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Liner dissociation in total hip arthroplasty: a systematic review

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Abstract. – OBJECTIVE: Liner dissociation (LD) is a rare catastrophic mechanical failure of total hip arthroplasty (THA). The study aims at reviewing the available literature regarding liner dissociations to point out their prevalence, describing any possible association and highlighting the surgical management at the time of revision.

MATERIALS AND METHODS: A systematic review of the literature was conducted from January 2002, until February 2022, according to the PRISMA guidelines. The main keywords were: "dissociation" AND "liner" OR "hip arthroplasty" OR "THA" and their MeSH terms in any possible combination. Cases of liner dissociation with all levels of evidence of any age published in indexed journals were included. The study quality of all included studies was evaluated using the MINORS criteria. The kappa (k) value was used to assess the consensus between reviewers in the selection of articles and methodological quality assessment. Finally, a sub-analysis was performed specifically concerning the elderly population.

RESULTS: Thirty-one manuscripts met the inclusion criteria of the systematic review (21 case reports and 10 case series). 124 LD in 123 patients, (53% females and 47% males) were evaluated. The overall prevalence of LD was 0.15%. The mean age at surgery was of 56.5 years (range 31-75 years). LD occurred in a primary surgery setting in 86% of the cases, at a mean time of presentation of 45.8 months after replacement surgery. 39.5% of the cups and 8.8% of the stems required revision. The mean follow-up after the revision was 18.4 months. Complications after revision occurred in 19.6% of cases, including 3 cases of re-dissociations. Re-revision was required in 13.6% of the revisions. The sub-analysis of the elderly population included 28 cases of LD identified in 10 manuscripts, with an average age of 73.5 years.

CONCLUSIONS: LD is a rare but catastrophic mechanical complication of modular THA that requires implant revision. The LD is not related to a specific prosthetic implant, liner material or design, acetabular positioning within the safe zone or age group.

Key Words:
Liner dissociation, Total hip arthroplasty, Mechanical failure.

Introduction

The introduction of modular components and their increasing use has improved the adaptability of total hip replacement surgery. Exchangeable parts allow for optimized hip offset, femoral anteversion and limb length[1,2].

A catastrophic mechanical failure of total hip arthroplasty (THA) associated with modularity implants is the failure of the fixation between the acetabular shell and the liner component, known as liner dissociation (LD). This complication has different causes and requires hip revision surgery[3].

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LD can have an early or late presentation and usually occurs without any associated trauma. Failure mechanisms include fatigue, wear and impact. Component placement and weakness of the liner locking mechanism are key contributing factors[4,5].

The first described cases concerned the Harris-Galante acetabular component (Zimmer, Warsaw, IN, USA), which has been replaced on the market with new generation prostheses[6,7].

This issue is rarely seen nowadays because of improved prosthetic designs. However, recently, cases[8] of LD have been also reported with the use of the newest prosthetic designs, indicating an increasing number or better understanding of this complication.

The Pinnacle acetabular component (DePuy, Warsaw, IN, USA) has been associated with several cases of LD, so much that by some authors[9] LD is considered a specific complication of this type of implant.

However, LD is also described in the literature[10,11] with multiple other types of implants and different component materials.

Furthermore, considering that most patients requiring total hip replacement are elderly, we studied LD with particular attention to this population[12,13].

The aim of the study is to review the available literature regarding liner dissociations to point out their prevalence.

The secondary objectives are to describe the association with different implants and components used and to highlight the surgical management at the time of revision with this type of mechanical THA failure.

Finally, a sub-analysis of elderly patients, over the age of 65, was performed.

Materials and Methods

Search Strategy and Design

A systematic review of the literature was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The research was performed in the electronic databases of Cochrane Central and Medline *via* PubMed. The main keywords were as follows: "dissociation" AND "liner" OR "hip arthroplasty" OR "THA" and their MeSH terms in any possible combination. The search was conducted from January 2002, until February 2022 (Figure 1).

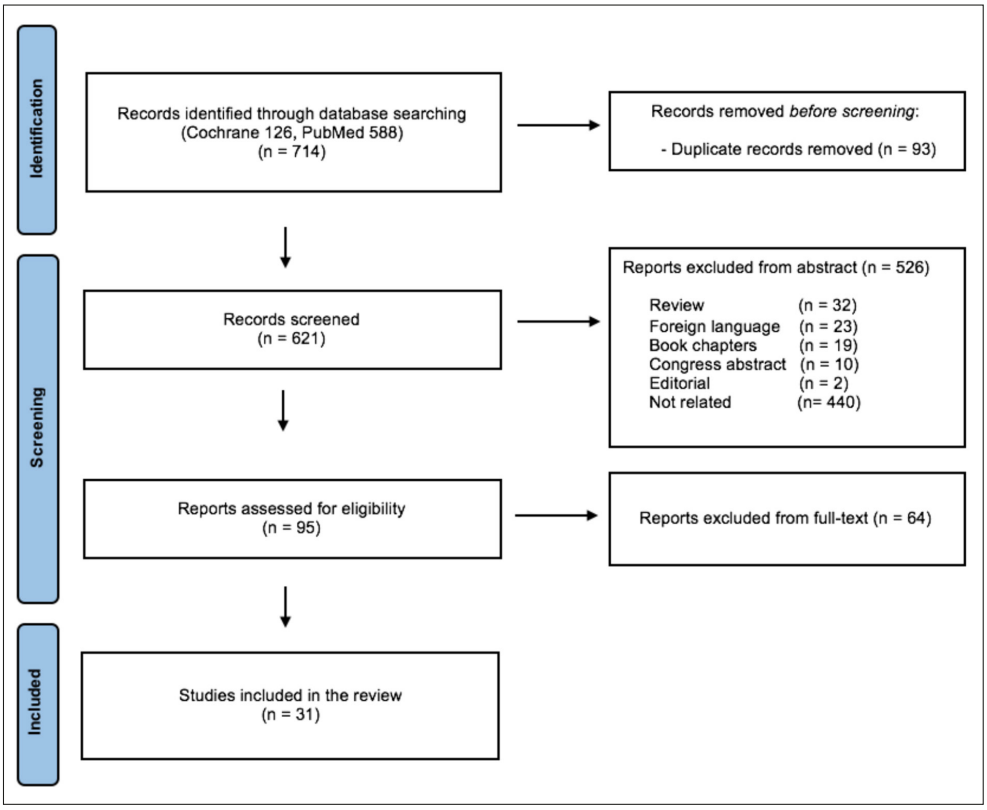

Figure 1. PRISMA flow diagram for study selection.

Eligibility Criteria

Inclusion criteria were: (1) cases of liner dissociation; (2) all levels of evidence; (3) male and female patients of any age; (4) studies published as full-text articles in indexed journals in English; (5) human studies. Exclusion criteria were: (1) surgical technical reports; (2) expert opinions or letters to the editor; (3) cadaveric or animal studies; (4) surveys; (5) reviews; (6) imaging studies.

Study Selection

The study selection of eligible publications was carried out independently by two authors (C.G. and S.R.). Articles were reviewed based on the title and abstract. After the exclusion of the ineligible articles, the full texts of the remaining were reviewed. Any discrepancies were resolved by the consensus of the senior author (C.S.). Finally, the reference lists of included articles were analyzed to identify further relevant studies to include in the systematic review.

Methodological Quality Assessment

The study quality of all included studies was evaluated using the MINORS (Methodological Index for Non-Randomized Studies) criteria. Each item was scored from 0 to 2, with maximum scores of 16 for non-comparative studies and 24 for comparative studies. Each study included was scored by 2 authors (C.G. and S.R.).

Data Extraction and Analysis

The authors used a standardized data extraction form that included the following: (1) study details – author, year, nationality, study design, level of evidence and MINORS score; (2) study population – cohort size of case series, population size, prevalence, gender, age at the time of surgery; (3) diagnosis, history information and time of presentation; (4) surgery information – type of surgery and approach; (5) implant information – cup (implant, size, screws, abduction angle, anteversion angle), liner (material, design type, size) and femoral head (material, size); (6) revision surgery information – cup, liner, stem; (7) follow-up after revision; (8) postoperative complications; (9) further re-revision. In the event of re-dissociations after the revision surgery, only the first case was considered. Finally, a sub-analysis of elderly patients was performed. Only manuscripts with a mean age at the time of the surgery greater than 65 years were included in the evaluation.

Statistical Analysis

The kappa (k) value was used to assess the consensus between reviewers in the selection of articles and methodological quality assessment. The agreement was classified as poor with $k < 0.30$, partial with $0.30 < k < 0.60$ and total with $k > 0.60$. A meta-analysis was not performed, due to the high heterogeneity between studies; however, more indirect comparisons were made.

Results

Literature Search and Study Characteristics

The initial search included 714 studies (588 from PubMed, 126 from Cochrane). After excluding the duplicates, the articles were included based on title and abstract. The full texts of the remaining 95 articles were examined according to the inclusion and exclusion criteria.

31 articles met the inclusion criteria of the systematic review[3-5,8-11,14-37] (Figure 1).

There was a high level of agreement among reviewers regarding the title (k = 0.93; 95% CI, 0.92-0.94), abstract (k = 0.91; 95% CI, 0.89-0.93), full text (k = 0.93; 95% CI, 0.92-0.94), and MINORS scores (k = 0.90; 95% CI, 0.88-0.92). The selected articles were published between 2003 and 2022. 21 case reports and 10 case series were included. All studies had level-IV evidence. The mean MINORS score was 7 (range 6-10).

Eleven studies were conducted in the USA[5,8,14,16-19,25,27,29,33], five in the UK[4,9,10,20,22], three in Japan[11,23,24], two in Canada[3,37], two in Ireland[31,34], two in New Zealand[28,32], one in Australia[35], one in France[15], one in India[36], one in the Netherlands[21], one in Spain[30], one in South Korea[26] (Table I).

Demographic Data

124 LD in 123 patients (53% females and 47% males) were evaluated. The prevalence of LD was 0.15%. The mean age at the time of the surgery was of 56.5 years (range 31-75) (Table I).

The initial diagnosis for THA was osteoarthritis (OA) in 66.7%, avascular necrosis (AVN) in 22.2%, femoral neck fracture (FNF) in 7.4%, and other causes in 3.7%. LD occurred in the primary surgery setting in 86% and revision cases in 14%. In the revision setting, the diagnosis was THA complication in 75% and failure of a previous osteosynthesis in 25% (Table II).

Table I. Characteristics of studies included in the review.

Author	Year	Nationality	Study design	Number of patients	Mean age at surgery (year)	Level of evidence	MINORS
Bhinda and Sarkar[10]	2003	UK	Case report	1	75	IV	6
Yamamoto et al[11]	2004	Japan	Case report	1	57	IV	6
Langdown et al[4]	2007	UK	Case series	1	/	IV	6
Thoms and Marwin[14]	2008	USA	Case report	1	87	IV	6
Girard et al[15]	2009	France	Case report	1	53	IV	6
Mesko[16]	2009	USA	Case report	1	76	IV	6
Barrett17	2011	USA	Case report	1	46	IV	6
Gray et al8	2012	USA	Case report	4	53.2	IV	6
Mayer et al18	2012	USA	Case report	1	70	IV	6
Sporer and Chalmers[19]	2012	USA	Case report	1	47	IV	6
Jameson et al[20]	2013	UK	Case series	10	/	IV	10
Nellensteijn et al[21]	2013	The Netherlands	Case report	1	85	IV	6
O'Neill et al[22]	2015	UK	Case report	1	83	IV	6
Kawano et al[23]	2016	Japan	Case series	2	76	IV	6
Takasago et al[24]	2016	Japan	Case report	1	64	IV	6
Yun et al[25]	2016	USA	Case report	23	64.5	IV	10
Napier et al[9]	2017	UK	Case series	8	78	IV	10
Baek et al[26]	2018	South Korea	Case series	3	48.7	IV	10
Jones et al[27]	2018	USA	Case report	2	78	IV	6
Kagan et al[5]	2018	USA	Case report	3	47.3	IV	6
Singleton[28]	2018	New Zealand	Case series	6	66.8	IV	10
Zou et al[29]	2018	USA	Case report	1	54	IV	6
Ayora et al[30]	2019	Spain	Case report	1	35	IV	6
Parkar et al[3]	2019	Canada	Case report	1	56	IV	6
McQuail et al[31]	2020	Ireland	Case report	1	53	IV	6
Gwynne-Jones and Memon[32]	2020	New Zealand	Case series	6	68.2	IV	10
Shnaekel et al[33]	2020	USA	Case series	7	59	IV	10
Keohane et al[34]	2021	Ireland	Case report	1	74	IV	6
Perkins et al[35]	2021	Australia	Case series	26	59	IV	10
Ratnakar et al[36]	2021	India	Case report	1	31	IV	6
Kostretzis et al[37]	2022	Canada	Case series	5	50.4	IV	6
Tot			**21 CR, 10 CS**	**123 (53% F, 47% M)**	**56.5 years**	**IV**	**Mean 7, Median 6**

Surgery Information at the Time of Presentation and Implant Components

LD occurred at a mean delay of 45.8 months after replacement surgery. The posterior approach was used in 43.5% of patients, the lateral approach in 30.4%, and the anterior approach in 26.1%. In 93.8% of the cases, LD onset was atraumatic, while in 6.2% a traumatic event was reported.

Most of the LD (76.6%) occurred with the Pinnacle Depuy implant; although other implants were involved (S-ROM Depuy, ABS Kyocera, Trident Stryker, EP-FIT PLUS Smith & Nephew, AMS-HA Kyocera, Bencox CorenTec, R3 Smith & Nephew, Dynasty Wright Medical, Maxera Zimmer) in 23.4%.

The mean cup size was 54 mm (median 56, mean 54, range 44-60 mm).

Regarding cup position, the mean abduction angle was 46.2° degrees and the mean anteversion angle was 18° degrees.

The liner was polyethylene (PE) in 89.5% of the cases, ceramic in 9.6%, and metal in 0.9%. Liner design was neutral in 65.1%, offset face-changing in 31.4%, and constrained in 3.5%.

The femoral head implant used was ceramic in 54.1% and metal in 45.9%. The mean femoral head size was 32.5 mm (median 28, mean 32, range 22-48 mm) (Table III, IV).

Surgery Information at the Time of Revision After Liner Dissociation

39.5% of the cups and 8.8% of the stems required revision, while the initial components were retained in the remaining 60.5% and

Table II. Characteristics of studies included in the review.

Author	Liner dislocation	Case series population	Prevalence	Original diagnosis	Surgery type	Diagnosis in revision
Bhinda and Sarkar[10]	1	/	/	/	Revision	THA dislocation
Yamamoto et al[11]	1	/	/	AVN	Primary	/
Langdown et al[4]	1	113	0.9%	OA	Primary	/
Thoms and Marwin[14] fracture	1	/	/	/	Revision	HA Periprosthetic
Girard et al[15]	2	/	/	AVN	Primary	/
Mesko[16]	1	/	/	OA	Primary	/
Barrett[17]	1	/	/	OA	Revision	THA Aseptic mobilization
Gray et al[8]	4	/	/	3 OA, 1 AVN	Primary	/
Mayer et al[18]	1	/	/	OA	Primary	/
Sporer and Chalmers[19]	1	/	/	OA	Primary	/
Jameson et al[20]	10	35,386	0.03%	/	/	/
Nellensteijn et al[21]	1	/	/	FNF	Revision	THA Aseptic mobilization
O'Neill et al[22]	1	/	/	OA	Primary	/
Kawano et al[23]	2	4,153	0.05%	1 AO, 1 dislocation	Primary	/
Takasago et al[24]	1	/	/	OA	Primary	/
Yun et al[25]	23	/	/	/	/	/
Napier et al[9]	8	3,145	0.25%	/	/	/
Baek et al[26]	3	459	0.65%	AVN	Primary	/
Jones et al[27]	2	/	/	1 OA, 1 AVN	1 Primary, 1 Revision	THA dislocation
Kagan et al[5]	3	/	/	2 OA, 1 AVN	Primary	/
Singleton[28]	6	286	2.1%	OA	Primary	/
Zou et al[29]	1	/	/	OA	Primary	/
Ayora et al[30]	1	/	/	OA	Revision	THA dislocation
Parkar et al[3]	1	/	/	FNF	Revision	Failed osteosynthesis
McQuail et al[31]	1	/	/	OA	Primary	/
Gwynne-Jones and Memon[32]	6	535	1.1%	4 OA, 2 FNF	Primary	/
Shnaekel et al[33]	7	655	1.1%	5 OA, 2 AVN	Primary	/
Keohane et al[34]	1	/	/	/	Primary	/
Perkins et al[35]	26	212	12.3%	/	/	/
Ratnakar et al[36]	1	/	/	Pipkin fracture	Revision	Failed osteosynthesis
Kostretzis et al[37]	5	3,047	0.16%	4 OA, 1 AVN	Primary	/
Tot.	**124**	**47,991**	**0.15%**	**67% OA, 22% AVN, 7% FNF, 4% other**	**86% Primary, 14% Revision**	**75% Arthroplasty complication, 25% Failed osteosynthesis**

91.2% of the cases, respectively. The presence of metallosis has been documented in 19.3% of cases.

The mean follow-up after the revision was 18.4 months (range 1-52 months). Complications after revision occurred in 19.6% of cases, including 3 cases of re-dissociations. Re-revision was required in 13.6% of the revisions (Table V).

Elderly Population

28 LD were identified in 10 manuscripts, with an average age of 73.5 years. The primary diagnosis in 77.8% of cases was OA. LD occurred in primary settings in 90% of cases. The mean presentation time was 45 months after replacement surgery. The most frequently used approach was the lateral approach in 73.7% of cases. In all cases, the LD occurred in the absence of known trauma. Metallosis was observed in 29.6% of cases (Table VI).

Discussion

The most important finding of the present study is that LD is an uncommon complication

Table III. Surgery information at the time of presentation.

Author	Approach	Time of presentation (months)	Trauma (yes/no)	Cup implant	Femoral head implant	Mean femoral head size (mm)
Bhinda and Sarkar[10]	/	9	No	S-ROM Depuy	/	/
Yamamoto et al[11]	/	44	No	ABS Kyocera	Ceramic	28
Langdown et al[4]	Posterior	/	No	Trident Stryker	/	/
Thoms and Marwin[14]	Lateral	1.5	No	Trident Stryker	/	22
Girard et al[15]	Posterolateral	41	No	EP-FIT PLUS Smith & Nephew	Metal (CoCr)	28
Mesko[16]	/	23	No	Pinnacle Depuy	Metal (CoCr)	32
Barrett[17]	/	34	No	Pinnacle Depuy	/	/
Gray et al[8]	3 Posterolateral, 1 Anterior	13.1	No	Pinnacle Depuy 1 Ceramic	1 Metal (CoCr),	32
Mayer et al[18]	Lateral	53	No	Pinnacle Depuy	Metal (CoCr)	32
Sporer and Chalmers[19]	Posterolateral	4	No	Pinnacle Depuy	Metal (CoCr)	36
Jameson et al[20]	/	/	No	Pinnacle Depuy	/	/
Nellensteijn et al[21]	Lateral	36	No	Trident Stryker	/	/
O'Neill et al[22]	Posterolateral	60	No	Pinnacle Depuy	/	/
Kawano et al[23]	Posterolateral	117	No	AMS-HA Kyocera	Metal (CoCr)	26
Takasago[24]	Posterolateral	120	No	AMS-HA Kyocera	Ceramic	28
Yun et al[25]	/	48	No	Pinnacle Depuy	/	31.3
Napier et al[9]	Posterolateral	57.2	No	Pinnacle Depuy	/	/
Baek et al[26]	Posterolateral	0	No	Bencox CorenTec	Ceramic	36
Jones et al[27]	/	36	1 No, 1 Yes	Trident Stryker	Metal (CoCr)	/
Kagan et al[5]	Anterior	25	2 No, 1 Yes	Pinnacle Depuy	Ceramic	32
Singleton[28]	Lateral	10.5	No	Pinnacle Depuy (Stainless steel)	Metal	28
Zou et al[29]	Posterolateral	96	No	Smith and Nephew (Oxynium)	Metal	/
Ayora et al[30]	Posterolateral	24	No	Pinnacle Depuy	Ceramic	28
Parkar et al[3]	Posterolateral	60	Yes	R3 Smith & Nephew	Metal (CoCr)	36
McQuail et al[31]	Anterolateral	24	No	Pinnacle Depuy	Ceramic	32
Gwynne-Jones and Memon[32]	1 Posterolateral, 5 Lateral	37.2	No	Pinnacle Depuy 1 Metal (CoCr)	5 Ceramic, 28.7	
Shnaekel et al[33]	Anterior	73	8 No, 1 Yes	Dynasty Wright Medical	5 Metal (CoCr), 4 Ceramic	39.6
Keohane et al[34]	Posterolateral	108	No	Pinnacle Depuy	Metal (CoCr)	32
Perkins et al[35]	/	38	No	Pinnacle Depuy 9 Metal (CoCr)	17 Ceramic,	32
Ratnakar et al[36]	Posterior	18	No	Pinnacle Depuy	/	/
Kostretzis et al[37]	/	66.2	No	Maxera Zimmer	Ceramic	46.4
Tot	**44% P, 30% L, 26% A**	**45.8 months**	**94% , atraumatic 6% traumatic**	**77% Pinnacle depuy, 23% other**	**54% ceramic, 46% metal**	**Mean 32.5, Median 28**

of THA, as confirmed by the low prevalence (0.15%) within the case series present in the review. Furthermore, the LD is not associated with a specific type of implant or material or with a mispositioning of the components[38-40]. In fact, in the current study, the mean abduction angle (46.2°) and the mean anteversion angle (18°) are within the safe zone to match the native hip motion and avoid impingement.

Modularity allows great versatility and the possibility to adapt surgical strategies and steps according to the local anatomy. This adaptability is even more important in the setting of revision surgeries when joint stability, limb equality and physiological range of motion are harder to achieve[1].

However, there are some potential drawbacks related to the introduction of different interfaces, such as wear and corrosion of the components[2].

A complication, specifically associated with modularity, is the dissociation of the acetabular liner. LD is an uncommon mode of mechanical failure of the liner from its acetabular shell, that requires revision surgery[3].

Table IV. Implant components information.

Author	Mean cup size (mm)	Liner material	Liner design type	Mean cup abduction angle (°)	Mean cup anteversion angle (°)
Bhinda and Sarkar[10]	/	PE	Modular Poly Dial	/	/
Yamamoto et al[11]	46	Ceramic	/	/	/
Langdown et al[4]	/	Ceramic	/	/	/
Thoms and Marwin[14]	/	PE	Constrained	/	/
Girard et al[15]	/	PE	PE sandwich housing a low-carbon metallic insert	/	/
Mesko[16]	54	PE	Neutral	/	/
Barrett[17]	46	PE	Offset face-changing	64°	/
Gray et al[8]	51	PE	Offset face-changing	55°	21.5°
Mayer et al[18]	52	PE	Neutral	52.5°	22.5°
Sporer and Chalmers[19]	54	Metal	/	/	/
Jameson et al[20]	/	/	/	/	/
Nellensteijn et al[21]	/	PE	/	/	/
O'Neill et al[22]	54	PE	/	45.1°	10.7°
Kawano et al[23]	47	PE	Neutral	49°	13.5°
Takasago et al[24]	52	Ceramic	/	/	/
Yun et al[25]	/	PE	15 Neutral; 8 offset face-changing	47°	20°
Napier et al[9]	/	/	/	50.5°	12.1°
Baek et al[26]	56	Ceramic	/	/	/
Jones et al[27]	/	PE	Tripolar constrained	/	/
Kagan et al[5]	52	PE	Neutral	39.6°	24.7°
Singleton[28]	56.3	PE	Neutral	41.8°	/
Zou et al[29]	/	PE	/	/	/
Ayora et al[30]	44	PE	Offset face-changing	38°	36°
Parkar et al[3]	60	PE	Neutral	/	/
McQuail et al[31]	52	PE	/	/	/
Gwynne-Jones and Memon[32]	55	PE	5 Neutral,		
1 Offset face-changing	39°	10°			
Shnaekel et al[33]	56.9	PE	Neutral	/	/
Keohane et al[34]	54	PE	Neutral	/	/
Perkins et al[35]	/	PE	14 Neutral,		
12 Offset face-changing	/	/			
Ratnakar et al[36]	/	PE	/	48°	34°
Kostretzis et al[37]	57.2	Ceramic	/	41.6°	16.8°
Tot	**Mean 54, Median 56**	**90% PE, 10% Ceramic, 1% Metal**	**65% Neutral, 31% Offset face-changing, 4% Constrained**	**46.2°**	**18°**

The results of the current study have shown that LD is a complication that affects adult patients (mean 56.5, range 31-75 years) of both genders (53% female and 47% male) after a mean delay from the replacement surgery of almost 4 years (45.8, range 0-120 months), especially in the primary setting (86% primary THA) (Table II).

The diagnosis of LD can be difficult, because the presentation of symptoms is subtle, without prior trauma (93.8% atraumatic LD in the current study), and patients can occasionally maintain acceptable mobility after dissociation[34].

Furthermore, LD can create the appearance of a correctly positioned THA in the anterior-posterior X-ray view. Instead, the presence of an eccentrically located femoral head showing contact with the acetabular metal shell, and specific imaging signs such as the "crescent sign" and the "tram track sign", can help the diagnosis. Those findings are described as radiolucency medial to the femoral neck on X-rays views and curved double hyperechoic lines anteromedial to the femoral neck on ultrasound examination, respectively[41,42].

The first cases described in the literature refer to Harris-Galante Porous acetabular components

Table V. Surgery information at the time of revision.

Author	Cup revision (yes/no)	Stem revision (yes/no)	Metallosis at time of surgery (yes/no)	Mean follow-up after revision (months)	Complications after revision (yes/ no)	Re-revision (yes/ no)
Bhinda and Sarkar[10]	No	No	/	/	No	No
Yamamoto et al[11]	/	/	/	/	/	/
Langdown et al[4]	/	/	/	/	/	/
Thoms and Marwin[14]	No	Yes	No	1.5	Yes (1 re-dissociation)	Yes
Girard et al[15]	Yes	No	2 Yes	34.5	Yes (dislocation), No	No
Mesko[16]	No	No	/	9	No	No
Barrett[17]	No	No	/	12	Yes (1 dislocation)	No
Gray et al[8]	Yes	No	/	27	No	No
Mayer et al[18]	Yes	No	Yes	12	No	No
Sporer and Chalmers[19]	Yes	Yes	Yes	36	No	No
Jameson et al[20]	/	/	/	/	/	/
Nellensteijn et al[21]	No	No	/	/	/	/
O'Neill et al[22]	Yes	No	Yes	/	No	No
Kawano et al[23]	Yes	No	/	/	/	/
Takasago et al[24]	No	No	Yes	29	Yes (pseudotumor due to metallosis)	Yes
Yun et al[25]	8 Yes, 15 No	/	/	/	/	/
Napier et al[9]	3 Yes, 5 No	No	6 Yes, 2 No	13.6	2 Yes (1 Dislocation, 1 re-dissociation)	2 Yes, 6 No
Baek et al[26]	1 Yes, 2 No	No	No	52	No	No
Jones et al[27]	No	No	1 Yes, 1 No	12	No	No
Kagan et al[5]	No	No	/	11.4	Yes (1 infection)	1 Yes
Singleton[28]	No	No	/	15.5	No	No
Zou et al[29]	Yes	Yes	Yes	/	No	No
Ayora et al[30]	No	No	Yes	12	No	No
Parkar et al[3]	Yes	No	Yes	1	Yes (1 Dislocation)	Yes
McQuail et al[31]	No	No	/	/	/	/
Gwynne-Jones and Memon[32]	No	5 No, 1 Yes	/	/	No	No
Shnaekel et al[33]	5 Yes, 4 No	3 Yes, 6 No	6 Yes, 3 No	/	Yes (2 re-dissociations)	2 Yes/5 No
Keohane et al[34]	Yes	No	/	12	No	No
Perkins et al[35]	/	/	/	/	/	/
Ratnakar et al[36]	No	No	/	12	No	No
Kostretzis et al[37]	Yes	/	/	12	No	No
Tot	**39.5%**	**8.8%**	**19.3%**	**18.4 months**	**19.6%**	**13.6%**

(Zimmer, Warsaw, IN, USA) and has been attributed to the failure of the locking mechanism, with which the liner is fixed on the acetabular shell[6].

The failure of the locking mechanism may be the result of micro-movements between the liner and the acetabular shell and impingement with the femoral component, which can cause wear or abnormal deformation of the liner, resulting in dissociation of the liner and implant failure[7].

With the newest implants on the market, a reduction in the rate of LD was expected; however, some cases are still reported. Several cases[5,9] have involved the Pinnacle acetabular component (DePuy, Warsaw, IN, USA), suggesting a possible specific problem associated with this particular implant.

A 2008 Food and Drug Administration (FDA) database review showed 41 cases of LD with the Pinnacle acetabular component[25].

In 2013, the National Joint Registry of England and Wales reported a 0.04% polyethylene LD rate with the DePuy Pinnacle/Corail system in 35,386 procedures[20].

Furthermore, in 2017, an incidence of 0.17% was described as a concern because of the underestimation of the frequency of liner dissociation[9].

The Pinnacle locking mechanism has been considered as a possible cause of the failure by

Table VI. Sub-analysis group of elderly patients.

Author	Number of patients	Mean age at surgery	Diagnosis	Surgery type	Approach	Time of presentation	Cup implant	Mean cup size	Material of liner	Mean femoral head size	Cup revision	FU after revision	Complications after revision	Re-revision after revision	Metallosis at time of surgery
Thoms and Marwin[14]	1	87	/	Revision	Lateral	3	Trident Stryker	/	PE	22	No	1.5	1re-dissociation	1	
Mesko[16]	1	76	OA	Primary	/	23	Pinnacle Depuy	54	PE	32	No	9	No	No	
Mayer et al[18]	1	70	OA	Primary	Lateral	53	Pinnacle Depuy	52	PE	32	Yes	12	No	No	Metallosis
Nellensteijn et al[21]	1	85	FNF	Revision	Lateral	36	Trident Stryker	/	PE	/	No	/	/	/	
O'Neill et al[22]	1	83	OA	Primary	Posterolateral	60	Pinnacle Depuy	54	PE	/	Yes	/	No	No	Metallosis
Kawano et al[23]	2	76	1 AO, 1 dislocation	Primary	Posterolateral	117	AMS-HA Kyocera	47	PE	26	Yes	/	/	/	
Napier et al[9]	8	78	/	/	Posterolateral	57.25	Pinnacle Depuy	/	/	/	3 yes, 5 no	13.6	1 dislocation, 1 re-dissociation	2	6 metallosis
Singleton[28]	6	66.8	OA	Primary	Lateral	10.5	Pinnacle Depuy	56.3	PE	28	No	15.5	No	No	
Gwynne-Jones and Memon[32]	6	68.2	4 OA, 2 FNF	Primary	1 posterolateral, 5 lateral	37.2	Pinnacle Depuy	55	PE	28.7	No	/	No	No	
Keohane et al[34]	1	74	/	Primary	Posterolateral	108	Pinnacle Depuy	54	PE	32	Yes	12	No	No	
Tot	**28**	**73.5 years**	**78% OA, 17% FNF, 5% other**	**90% primary, 10% revision**	**74% L, 26% P**	**45 months**	**86% Pinnacle depuy, 14% Other**	**54 mm**	**100% PE**	**28 mm**	**29% Yes, 71% No**	**13.2 months**	**16%**	**12%**	**29.6%**

several authors[16,18], as it is had been found to be less efficient than other designs and associated with breakage of the peripheral locking tabs.

Perkins et al[35] performed a dissociation test comparing Pinnacle (Depuy) and Trident (Stryker), reporting worse results with Pinnacle liners, which showed a lever-out strength that reduces significantly over time compared to Trident liners.

In contrast, Gray et al[8] found no obvious damage to the locking mechanism in their cases[8]. Furthermore, as highlighted by Bonilla and Bautista[43], the Australian and the United Kingdom registries showed a 10-year survival rate of 94% using this implant with a low revision rate, which is comparable with the most durable implants[44,45].

In any case, 23.4% of the reported LD in literature involved implants from other companies, such as S-ROM (Depuy Synthes, Warsaw, IN, USA), ABS or AMS-HA (Kyocera, Med, Osaka, Japan), Trident (Stryker, Mahwah, NJ, USA), R3 or EP-FIT PLUS (Smith & Nephew, Memphis, TN, USA), Bencox (CorenTec, Seoul, Korea), Dynasty (Wright Medical Technology Inc, Arlington, TN, USA) and Maxera (Zimmer, Warsaw, IN, USA) (Table III).

Since LD occurs with different implants, it can be presumed that this mechanical complication of THA is due to causes related to hip replacement and not to the failure of a specific prosthetic implant.

In the present study, LD occurred with different liner materials, most using polyethylene (89.5%), while the others using ceramic (9.6%) or metal (0.9%). Furthermore, LD occurred with neutral designs (65.1%), offset face-changing liners (31.4%) or constrained liners (3.5%) (Table IV).

Regarding the association with the surgical approach, the present systematic review showed that LD is not associated with a specific approach, as similar LD rates are reported for the three most common approaches (Table III).

In contrast, Singleton[28], in a comparative study between 88 THA performed with the lateral approach and 173 THA with the posterior approach, found that all cases of LD occurred in the lateral approach group.

Overall, there is no clear cause for the dissociation of the liner in total hip replacement.

Martinez-Ayora et al[30] proposed a role for hip dysplasia with anatomical abnormalities, which might contribute to impingement between the liner and the femoral component.

The movements that may trigger dissociations have been described and it has been postulated that rotational torque associated with larger femoral heads may be associated with a liner failure. Five of the 8 dissociations in Napier's report, described the triggering movement as rising from a squat position[9].

Also, Mayer et al[18] reported repetitive squatting in the described patient. In contrast, Singleton[28] associated hip flexion with the triggering dissociation, and half of the cases reported subjective episodes of instability before the decisive dissociation.

Another possible issue is an iatrogenic or intraoperative error. In fact, an association between early dissociations (within the first two years) and acetabular malposition has been found[10,14,25]. Gray et al[8] reported excessive abduction of the acetabular component in all their cases.

Also, Napier et al[9] reported malpositioning in 2 of their 4 cases, with an overly abducted acetabulum, which had multiple episodes of dissociations. Furthermore, Gwynne-Jones and Memon[32] reported a case of malpositioning, in which the error occurred on the femoral side with resultant posterior impingement.

An intraoperative incompletely seated polyethylene puts the liner at risk for failure. The manufacturer's recommendations aim at a scrupulous inspection of every derotational tab for complete seating. There seems to be a need to create a more objective verification method for the locking mechanism engagement[3,4,26].

Treatment should be individualized, with regards to the stability of the fixation and the position of the components or impingement. In the current study, 39.5% of the cups and 8.8% of the stems required revision, while, in most cases, the initial components were retained.

Some authors suggest routine acetabular revision, since the polyethylene substitution may be insufficient to prevent further problems because similar mechanical forces will interact with the new liner[16].

A possible catastrophic complication associated with LD is metallosis, which accounts for approximately 5% of total hip replacement complications. It is caused by the release of debris from the prosthetic components due to the wear of the implant. While it is generally associated with metal-on-metal implants, it has also been described in the non-metal THA[46,47].

In the current study, metallosis is documented in 19.3% of cases. Extensive metallosis and damage to the implant components were observed more frequently in cases with delayed diagnosis[9].

A sub-analysis of elderly patients over the age of 65 was performed because this age group is the most frequently exposed to THA surgery[12,13].

Elderly patients are frailer because they are more prone to embolic complications, periprosthetic infections and acetabular fragility fractures[48-50]. Similar LD results to the overall population were observed in this population. As widely demonstrated in the literature, this type of age group patients could have benefits from revision surgery using dual mobility cups[51-53].

Limitations

The main limitation of the study is the presence of a low level of evidence, as evidenced by the mean MINORS score of seven. Furthermore, as most of the manuscripts are case reports and involve different implants, it is not possible to obtain a global incidence of LD. A further limitation of the study is the absence of a statistical comparison between the different age subgroups of patients.

Conclusions

Liner dissociation is a rare but catastrophic mechanical complication of modular THA, that requires implant revision. LD is not related to a specific prosthetic implant, liner material or design, surgical approach, or acetabular positioning within the safe zone.

LD occurs in most cases in the absence of trauma. Revision of the cup is needed in almost 40% of patients, while in a few cases a revision of the stem is required. Metallosis could be associated with LD, particularly in cases of delayed diagnosis. LD results similar to those in the general population have been observed in elderly patients.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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None.

Ethics Approval

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Orthopedic and Traumatology Institute of the Fondazione Policlinico Universitario A. Gemelli IRCCS - Sacred Heart Catholic University, Rome, Italy.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Authors' Contribution

CG and SR wrote the manuscript. GC, LP, EG, FM, MM and VB collected the data. KC and MMG provided data analysis. SC, ER and GM are the senior authors who designed the study and reviewed the manuscript. The authors approved the submitted version.

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