispherical bipolar component slightly greater than 180 degrees in cross-sectional profile, consisting of a metal outer surface, and polyethylene inner surface. The bipolar component is constrained within the acetabular liner by a metal retaining ring snapped in place over the polyethylene flange. The inner cavity of the bipolar component is designed to receive a standard prosthetic femoral head, which is inserted in a press-fit fashion and retained within the component because of the interference fit between the diameter of the opening and the size of the femoral head. The pre-assembled unit is designed to snap into a press-fit metal acetabular shell from the same manufacturer, with the possibility of augmenting cup fixation using acetabular screws. After both the acetabular cup and femoral components are in place, the pre-assembled constrained unit is snapped by the surgeon onto the femoral head. The femoral component-constrained liner assembly is then reduced into the fixed acetabular cup and snapped into place. The result is a prosthetic hip joint with two articulating

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Fig. 1 Schematic of the tripolar constrained liner construct reviewed in this article

surfaces: one between the acetabular liner and the bipolar component and the second between the bipolar component and the femoral head. Both bearings are designed to prevent dislocation of the articulating surfaces as previously described, resulting in a constrained articulation. This double-bearing design is typically known as a tripolar constrained liner, in contrast to a bipolar constrained liner design that consists of a single articulating surface. A wide range of component sizes are available, able to accommodate femoral head sizes ranging from 22 to 32 millimeters and acetabular cup inner diameters of 48 to 72 millimeters. As a result, the existing femoral head and acetabular cup can frequently be re-used if well fixed and undamaged, with placement of a constrained unit to improve stability of the prosthetic joint.

While constrained liners appear to successfully increase stability of the prosthetic hip joint in the majority of patients, management of a dislocated constrained assembly is typically more complex than with a standard total hip arthroplasty. While there have been isolated reports of successful closed reduction of a dislocated constrained prosthetic hip joint with dislocation of the inner femoral head and otherwise well-fixed components [23], failure of the constrained assembly typically requires open surgical treatment. Additionally, dislocation is frequently associated with catastrophic failure of one of the prosthetic components, preventing their re-use. Additionally, failure at the bone–cup interface can be associated with acetabular bone loss as well as the need to increase the cup size at the time of revision to achieve stable fixation, further complicating the revision surgery.

Specific demographic data extracted and evaluated included patient age at the time of surgery, gender, side operated, and number of revision surgeries on the ipsilateral hip prior to constrained liner implantation. Abductor muscle quality was judged intraoperatively at the time of constrained liner implantation and graded according to a four-point scale ranging from 0 points (if no functional abductors were present) to 3 points (if the abductor mass had no defects and no gross fibrosis). A complete description of the grading scale, as well as the number of hips in each group, can be found in Table 1.

Patients were followed by the two senior authors (P.M.B. and M.A.M.) both clinically and radiographically for a mean of 51 months (range, 24–110 months) following their index arthroplasty. Failure of the implant was defined as

dislocation of the hip or gross loosening of the cup following constrained liner implantation. Any failures were classified by the method previously described by Guyen et al. which includes the following groups: type I failure occurs at the acetabular cup/bone interface; type II failure occurs at the acetabular cup/polyethylene liner interface; type III failure occurs at the bipolar locking mechanism; and type IV failure occurs at the inner bearing of the bipolar component [13]. Type V failures (infection) were not included in our study to avoid confounding the results because of recurrences of a periprosthetic infection. Clinical outcomes were assessed using the Harris hip score at regular outpatient visits as per our institution's standard total hip arthroplasty follow-up protocol [15]. Plain film anteroposterior and frog leg lateral radiographs were assessed at each outpatient follow-up visit for component alignment, migration as compared to previous radiographs, and the presence of progressive zonal lucencies.

All data were extracted to an Excel spreadsheet (version 11, Microsoft Corporation, Redmond, Washington) for compilation and analysis by two of the co-authors (M.G. Z. and L.H.M.). Statistical analyses were performed using SigmaStat statistical software (version 3.00, Systat Inc, San Jose California), using chi square, Fisher exact, and Mann-Whitney rank sum tests where appropriate.

Results

Thirty-nine of the 43 hips required no further re-operation of the acetabular component and/or liner over the study period, for an overall survival rate of 91%. The mean Harris hip score for these patients was 82 points (range, 38–100 points) at final follow-up. Of the four hips that experienced failure of the acetabular liner/and or cup, there were two type I failures (at the cup/bone interface), one type II failure (at the liner/cup interface), and one type III failure (at the locking mechanism; Fig. 2). The time between implantation and failure of the constrained liner ranged from one week to 23 months.

Radiographic evaluation revealed stable, well-fixed acetabular components in all 39 surviving hips without any progressive radiolucencies at final follow-up.

All four of the hips that experienced failure of the constrained liner had grade III abductors at the time of

Table 1 Grading of intraoperative abductor muscle quality

Grade	Description	Number of hips	Number of failures
0	No functional abductor mass present	3	0
I	Marked abductor defect	4	0
II	Gross fibrosis and scarring; no defect	15	0
III	No gross fibrosis; no defect	21	4

Fig. 2 Anteroposterior radiograph of the right hip in a patient who experienced type III failure of a tripolar constrained liner, originally implanted because of a history of recurrent hip dislocation

Fig. 3 Anteroposterior radiograph of the right hip of the same patient as in Fig. 2 following revision of the acetabular cup and implantation of a neutral liner. While considerable heterotopic ossification can be seen, the hip was functioning well with no instability

the index arthroplasty (no defects and no gross fibrosis). Chi-square analysis did not reveal any association between the occurrence of constrained liner failure and deficiencies in the observed intraoperative abductor muscle quality ($p=0.202$).

Two of the four hips that experienced constrained liner failure had undergone at least one revision surgery prior to the index arthroplasty, as compared to 11 of 39 of the surviving hips ($p=0.572$). The hips that failed had undergone a greater mean number of revision operations prior to constrained liner implantation when compared to the hips that survived at final follow-up (0.8 versus 0.4 revision operations; $p=0.404$).

Three of the four patients who experienced liner failure eventually underwent revision of the acetabular cup with placement of a new liner (Fig. 3), and had not experienced any further dislocations at a mean follow-up of 49 months (range, 24–72 months). A new constrained liner was implanted in two of these three revised cups, while a non-constrained liner was used in the remaining hip. The acetabular shell was left in place in the fourth patient, with placement of a new constrained liner only.

Discussion

The use of constrained liners in total hip arthroplasty has been questioned because of the variably reported success rates, which prompted our interest in performing this study. Overall, we found that this type of constrained liner

provided good outcomes in preventing recurrent dislocations in patients following total hip arthroplasty, with a 91% success rate at a mean follow-up of 51 months (range, 24–110 months). While no association was found between the quality of the abductor mechanism at the time of liner implantation and recurrent dislocation, a prior history of revision hip surgery as well as a greater number of revisions increased the risk of failure.

Some of the operated patients had a known problem with the inclination and/or version of the acetabular cup. However, as the cups were well fixed at the time of revision, the operating surgeon hoped to avoid a more complex revision procedure of the cup by placing a constrained liner in the existing cup. Three of the four failures underwent additional revision of the cup to a more appropriate alignment, including one patient who was successfully revised using a neutral liner. As a result, the authors believe that surgeons should not rely on a locking liner alone to provide stability in patients with prosthetic instability and/or recurrent dislocations, but should revise the cup to ensure optimal alignment, and re-evaluate at that point whether a locking liner needs to be used to provide additional stability.

The limitations of this study include the retrospective design, the absence of a comparison or control group, the relatively small number of hips included, the short follow-up period, and the visual rather than functional assessment of abductor muscle quality. Additionally, assessment of abductor muscle function was made

postoperatively. Only a single design of constrained liner was included in this study, and no attempt was made to compare outcomes to those achieved with alternative techniques for the management of hip instability such as a trochanteric slide osteotomy or a complete component revision. Despite these limitations, the authors believe that this study provides further evidence of the relatively good early success of this tripolar constrained liner in preventing recurrent dislocations in patients with documented or expected hip instability, and suggests that revision surgery history may be a prognostic factor for failure of the constrained assembly.

Several authors have reported good success rates with the use of constrained liners. Lombardi et al. reported promising early results with the use of an S-ROM (DePuy, Warsaw, Indiana) bipolar constrained liner design in 57 hips, finding a dislocation rate of 4.5% at a mean follow-up of 30 months [19]. Della Valle et al. found a re-dislocation rate of 16% in 55 hips treated with a Duraloc (DePuy, Warsaw, Indiana) modified bipolar constrained liner at a minimum of two years follow-up [9]. Cooke et al. reported a 14% re-operation rate in 58 hips for failure of the tripolar constrained liner at a minimum follow-up of two years (range, 2–3.6 years; mean not reported) [8], and Callaghan et al. reported a 6% acetabular component failure rate in 101 hips treated with a tripolar constrained liner at a mean follow-up of ten years (range, 6–14 years) [6]. A number of other authors have reported similar failure rates in study groups ranging in size from 31 to 389 hips, with mean follow-up times between three and ten years [5, 12, 13, 18, 25]. With a 9% failure rate at a mean follow-up time of 51 months, the results of our study are consistent with those previously reported for patients treated with a tripolar constrained liner.

Some authors have reported suboptimal success rates with the use of a constrained liner in total hip arthroplasty. Anderson et al. reported a re-dislocation rate of 29% in 21 hips treated with the use of an S-ROM (DePuy, Warsaw, Indiana) bipolar constrained liner at a mean follow-up of 31 months (range, 24–64 months) [2]. At a mean follow-up of 11 years (range, 10–18 years), Berend et al. reported a re-dislocation rate of 29% with the use of the same liner design, and an overall failure rate for all causes of 42% [3]. These failure rates are considerably higher than that found in this study and may be due to design issues. Some authors have remarked that tripolar constrained liners have more favourable success rates compared to bipolar designs, possibly because of a relatively lower constraint of angular motion [3, 29].

The association between abductor mechanism deficiency and an increased risk of dislocation of unconstrained total hip arthroplasties has been described by several authors. In an analysis of risk factors for dislocation following revision

hip arthroplasty, Alberton et al. found trochanteric non-union to significantly increase the risk of dislocation ($p < 0.001$), occurring in seven out of nine hips in the study group [1]. Kung et al. compared the effect of dislocation rates following revision total hip arthroplasty in patients with and without functioning abductors and two different femoral head sizes, at a mean follow-up of 27 months (range, 6–84 months) [17]. The authors found an overall dislocation rate of 10% in patients with intact abductors and 38% in those with absent abductors, with no difference in the incidence of dislocation on the latter group when stratified by femoral head size ($p = 0.74$). In contrast, in our study, no association was found between abductor quality and the risk of recurrent dislocation, suggesting that the constrained liners used here may have effectively compensated for the stability otherwise provided by the abductor mechanism.

A number of factors have been proposed to be associated with an increased risk of constrained liner failure and recurrent dislocation, including a history of recurrent dislocation prior to constrained liner implantation [3, 9], placing a constrained liner into a well-fixed previously implanted acetabular shell without careful scrutiny of component alignment [3, 4, 9], inadequate cementing and/or seating of the constrained liner within the acetabular cup [5, 7, 14], and failure to fill bone defects and use multiple screw fixation in otherwise well-fixed acetabular cups [12, 16]. The results of our study suggest that one or more previous revision surgeries may additionally predispose to failure of constrained acetabular liners. Ensuring postoperative integrity of the capsular tissue has been reported to decrease the incidence of dislocation following primary total hip arthroplasty performed using a posterior approach. It is possible that tissue damage resulting from multiple hip procedures compromises hip stability to a degree that in many patients cannot be sufficiently compensated through the use of a constrained liner alone. In patients who have undergone one or more revision operations prior to constrained liner implantation, a low threshold for component revision may be beneficial in ensuring optimal cup positioning and fixation, and maximising the probability of prosthesis survival. This is further supported by the finding that two of the four failures in this study group underwent subsequent revision of the acetabular cup, with no further dislocations. Further investigation is necessary to confirm this observation.

Although there has been an isolated report of successful closed reduction of a dislocated constrained total hip arthroplasty [20], the prosthesis design and modes of failure almost always necessitate open revision, a clear disadvantage over standard unconstrained total hip arthroplasties. For this reason, as well as the greater limitation of angular motion associated with constrained liners, their use should

be avoided unless the risk of postoperative hip instability is high even with properly positioned components.

In summary, the use of a tripolar constrained acetabular liner had good success rates, with 91% survival at a mean follow-up of four years. While abductor muscle quality does not appear to be associated with implant failure, a history of one or more previous revision hip arthroplasty procedures may increase the risk of subsequent dislocation. The authors further recommend that surgeons not rely on the use of a constrained liner alone in an attempt to compensate for other correctable factors such as component positioning.

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