

Clip as Nidus for Choledocholithiasis after Cholecystectomy—Literature Review

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ABSTRACT

Background and Objectives: Foreign material in the biliary tree may serve as a nidus for stone formation and would usually present as choledocholithiasis with jaundice or cholangitis. Overall it is a rare occurrence, but there are many anecdotal reports of ingested matter or surgical material such as suture or clips causing biliary stones. Especially interesting are the cases in which there is migration of a metallic clip used in laparoscopic cholecystectomy. Cholecystectomy is such a common operation that although the phenomenon is rare, it is important because it is preventable, and as such a review of the topic seems worthwhile.

Methods: The available literature was searched using the EMBASE and Ovid databases and reviewed. The various devices and sutures used to occlude the cystic duct in laparoscopic cholecystectomy are discussed with reference to their safety.

Results and Conclusion: We found that the harmonic scalpel is a reasonable alternative with minimal complications but is however limited by cost. Electrosurgical vessel-sealing, ultrasonic shears, absorbable sutures such as endoloops (PDS), and polymer clips as well absorbable magnesium-calcium-zinc alloy clip are discussed.

Key Words: clip migration, laparoscopic cholecystectomy, biliary surgery, surgical clip, electrosurgical vessel-sealing devices, ligasure, ultrasonic coagulating shears, harmonic scalpel, absorbable clips

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INTRODUCTION

Laparoscopic cholecystectomy (LC) for gallstones is a common procedure with a low rate of complications. It superseded open surgery about 30 years ago because it was obviously superior despite initial concerns about a higher rate of bile duct injury. LC involves identifying and clipping the cystic artery and duct before dividing these structures to excise the gallbladder. Usually a metallic or polymer clip is used to ligate the cystic duct because it is easier than suture ligation. In the traditional open approach, these structures were usually ligated with absorbable sutures. In the days before clips, some surgeons (and old textbooks) cautioned against the use of nonabsorbable sutures such as silk, anywhere within Calot's triangle.

Choledocholithiasis due to a metallic clip used during LC is rare as when it occurs it should be easily recognizable because the imaging will be diagnostic (**Figure 1**). The pathophysiology is unknown, but ischemia and chronic inflammation with erosion are postulated. Two cases are shown to illustrate the phenomenon (**Figures 2, 3, and 4**) and a literature review is presented. In addition, a literature review of alternatives to nonabsorbable clips for the cystic duct is used as the basis for a discussion on this topic.

Methods and Results

The available literature was searched using the EMBASE and Ovid databases and reviewed. A search strategy was developed to identify further incidences of clip choledocholithiasis.

The terms clip, choledocholithiasis, and cholecystectomy were applied across the databases of EMBASE and Ovid. The search terms were combined using the AND function. The search yielded 95 results. Duplicates were removed to yield 67 records. Twenty-four records were unrelated to complications postcholecystectomy and removed, leaving 42 records. Two nonenglish reports were removed because no abstracts or full-text translations were readily available. Twenty-one publications were identified from reviewing the references of the initial 40 publications and Google Scholar. Attempts were made to retrieve the full text of all relevant

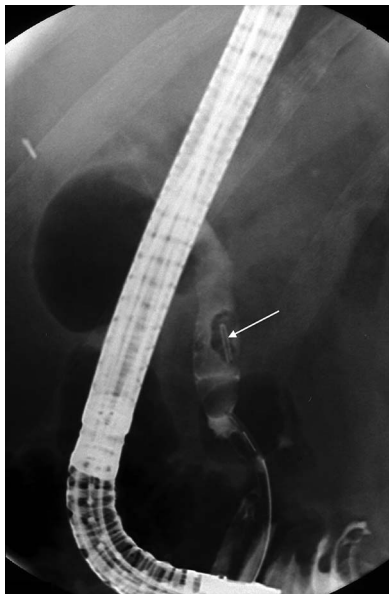


Figure 1. Obstructive jaundice in a 70-year-old man, 12 years after laparoscopic cholecystectomy. ERCP cholangiogram clearly shows the presence of a metallic clip in the stone (arrow).

publications. In circumstances in which full articles were not available, only abstracts written in English were reviewed and excluded if inadequate details were provided. A summary of these results can be seen in **Table 1**.

A literature search was also undertaken to explore the possible alternatives to ligate the cystic duct, namely absorbable materials and electro-surgical clipless alternatives. The terms cholecystectomy, clip, and absorbable were chosen to identify absorbable materials as suitable alternatives to titanium clips. The AND function was applied to yield 68 results. Duplicates were removed to yield 49 records. Seventeen articles were of no relation, four were not of the English language, six articles were case reports, and two had inadequate details within abstracts. These articles were excluded, yielding a total of 20 articles.

The terms cholecystectomy and ligasure with the AND function yielded 94 articles. Twenty-one duplicates removed. Sixty of those records were removed because they were related to gastric resection, splenectomies, hepatectomies, and hysterectomies. Two publications were in a foreign language and one had insufficient details even within abstract. This yielded a total number of 10 articles.

The terms cholecystectomy AND electro-surgical yielded 96 results. Thirty-two were duplicates. Fifty-nine were unrelated to cholecystectomies or pertaining gallbladder bed dissection but not ligation of the cystic duct. Two of



Figure 2. A 68-year-old man presented with cholangitis having had open cholecystectomy 35 years before. Computed tomography showed a metallic clip in the bile duct with proximal dilatation (Toshiba Aquilion Prime 160 slice).

the remaining articles were in a foreign language with inadequate details on abstract, yielding a total of three articles. A summary of this search can be seen in **Table 2**.

DISCUSSION

Two cases of clip induced choledocholithiasis diagnosed and treated by the authors were the basis for this review (**Figures 1–4**). The literature shows that nonabsorbable clips used during biliary surgery can migrate and cause various complications. If the clips enter the common bile duct,¹ it could cause choledocholithiasis,^{2–31} leading to cholangitis.^{32–48} If the clip embeds itself into the duodenal wall, it could cause duodenal ulceration.^{49–52} Clips may cause complications such as Mirizzi syndrome postcholecystectomy⁵³ or even rarely result in choledochoduodenal fistula.^{33,54} The time frame of these complications have been reported between 2 weeks and up to 35 y after postcholecystectomy.

Various foreign materials have been reported as the nidus of a gallstone including clips or sutures used during an operation or ingested material such as vegetable or plant matter. Ingested material can more easily enter the biliary system in which there has been surgery such as biliary enteric anastomosis or sphincterotomy; however, it has

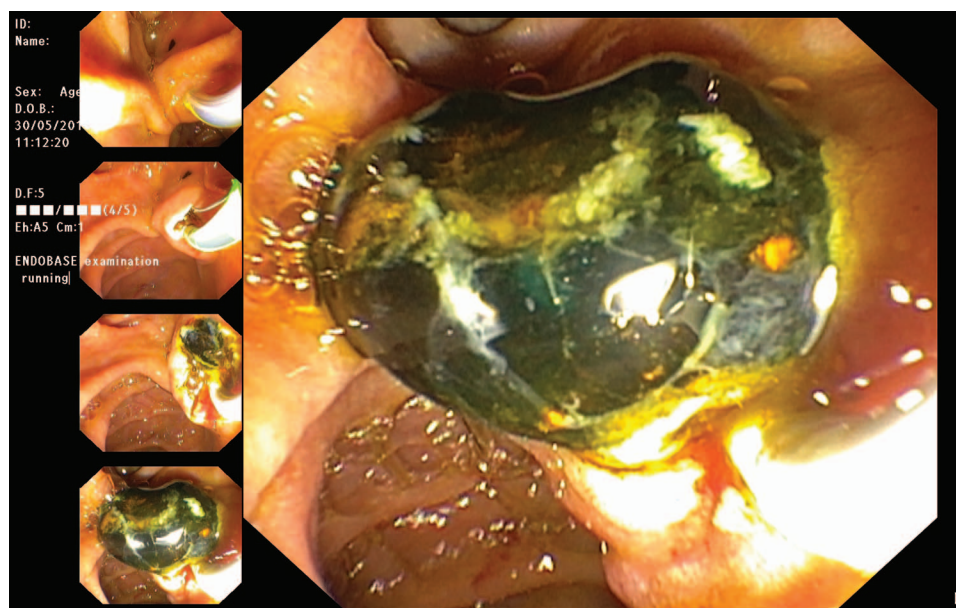


Figure 3. Endoscopic view of the same patient after endoscopic sphincterotomy and balloon trawl removal of the stone with the clip just visible within the stone.

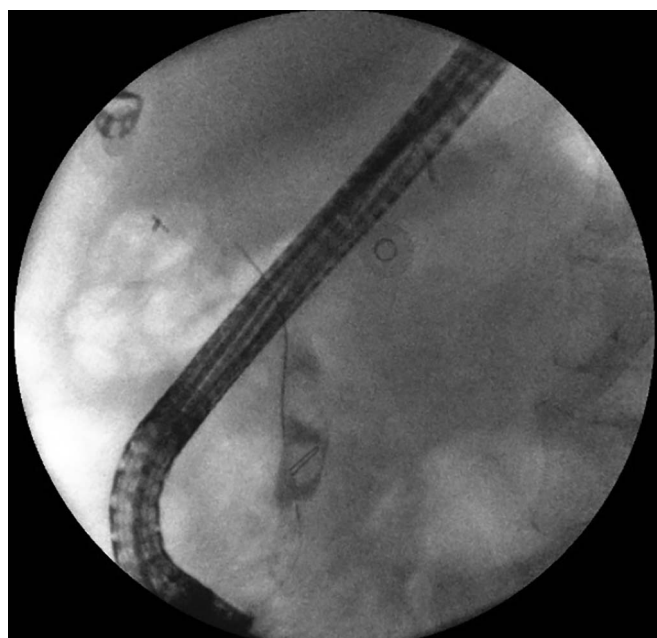


Figure 4. ERCP cholangiogram of the same patient showing a bile duct stone formed on a metallic clip.

been shown to occur even in patients who have not had prior intervention.⁵⁵

Various suture materials, both absorbable and nonabsorbable used during biliary surgery, have been re-

ported as the nidus for choledocholithiasis.^{56,57} During a choledochotomy, stones can form on the suture used to close the duct.⁵⁸ With modern suture materials, this is likely to be less common.

Inadvertent entry of a clip into the common bile duct for example during bile duct exploration is obviously a different scenario to the more important complication of a cystic duct clip migrating into the bile duct. The pathophysiology of how a clip migrates into the bile duct is unknown. Chong et al.³⁵ postulated localized inflammation, ischemia, and necrosis with subsequent migration.

A case report by Ahn et al.⁵⁹ describes a patient who presented three times for choledocholithiasis, and on the initial cholangiogram was found to have two presumed extraluminal clips near the common hepatic duct. On the third presentation, choledochoscopy was performed and found the two metallic clips ulcerating into common hepatic duct wall. This suggests erosion of the clips over time, possibly as a result of foreign body reaction or, as the report describes, serial maceration theory. This hypothesis is further reinforced the case report of Schreuder⁶⁰, describing a coil of the right hepatic artery migrating to the common bile duct causing choledocholithiasis.

Pang et al.⁶¹ presented a case series of six cases over a 10-year period with choledocholithiasis because of a Weck Hem-o-lok polymer locking ligation system clip at its core. These patients had undergone bile duct explora-

Table 1.
Summary of Cases Reviewed

Author	Year	Complication Type	Core Type	Postoperative Time	Age	Sex	Indication	Clinical Course	CBD Explored?
Ahn et al.	2005	Choledocholithiasis	Clip-metal	1 year	56	F	Cholelithiasis	Three presentations: first presentation failed ERCP and required PTC, extracted stones and found two clips likely extraluminal to common hepatic duct; third presentation performed choledochoscope, found clips penetrated common hepatic duct.	Not specified
Alsamman et al.	2019	Choledocholithiasis	Clip-metal	5 years	84	M	Not specified	Not specified	Not specified
Angel et al.	2004	Choledocholithiasis	Clip-metal	7 months	52	F	Acute cholecystitis	Not specified	Not specified
Arifon and Mestieri	2016	Choledocholithiasis	Clip-unknown type	18 months	50	F	Not specified	Not specified	Yes
Atwell and Hawes	2007	Choledocholithiasis	Clip-metal	6 years	57	M	Acute cholecystitis	Large common hepatic duct perforation, requiring biliary stent; very turbulent postoperative period, with 10 ERCPS over 6 years and no evidence of clip stones identified.	Yes
Battat et al.	2016	Choledocholithiasis	Clip-metal	12 years	54	F	Biliary pancreatitis	Not specified	Not specified
Chen et al.	2018	Migration–duodenum	Clip-metal	3 years	56	F	Chronic cholecystitis	Not specified	Not specified
Chong and Chong	2010	Migration–duodenum Various	Clip-metal Mostly metal clips except two cases of absorbable clips	1 year 11 days to 20 years	59 31–88	F Various	Acute cholecystitis Various	Not specified	Not specified Not specified
Chong et al.	2004	Choledocholithiasis	Clip-metal	4 years	58	M	Not specified	Uncomplicated; three clips used at LC, one migrated	No
Cookson et al.	2015	Choledocholithiasis	Clip-metal	3 years	54	F	Cholelithiasis	Not specified	Not specified
Ghavidel	2015	Choledocholithiasis	Clip-metal	10 years	55	F	Not specified	Uncomplicated	No
Gonciarz et al.	2010	Choledocholithiasis	Clip-metal	2 months	44	F	Cholelithiasis	Subhepatic collection percutaneously drained	Not specified
Gonzalez et al.	2011	Choledocholithiasis	Clip-metal	10 years	54	F	Not specified	Not specified	Not specified
Hai et al.	2003	Choledocholithiasis	Clip-unknown type	14 years	78	F	Not specified	Not specified	Not specified
Herline et al.	1998	Choledocholithiasis	Clip-metal	6 years	57	M	Not specified	Not specified	Not specified
Hong et al.	2014	Choledochoduodenal fistula	Clip-metal	20 years	78	F	Cholelithiasis	Not specified	Not specified
				10 years	48	F	Not specified	Uneventful	No

Table 1.
Continued

Author	Year	Complication Type	Core Type	Postoperative Time	Age	Sex	Indication	Clinical Course	CBD Explored?
Hussameddin et al.	2018	Choledocholithiasis	Clip-metal	16 years	70	M	Cholelithiasis	Uneventful	No
Kager and Ponsioen	2009	Choledocholithiasis	Clip-metal	4 years	65	F	Cholelithiasis	Subhepatic abscess, second laparotomy	Not specified
Karanth et al.	2010	Choledocholithiasis	Clip-metal	1 year	41	F	Not specified	Not specified	Not specified
Kelly and Hugh	1993	Choledocholithiasis	Cherry stalk	NA	47	M	Cholecystitis	Filling defect found on operative cholangiography requiring choledochotomy	Yes
Khanna and Vij	2005	Choledocholithiasis	Clip-metal	5 years	Mid	F	Gallstone disease	Not specified	Not specified
Kim et al.	2019	Choledocholithiasis	Clip-metal	14 years	74	F	Not specified	Not specified	Not specified
Kim et al.	2007	Choledocholithiasis	Prolene	15 years	74	M	Calculous cholecystitis	Open cholecystectomy, found CBD stone requiring choledochotomy to distal CBD, repaired with prolene plus T-tube	Yes
Kou et al.	2019	Choledocholithiasis	Clip-Hem-o-lok	3 years	84	M	Choledocholithiasis	CBD stone, failed choledochoscope plus ERCP, then converted laparotomy plus T-tube, then repeat ERCP	Yes
Kurella and Maple	2011	Choledocholithiasis	clip-unknown type	28 years	48	M	Cholecystitis	Not specified	Not specified
Lee et al.	2003	Choledocholithiasis	Clip-metal	14 months	50	M	Cholecystitis	Not specified	Not specified
Liu et al.	2012	Migration-CBD	Clip-metal	2-3 months	35-76	6 M, 2 F	Not specified	Clips found in T-tube, choledochoscope found rough and inflamed CBD wall	Some
Maeda et al.	2013	NA	Nylon	NA	75	M	NA	History of gastric cancer underwent distal gastrectomy	NA
McMahon et al.	2010	Choledocholithiasis	Clip-metal	8 years	32	F	Cholelithiasis	Short, wide cystic duct, complicated with iatrogenic stricture of CBD	No
Menichella et al.	2012	Choledocholithiasis, bilioduodenal fistula	Clip-metal, catgut	10 years	77	F	Not specified	Not specified	Yes
Mills et al.	2015	Migration-CBD	Clip-metal	3 years	61	F	Not specified	Not specified	Not specified
Munoz et al.	2010	Choledocholithiasis	Clip-metal	30 years	57	F	Not specified	Not specified	Not specified
Nagomi et al.	2016	Mirrizi syndrome	Clip-polymeric	Immediate	62	F	Cholelithiasis	NA	No
Obama et al.	2000	Choledocholithiasis	Clip-metal	5 years	53	F	Not specified	Not specified	Not specified

Table 1.
Continued

Author	Year	Complication Type	Core Type	Postoperative Time	Age	Sex	Indication	Clinical Course	CBD Explored?
Oh et al.	2003	Choledocholithiasis	Clip-metal	10 years	48	M	Not specified	Not specified	Not specified
Olson and Dries	2015	Choledocholithiasis	Clip-metal	4 years	54	F	Cholelithiasis	Not specified	Not specified
Paglia and Kew	2017	Migration-CBD	Clip-metal	17 years	81	M	Not specified	Not specified	Not specified
Panda et al.	2012	Migration-duodenum	Clip-metal	4 months	54	M	Chronic calculous cholecystitis	Not specified	Not specified
Pang et al.	2019	Choledocholithiasis	Clip-Hem-o-lok	4 months	31	F	Choledocholithiasis	CBD 12 mm	Yes
		Choledocholithiasis	Clip-Hem-o-lok	3 months	60	F	Choledocholithiasis	CBD 11 mm	Yes
		Choledocholithiasis	Clip-Hem-o-lok	6 months	83	F	Choledocholithiasis	CBD 10 mm	Yes
		Choledocholithiasis	Clip-unknown type	Not specified	61	F	Chronic cholecystitis	CBD 11 mm	Not specified
		Choledocholithiasis	Clip-Hem-o-lok	1.5 years	72	F	Choledocholithiasis	CBD 13 mm	Yes
		Migration-CBD	Clip-Hem-o-lok	2 months	64	F	Choledocholithiasis	CBD 15 mm	Yes
Peters et al.	2017	Choledocholithiasis	Clip-metal	33 years	57	F	Not specified	Not specified	Not specified
Petersen	2002	Choledocholithiasis	Clip-metal	14 years	79	F	Cholelithiasis	Open cholecystectomy, no complications specified	Not specified
Photi et al.	2014	Migration-CBD	Clip-metal	9 years	42	M	Not specified	Not specified	Not specified
Rajendra et al.	2009	Choledocholithiasis	Clip-metal	14 years	41	F	Not specified	Not specified	Not specified
Rasool et al.	2017	Migration-CBD	Clip-metal	3 weeks	37	M	Calculous cholecystitis	Uneventful	No
Rawal	2017	Choledocholithiasis	Clip-metal	4 months	38	F	Acute cholecystitis	Not specified	Not specified
Ray and Bhattacharya	2013	Choledocholithiasis	Clip-metal	6 years	62	M	Acute calculous cholecystitis	Difficult Calot's dissection, wide edematous cystic duct, used ligaclip 400; developed biliary fistula which healed 14 d with conservative treatment	No
Salmon	1992	Choledocholithiasis	Chromic catgut	12 years	81	M	Not specified	Bile leak requiring second operation	Not specified
Samim and Armstrong	2008	Migration - duodenum	Clip-metal	15 years	70	F	Not specified	Not specified	Not specified
Schreuder	2019	Choledocholithiasis	Clip-metal	6 years	66	F	Cholecystolithiasis	Transient postoperative cholestasis	Not specified
		Choledocholithiasis	Clip-metal	4 years	63	M	Not specified	Bile duct injury, intraabdominal abscess	Yes
		Choledocholithiasis	Clip-metal	17 years	50	M	Choledocholithiasis	Uneventful	Not specified
		Choledocholithiasis	Coil	5 years	48	F	Cholecystolithiasis	Complete transection of CBD; biloma, pseudoaneurysm of right hepatic artery (coiled)	Yes

Table 1.
Continued

Author	Year	Complication Type	Core Type	Postoperative Time	Age	Sex	Indication	Clinical Course	CBD Explored?
Seyyedmajidi et al.	2013	Migration–duodenum	Clip–Hem-o-lok	8 months	41	F	Cholelithiasis	Not specified	Not specified
Sharma et al.	2013	Choledocholithiasis	Clip-metal	2 years	56	F	Not specified	Not specified	Not specified
Sornaz et al.	2016	Choledocholithiasis	Clip-metal	5 years	69	M	Not specified	Uneventful	No
Steffen et al.	2007	Choledocholithiasis	Clip-metal	15 years	83	F	Not specified	Not specified	Not specified
Teasdale et al.	2017	Choledocholithiasis	Clip-metal	3 years	70	M	Not specified	Bile leak, management not specified	Not specified
Tseng et al.	2011	Choledocholithiasis	Clip-metal	10 years	65	M	cholelithiasis	Not specified	Not specified
Van Den Heuvel et al.	2015	Migration–CBD	Clip-metal	1 year	70	M	Not specified	Not specified	Not specified
Xia et al.	2019	Migration–CBD, duodenum	Clip–Hem-o-lok, suture-unknown	1 year	56	F	Cholelithiasis	Not specified	Not specified
Yoshizumi et al.	2000	Choledocholithiasis	Clip-metal	1 year	63	M	Not specified	Cystic duct inflamed, bile leak on ERCP	No
Youssef et al.	1994	Choledocholithiasis	Clip-metal	4 years	62	M	Not specified	Not specified	Not specified

CBD, common bile duct; ERCP, endoscopic retrograde cholangiopancreatography; PTC, percutaneous transhepatic cholangiogram.

tion in addition to cholecystectomy and had a wide common bile duct of over 10 mm prior to operation.⁶¹ Bile duct exploration and wide cystic ducts are likely risk factors for clip migration.

Despite numerous advances in laparoscopic surgery, the method of occluding the cystic duct with nonabsorbable clips has not changed since the inception of LC. Failure to securely occlude the cystic duct will result in bile leakage and peritonitis. The safety and efficacy of simply clipping the cystic duct with metallic clips has stood the test of time, and there is no driver to change practice. Alternatives to ligation of the cystic duct include electro-surgical vessel-sealing devices such as LigaSure or ultrasonic shears such as the harmonic scalpel.

There have been clinical studies to show that LigaSure is a plausible alternative as shown by Turial et al., Downes et al., and Schulze et al.^{62–65} This has also been supported in a rat model by Marte et al.⁶⁶ However, animal studies by Matthews et al. and Shamiyeh et al. have showed that electro-surgical vessel-sealing devices have low bursting pressures, resulting in high rate of failure.^{67,68} In the absence of real evidence of its safety, electro-surgical vessel-sealing devices for the cystic duct cannot be recommended.

There are data on the safety of the harmonic scalpel for sealing the cystic duct. Abdallah et al. demonstrated in an ex vivo model that cystic duct bursting pressures were superior in the harmonic scalpel group compared with the other patient groups utilizing Ligacaps and LigaSure. This study was further evidence that electro-surgical vessel-sealing devices such as LigaSure can reproduce low cystic duct bursting pressures of an average of 219.7 mm Hg compared with 358 mm Hg in the harmonic scalpel group (mean of 219.7 mm Hg compared with 358 mm Hg in this study).⁶⁹

There are data that the harmonic scalpel is superior to conventional diathermy in performing an LC. The in vivo study by Zanghi et al. concluded that it significantly reduced operative time, intraoperative blood loss, and rates of gallbladder perforation.⁷⁰ If the harmonic is used for dissection, then its use on the cystic duct and artery would be logical. The absence of clips in Calot's triangle could only be a good thing and would preclude the possibility of clip induced cholelithiasis. After analyzing all direct and indirect costs, more hospitals might adopt the harmonic scalpel as a more cost-effective alternative overall.⁷¹

Absorbable materials have been commonly considered to be an alternative for cystic duct ligation. Numerous studies

Table 2. Summary of Studies Reviewed Investigating Alternatives to Ligating the Cystic Duct

Author	Year	Study Type	Animal/ Human	In/ex vivo	Sample Size	Comparison	Follow-up	Conclusion
Abdallah et al.	2015	Prospective randomised	Human	Ex	458	Ligaclip vs LS vs HS	None	HS has good sealing pressure
Bali	2018	Prospective randomised double blinded	Human	In	160	Silk vs titanium clips	2 weeks	Equal complications, silk more cost-effective, clips more time effective
Bencini et al.	2003	Retrospective cohort	Human	In	690	Absorbable vs titanium clips	Unsure	Equal
Darzi et al.	1997	Prospective	Human	In	415	Absorbable laproclip vs titanium	3 months	Equal
Downes et al.	2015	Prospective	Human	In	28	LS only	6 weeks	LS can be used to seal cystic duct
Feroci et al.	2011	Retrospective cohort	Human	In	664	Absorbable clip only	Unsure	Adequate alternative
Hawasli	1994	Prospective randomised	Human	In	50	Absorbable vs metal clips	3 months	Equally effective
Klein et al.	1994	NA	Animal	In	30	Absorbable vs metal clips	None	Equally effective, absorbable clips require more force to dislodge
Leung et al.	1996	Prospective	Human	In	227	PDS clip only	1 year	Effective
Marane et al.	2000	Not specified	Human	In	170	Polyglactin vs endoclip	Unsure	Suture cost-effective, safe
Marte and Pintozzi	2015	NA	Animal	In	30	LS vs electrosurg	None	LS can be used to seal cystic duct
Matthews et al.	2001	Prospective	Human	Ex	64	LS vs HS vs metal clip	None	Metal clip>LS>HS
			Animal	In	9	LS vs HS vs metal clip	None	HS or LS should not be used
Park and Lee	2014	Case series	Human	In	21	Endoloop	Unsure	Feasible option
Rohatgi and Widdison	2006	Audit	Human	In	494	Absorbable clips vs titanium clips	None	Absorbable locking clips superior, no migration or slipping
Saha	2000	Prospective	Human	In	70	Absorbable suture vs titanium clip	Unsure	Feasible option
Schulze et al.	2010	Prospective	Human	In	217	LS vs titanium clips	Unsure	LS safe

Table 2.
Continued

Author	Year	Study Type	Animal/ Human	In/ex vivo	Sample Size	Comparison	Follow-up	Conclusion
Schulze et al.	2002	Not specified	Animal	In	8	LS only	None	LS safe
Shah and Maharjan	2010	Prospective	Human	In	80	Silk only	2 weeks	Silk can be used
Shamiyeh	2002	NA	Animal	In	10	LS only	None	LS can be used to seal cystic duct
Shamiyeh et al.	2004	NA	Animal	In	9	LS only	None	LS not safe due to high rate of necrosis
Singal et al.	2018	Prospective randomised	Human	In	140	Silk vs titanium clips	2 months	Equally effective
Sundholm Tepper et al.	2017	NA	Animal	Ex	12	Absorbable ligatie vs hemoclips	None	Equally effective
Suo and Xe	2013	Prospective	Human	In	1096	Absorbable thread vs titanium clips/HS	Unsure	Safe alternative
Tempe et al.	2013	Prospective randomised	Human	In	73	HS vs electrocautery	None	HS good cost
Turial et al.	2011	Prospective	Human	In	22	LS	7 months	LS safe
Vongjarukorn	2018	Prospective randomised	Human	In	80	Hem-o-lok vs titanium clips	Unsure	Equal effective, hemolok cost-effective
Yang et al.	2014	Retrospective cohort	Human	In	1363	Absorbable clip vs titanium	Unsure	Absorbable safer more effective
Yano et al.	2003	Retrospective cohort	Human	In	772	Absorbable clip vs titanium	Unsure	Equally effective
Yoshida et al.	2017	NA	Animal	In	9	Absorbable magnesium clip only	None	Sufficient sealing
Zanghi et al.	2014	Retrospective	Human	In	261	HS vs metal clips	6 months	HS advantages: duration, perforation, bile leak

LS, LigaSure; HS, harmonic scalpel.

and reports have been published to show that the absorbable polymeric clip is a feasible alternative. In an animal study by Klein in 1994, a comparison between absorbable polymeric surgical clips and titanium clips showed that polymeric clips required more force to dislodge than titanium, both axially and transversely.⁷² A large retrospective cohort study by Yang et al. has showed that even just one absorbable clip could replicate the outcomes with titanium clips.⁷³ Other studies further support this claim that absorbable clips are safe.^{74–80}

Absorbable sutures are an alternative to metallic clips. LigaTie is a promising new sealing device resembling the cable tie, which has been shown to be effective in animal studies.⁸¹ PDS Endoloops are readily available and highly effective but requires the duct to be divided prior to placement.⁸² In some LCs, this is not a desirable strategy. Numerous authors including Suo et al., Marane et al., and Saha recommend use of absorbable sutures in cystic duct ligation.^{83–85} In low-resource settings, several studies have shown silk to be a suitable alternative.^{86,87} However, even absorbable sutures can be the nidus for biliary stone formation.⁵⁸

Yoshida et al. recently reported new clip technology using a magnesium-calcium-zinc alloy, which is almost completely absorbed by 6 months postoperatively.⁸⁸ This was a canine study, and there were no postoperative complications or electrolyte abnormalities reported. Absorbable surgical clip alternatives should be able to reduce the rate of clip induced choledocholithiasis but probably cannot preclude it.

CONCLUSION

In conclusion, any foreign material in the biliary tree, whether absorbable or nonabsorbable, can serve as a nidus for stone formation. Absorbable materials may be less likely to cause such a problem. The mechanism by which a cystic duct clip migrates and the factors that make it more likely, are speculative. Options to seal the cystic duct without clips include the harmonic scalpel and LigaSure. The harmonic scalpel has proven to be adequate in both animal and human studies but its use is limited by cost.

The routine use of nonabsorbable clips on the cystic duct is safe and effective; however, there will continue to be the rare cases of clip induced choledocholithiasis. This curious phenomenon of clip migration and stone formation after LC is so rare that it is not a reason to recommend a change in practice; however, there are readily available

alternatives that may lower the risk. The senior author routinely uses a PDS Endoloops on the cystic duct when the operative conditions easily allow it and especially in young patients. The fact that research is continuing with new methods and new clips in LC shows that surgeons must have an inkling that nonabsorbable clips on biliary structures is not optimum. It will be interesting to see whether in 20 years nonabsorbable clips will still be used on the cystic duct in LC.

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