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REVIEW ARTICLE

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Efficacy of combined sialendoscopic-assisted surgery in management of submandibular sialolithiasis: a systematic review

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Abstract

Background The introduction of sialendoscopy has been a major step forward in providing an accurate means of diagnosing and locating submandibular sialolithiasis, also in permitting minimally invasive surgical treatment that can successfully manage those stones aiming for gland preservation.

Methods We conducted a systemic review to assess the efficacy and safety of combined sialendoscopic assisted surgery in the management of submandibular sialolithiasis. This study included published medical articles from 2000 till 2022 concerning the efficacy and safety of combined sialendoscopic-assisted surgery in management of submandibular sialolithiasis searching Medline database (PubMed), Web of Science, Springer, Cochrane library, EMBASE. Fifteen articles met the inclusion criteria and were reviewed and analyzed.

Results The success rate of combined sialendoscopic assisted surgery in management of submandibular sialolithiasis is 0.955% with 95% CI: (91.4% to 98.5). The overall percentage of sialadenectomy cases in the included studies is 2%. The overall percentage of complications in the included studies is 8%.

Conclusion Combined sialendoscopic-assisted surgery is efficient and safe in management of submandibular sialolithiasis.

Keywords Sialendoscopy, Trans-oral incision, Submandibular, Sialolithiasis, Calculi, Stones, Transcutaneous

Background

Sialolithiasis accounts for 50% of major salivary gland diseases. Symptomatic cases suffer from acute onset of peri-prandial spasmodic pain and unilateral swelling of the involved gland which may be complicated by purulent infection. If left untreated, it can progress to extensive cellulitis, abscess formation, and airway compromise [1]. Sialoliths range in size as 88% of sialoliths are ≤ 10 mm with the majority ranging from 3 to 7 mm. Sialoliths ≥ 15 mm in length are rare and are called giant stones or megaliths [2, 3].

Approximately, 53% of submandibular gland (SMG) stones are proximal/hilar, 37% are distal, and 10% are intra-parenchymal [4]. Historically, submandibular sialadenectomy was the treatment of choice for proximal, hilar, and intra-parenchymal stones. Recent advances in minimally invasive techniques have led to successful stone removal with high rates of gland preservation. A combined approach pairing sialendoscopy and trans-oral stone removal is now considered the standard care of stones ≥ 8 mm and inaccessible stones with sialendoscopy alone, such as intra-parenchymal and peri-hilar stones [5]. The reduced operative field between the tongue and the mandible, and the risk of injury to the delicate structures

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in the floor of the mouth are still challenging in the combined approach [6].

Successful stone removal rates of 69–100% have been reported using the combined approach, with two recent large studies of the combined approach for hilar or parenchymal submandibular stones reporting a stone removal rate of 98.5% [7] and a stone removal rate of 90.13% [8]. Furthermore, submandibular gland preservation rates as high as 95% using the combined approach have been published [9–11].

Main text

Methods

This systematic review and meta-analysis were conducted and reported based on the PRISMA statement. This study was approved by an ethical committee of Faculty of Medicine Ain Shams University before the start of the study (FMASU M S 565/2022).

Eligibility criteria

All the cross-sectional, case–control, retrospective, and prospective cohort studies published in English language, conducted on patients with submandibular stones after failed response to pure endoscopic approach or assisted lithotripsy, in which patients underwent combined sialendoscopy with conservative surgical stone extraction for the management of submandibular sialoliths which started with endoscopic visualization and localization of the stone followed by a standard external or trans-oral approach to remove the stone without the need of gland removal followed by duct repair with stenting or marsupialization. The included studies reported success rate as cases free of residual stones.

Search strategy

The study included relevant medical articles from 2000 till 2022 concerning the efficacy and safety of sialendoscopic assisted surgery in the treatment of submandibular gland sialolithiasis through the MEDLINE database (PubMed), Web of Science, Springer, Cochrane Library, and EMBASE, using a combination of the following key words: sialendoscopy, trans-oral incision, submandibular, sialolithiasis, calculi, stones, and transcutaneous.

Selection of studies

We screened the title and abstract of the yielded articles seeking for the potentially matched articles. Then full texts of the potentially included articles were obtained and assessed for the final inclusions in the current study. The reference list of the included papers was reviewed also seeking for any relevant articles. Excluded articles included review articles, duplicated reports, and studies whose outcomes of interest were not clearly reported with quantifiable data or if it was not possible to extract and calculate appropriate data from published results, articles performed on patients with obstructive sialadenitis for any other cause rather than stones as stenosis because of strictures, kinks, previous radio-iodine treatment or radiotherapy treatment in the head and neck region, mucus plug, polyp, foreign bodies, tumor, external compression, variations in anatomical ductal systems or diagnosis of autoimmune disease as Sjogren's syndrome, patients with acute sialadenitis in last 2 weeks before surgery, pregnant or lactating females, patients who are unable to open the mouth sufficiently, patients who suffer of gland fibrosis due to previous surgery, and patients on anticoagulants or anti-platelets.

Only articles fulfilling the criteria of screening were included for further steps of data collection, analysis, and reporting.

Data extraction

We derived the data from the finally pertinent publications. An Excel sheet was constructed to collect the following items: author name and year, sample size, stone location, surgical approach, success rate, gland preservation, and complications.

Risk of bias assessment

In this study, examination of funnel plots and Egger's test were used to evaluate publication bias.

The outcomes

The outcomes investigated in this study were the success rate based on total extraction of stones resulting in no residual stones, number and percentage of complications, and number and percentage of failed cases that required sialadenectomy.

Data analysis

The data collected from each article was statistically analyzed utilizing the Stata 17 (StataCorp. 2021. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC). Studies included were tested for heterogeneity of the estimates using the Cochran Q chi-square test and I-squared (I^2) index. Event rates were expressed as proportion with its 95% confidence limits (95% CI). Because of the presence of significant heterogeneity, the random effect model was used for pooling of estimates from individual studies. A two-sided p value < 0.05 denoted statistical significance.

Results

We found 229 relevant articles; from those, 15 articles were included in evaluation of combined sialendoscopic-assisted surgery in the management of submandibular

gland sialolithiasis as shown in Table 1, and 214 articles were excluded (Fig. 1).

Table 2 showed that 78.46% was the percentage of the variation across studies that was due to heterogeneity rather than chance, and it might represent substantial heterogeneity, p value = <0.001. There was evidence for significant heterogeneity (Cochran Q = 65.57, P value <0.001, I-squared = 78.46%). So, studies were pooled using a random effect model.

Table 3 showed that a total of 15 studies were included in proportional meta-analysis. Sample size, event, and effect size were reported for each study as shown in Table 1. Number of studies combined was 15, number of observations was 1467, and number of events was 1380. Random effect model was used due to the presence of heterogeneity. The estimated overall effect was 1380 with 95% CI (91.4 to 98.5%) (Fig. 2).

Table 4 and Figs. 3, 4, 5, 6, 7 and 8 showed that Egger's test was done to assess potential publication bias, p value = 0.539 indicating no evidence of publication bias.

Table 5 showed that the percentage of cases that underwent sialadenectomy in the included studies ranged from 0% in 4 studies [10, 14, 18, 21] to 29% in the study of Ziegler et al. [12] (5/17 cases). The overall percentage of sialadenectomy cases in the included studies was 2% (35/1467 cases).

Table 6 showed that the percentage of complicated cases in the included studies ranged from 0% in 4 studies [10, 12, 17, 21] to 80% in the study of Wallace et al. [16] (4/5 cases). The overall percentage of complications in the included studies is 8% (118/1467 cases). The most common type of complication was recurrent sialadenitis

Table 1 Studies included in the meta-analysis for success rate

Study	Total	Free of residual stones
Ziegler et al., 2004 [12]	17	17
Marchal F., 2007 [10]	29	20
Nahlieli et al., 2007 [13]	172	165
Liu et al., 2009 [14]	28	27
Walvekar et al., 2009 [5]	16	14
Su et al., 2010 [15]	18	17
Wallace et al., 2010 [16]	5	5
Kopec et al., 2013 [17]	21	21
Gallipoli et al., 2013 [18]	18	16
Liu et al., 2013 [19]	70	66
N. Schwartz et al., 2015 [11]	39	33
Aleksandar and Jure, 2016 [20]	33	33
Xiao et al., 2016 [21]	8	8
Capaccio et al., 2017 [22]	479	472
Zhao et al., 2020 [8]	514	466

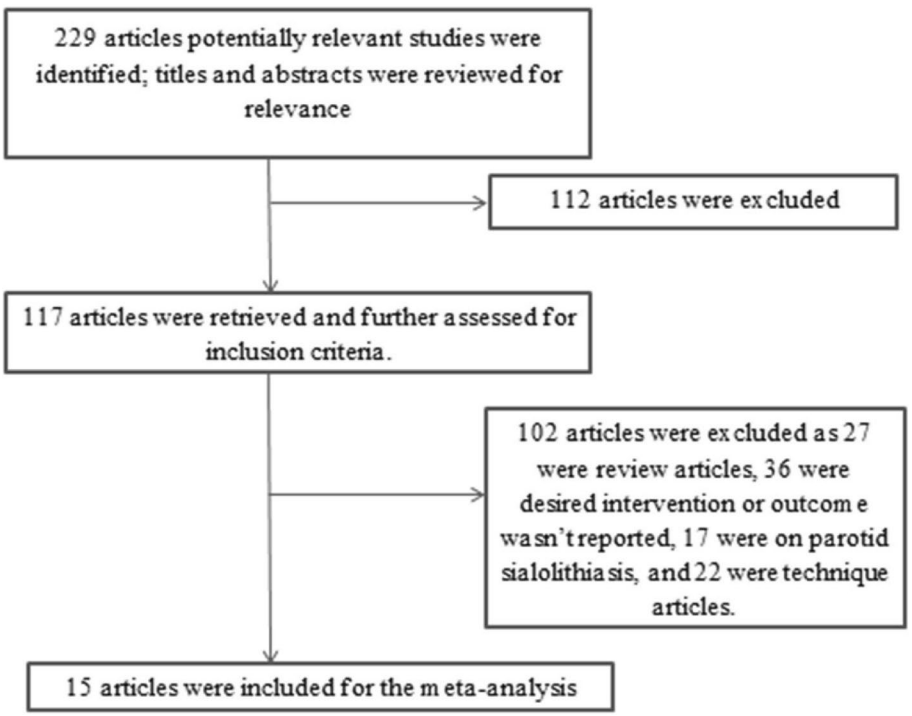

Fig. 1 Identification of relevant studies

Table 2 Tests for heterogeneity in the included studies

Cochran *Q* value	65.57
df (*Q*)	14
***P* value**	**<0.001**
***I*-squared: I^2 (inconsistency)**	78.46%
95% CI for I^2	65.36 to 86.84

df degree of freedom

(76 cases), followed by temporary lingual nerve paresthesia (24 cases).

Table 7 showed that all the studies included hilar stones except from two studies: Gallipoli et al. [18] for which all cases had Hilo-parenchymal stones, and Xiao et al. [21] for which all cases had intra-parenchymal stones. Four studies had hilar stones only [12, 15, 17, 19]. Two studies only included patients with stones in the three locations [8, 22]. The other 5 studies didn't comment on the location of the stones.

Discussion

Management algorithms based on sialolith size, orientation, and shapes have been published in the literature. It was suggested that the removal of submandibular stones smaller than 4 mm is amenable to sialendoscopy with basket or forceps retrieval, whereas larger stones may require the use of ancillary techniques such as fragmentation [23]. Similar size recommendations were reported, and retrieval success was found to be dependent on the stone's largest dimension being oriented favorably in the duct [5]. It was not possible to perform a meta-analysis by stone size in the present study because the data were not uniformly published in the included studies.

Four studies evaluated the efficacy of combined sialendoscopic approach in the management of hilar submandibular stones. A retrospective review was performed in 17 patients as hilar stones were extracted through a small trans-mucosal incision, after which the duct could be reconstructed and sutured under endoscopic control, only 5 patients required sialadenectomy [12]. A retrospective review of 70 patients who underwent combined approach was performed with a success rate of 92.9% [19].

Su et al. [15] performed a retrospective review in 18 cases which were treated with sialendoscopic assisted open sialolithectomy immediately after failure of intraductal removal of calculi by interventional sialendoscopy using grasping forceps and basket. The surgery failed in 1 patient with multiple sialoliths, and the procedure was converted to open sialadenectomy.

Kopec et al. [17] performed the combined approach in 21 patients due to large-sized stones, the intimate association of calcium deposits within the wall of the duct along with its presence inside the deep portions of the gland, and only three failed and required sialadenectomy.

One study evaluated efficacy of combined sialendoscopic assisted trans-cervical approach in treatment of non-palpable intra-glandular submandibular stones in 8 patients with 100% success rate [21]. Aleksandar and Jure [20] performed a retrospective study of the treatment of

Table 3 Pooling of estimated success rates using random effect model

Study	Sample size	Event	ES	95% CI	Weight% (random)
Ziegler et al., 2004 [12]	17	17	1.000	81.6 to 100	5.1
Marchal F., 2007 [10]	29	20	0.690	50.8 to 82.7	6.59
Nahlieli et al., 2007 [13]	172	165	0.959	91.8 to 98	10.17
Liu et al., 2009 [14]	28	27	0.964	82.3 to 99.4	6.49
Walvekar et al., 2009 [5]	16	14	0.875	64 to 96.5	4.93
Su et al., 2010 [15]	18	17	0.944	74.2 to 99	5.26
Wallace et al., 2010 [16]	5	5	1.000	56.6 to 100	2.31
Kopec et al., 2013 [17]	21	21	1.000	84.5 to 100	5.69
Gallipoli et al., 2013 [18]	18	16	0.889	67.2 to 96.9	5.26
Liu et al., 2013 [19]	70	66	0.943	86.2 to 97.8	8.75
N. Schwartz et al., 2015 [11]	39	33	0.846	70.3 to 92.8	7.38
Aleksandar and Jure, 2016 [20]	33	33	1.000	89.6 to 100	6.94
Xia et al., 2016 [21]	8	8	1.000	67.6 to 100	3.21
Capaccio et al., 2017 [22]	479	472	0.985	97 to 99.3	10.95
Zhao et al., 2020 [8]	514	466	0.907	87.8 to 92.9	10.99
Total (random effects)	**1467**	**1380**	**0.955**	**91.4 to 98.5%**	**100**

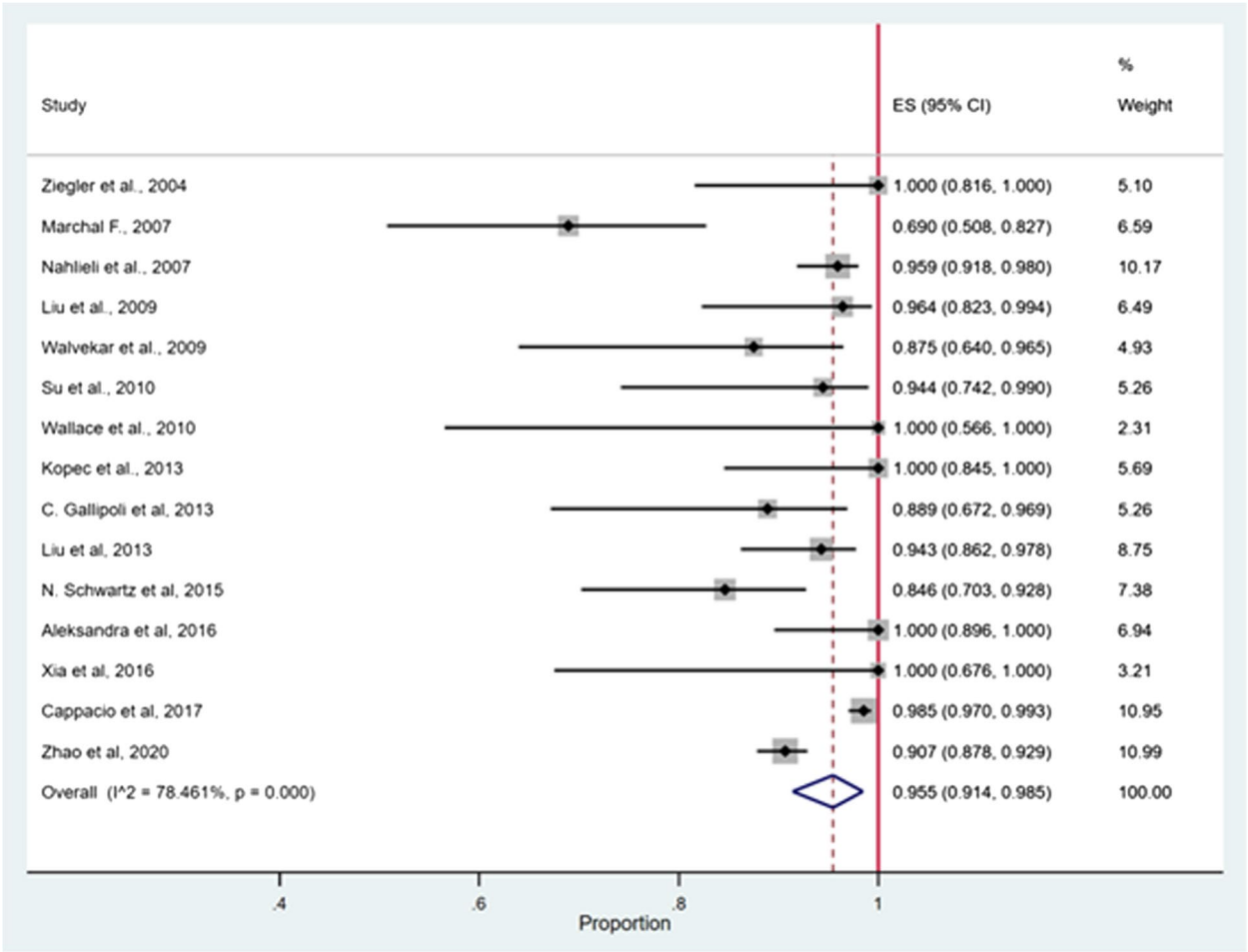

Fig. 2 Forest plot for the success rate

Table 4 Publication bias

Egger's test	
Intercept	-0.58
95% CI	-2.55 to 1.40
***P* value**	**0.539**

sialolithiasis in the submandibular gland via combined approach sialendoscopy, 31 through combined sialendoscopy trans-oral approach, and 2 through combined sialendoscopy trans-cervical approach and 1 of the cases developed fistula in the floor of the mouth 6 months later and required sialadenectomy.

Wallace et al. [16] reported their experience with management of giant salivary stones ≥ 15 mm via a combined approach technique using semi-rigid sialendoscopy through a retrospective case series. Forty-seven cases were identified during the review of literature and 7 from their case series. Of those 47 stones, 23 were hilar in location, 23 were glandular in location, and 1 of unknown location. The gland preservation rate in the 47 reported stones was 57% (17/30). Among patients where gland resection was reported, most of the patients (12/13) had hilar glandular stones. Only one patient with a ductal stone had a gland resection. In their series, combined approach enabled a gland preservation rate of 80% (4/5). Among these patients, stone location was hilar in six (86%) and ductal in one (14%). The mean size of stones from the literature review was 35 mm and from their series was 19 mm. They recommended trans-oral sialolithotomy for ductal giant stones and gland resection for giant hilar glandular stones with improved gland preservation rates (80 vs. 57%) independent of stone location and with preservation of salivary function.

Some studies evaluated the efficacy of combined sialendoscopic approach in the management of submandibular stones irrespective of their location. Nahlieli et al. [13] performed a retrospective review of 172

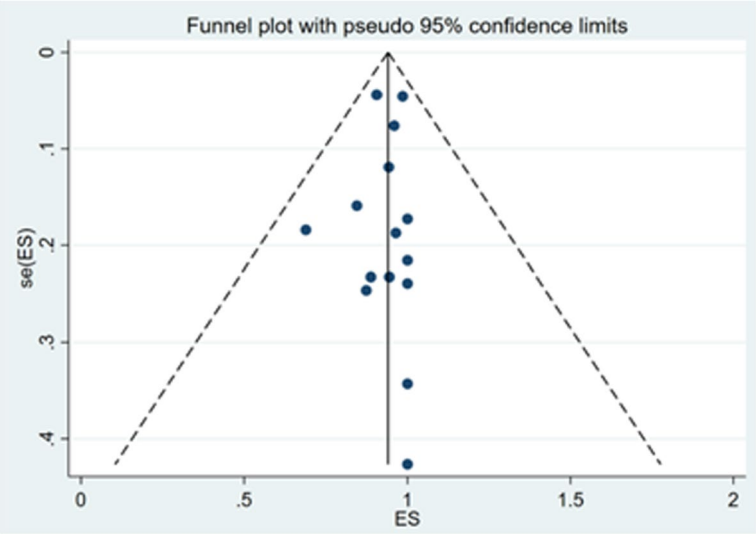

Fig. 3 Funnel plot for the success rate associated with combined sialadenoscopic assisted surgery in management of submandibular sialolithiasis

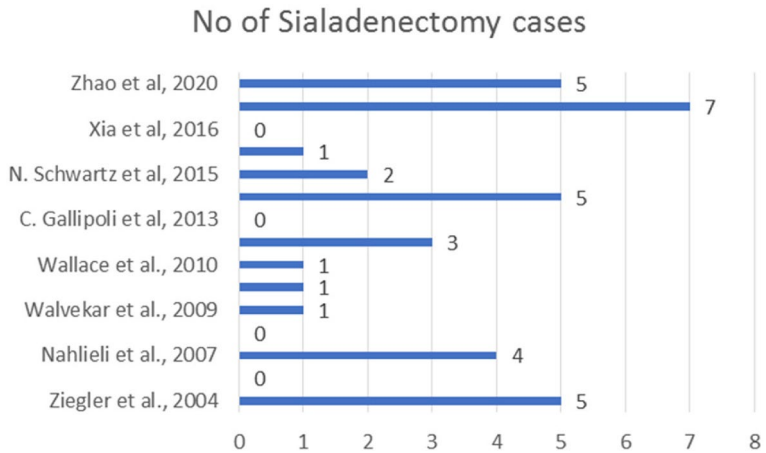

Fig. 4 Number of cases that underwent sialadenectomy in the included studies

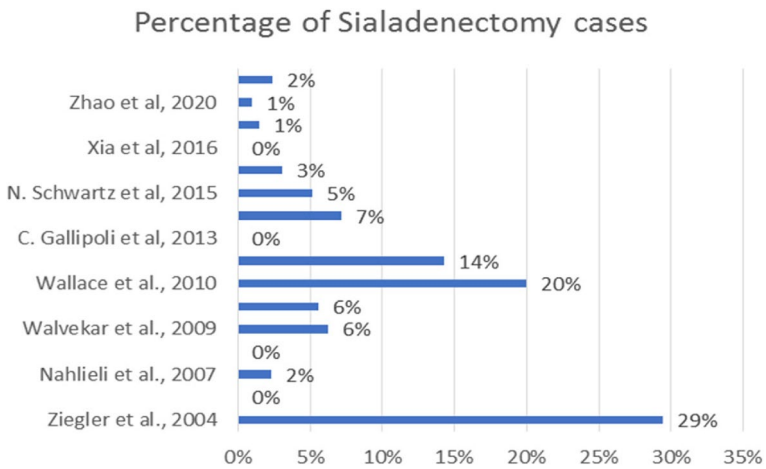

Fig. 5 Percentage of cases that underwent sialadenectomy in the included studies

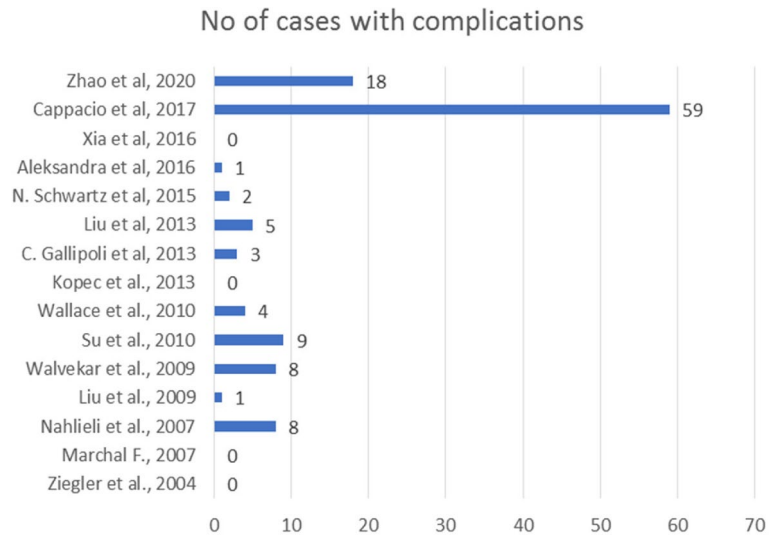

Fig. 6 Number of cases with complications

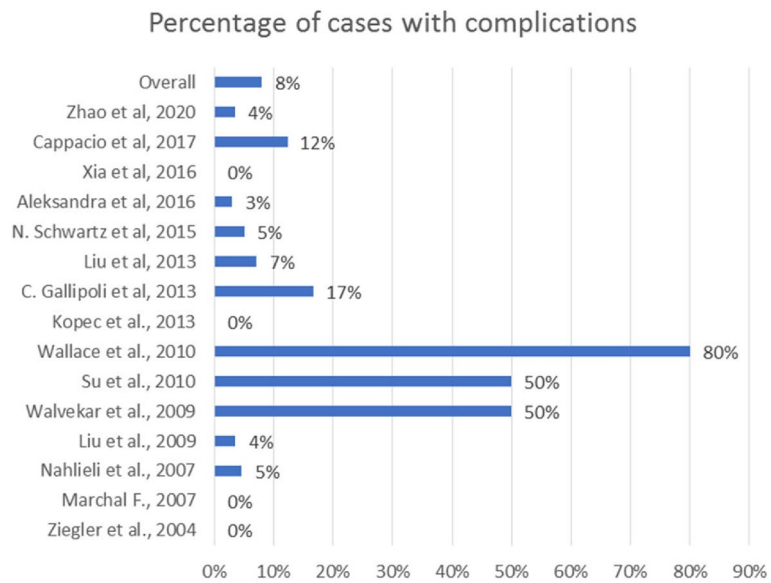

Fig. 7 Percentage of cases with complications

cases with posterior and hilar stones more than 5 mm in diameter which were treated primarily by trans-oral incision and marsupialization of the duct and gland through ductal stretching with a success rate of 98%. Twenty-six patients with multiple hilar stones were treated with a success rate of 81%. The overall success rate of the procedure was 96%. In 48 patients (28%), an additional undetected stone was diagnosed by endoscopy after the removal of the stone in the hilum. In 62 patients (36%), strictures were diagnosed endoscopically posterior to the stone.

Liu et al. [14] treated 28 cases with hilar and intraparenchymal submandibular stones with endoscopic-assisted surgery which failed in 1 case, and the remaining stone was left in situ. A retrospective case series for 514 consecutive patients with hilar and parenchymal submandibular stones treated through endoscopy-assisted surgery was performed in which the affected glands included 311 hilar in location, 84 post-hilar, 65 intraparenchymal, and 57 with multiple stones. Stones were successfully removed in 478 glands (92.5%, 478/517) in which the main treatment techniques included were

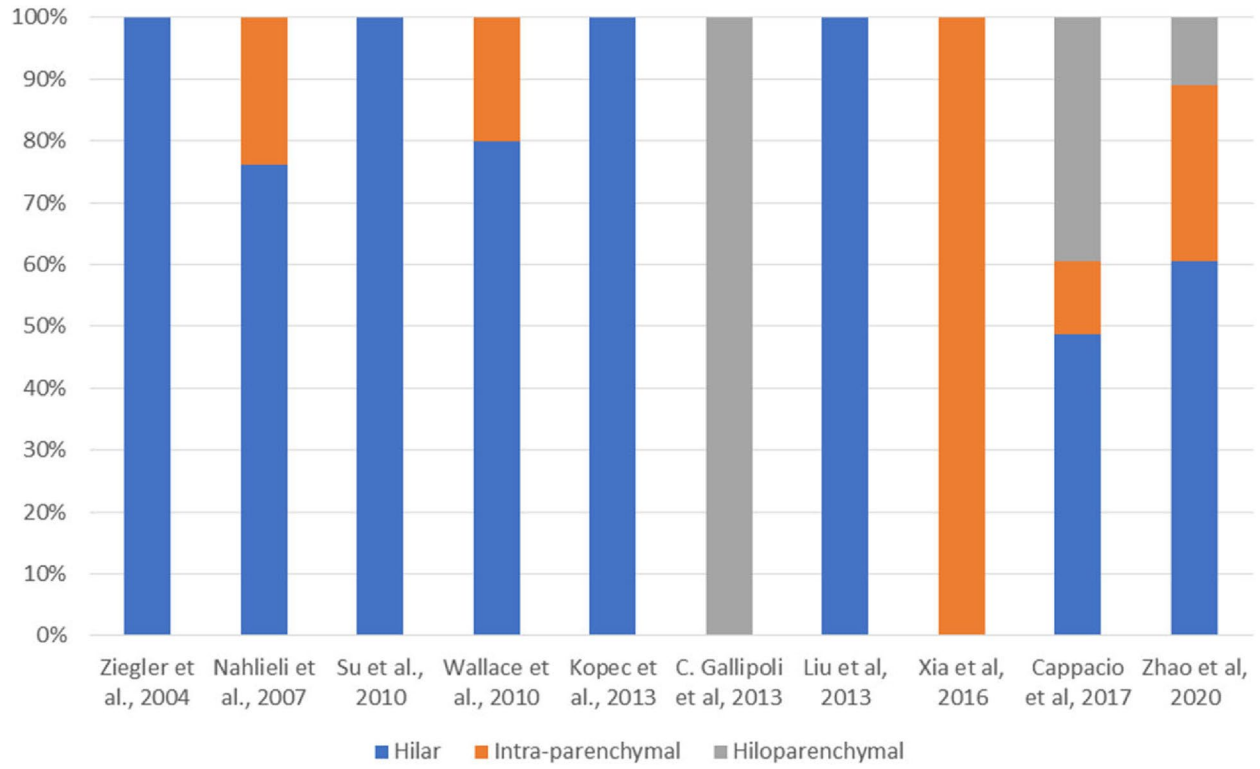

Fig. 8 Distribution of stone location

Table 5 Number and percentage of cases that underwent sialadenectomy

Study	Sample size	Sialadenectomy cases	Sialadenectomy percentage
Ziegler et al., 2004 [12]	17	5	29%
Marchal F., 2007 [10]	29	0	0%
Nahlieli et al., 2007 [13]	172	4	2%
Liu et al., 2009 [14]	28	0	0%
Walvekar et al., 2009 [5]	16	1	6%
Su et al., 2010 [15]	18	1	6%
Wallace et al., 2010 [16]	5	1	20%
Kopec et al., 2013 [17]	21	3	14%
Gallipoli et al., 2013 [18]	18	0	0%
Liu et al., 2013 [19]	70	5	7%
N. Schwartz et al., 2015 [11]	39	2	5%
Aleksandar and Jure, 2016 [20]	33	1	3%
Xiao et al., 2016 [21]	8	0	0%
Capaccio et al., 2017 [22]	479	7	1%
Zhao et al., 2020 [8]	514	5	1%
Overall	1467	35	2%

hilum ductotomy in 311 glands, intra-parenchymal ductotomy in 68, submandibulotomy in 14, intra-ductal retrieval in 74, and hilum ductotomy accompanied by intra-ductal retrieval in 11 and concluded that appropriate use of various endoscopy-assisted approaches helps preserve the gland and facilitates recovery of gland function in patients with different depths of hiloparenchymal submandibular stones [8].

Table 6 Number and percentage of complications of combined sialendoscopic-assisted surgery in the included studies

Study	Sample size	Recurrent sialadenitis	Temporary lingual nerve parasthesia	Ranula	Fistula in floor of mouth	Reduced salivary flow	Number of complications	Complications percentage
Ziegler et al., 2004 [12]	17	0	0	0	0	0	0	0%
Marchal F., 2007 [10]	29	0	0	0	0	0	0	0%
Nahlieli et al., 2007 [13]	172	7	1	0	0	0	8	5%
Liu et al., 2009 [14]	28	0	0	1	0	0	1	4%
Walvekar et al., 2009 [5]	16	4	4	0	0	0	8	50%
Su et al., 2010 [15]	18	0	3	0	0	6	9	50%
Wallace et al., 2010 [16]	5	1	3	0	0	0	4	80%
Kopec et al., 2013 [17]	21	0	0	0	0	0	0	0%
Gallipoli et al., 2013 [18]	18	3	0	0	0	0	3	17%
Liu et al., 2013 [19]	70	2	1	2	0	0	5	7%
N. Schwartz et al., 2015 [11]	39	0	1	0	1	0	2	5%
Aleksandar and Jure, 2016 [20]	33	0	0	0	1	0	1	3%
Xiao et al., 2016 [21]	8	0	0	0	0	0	0	0%
Capaccio et al., 2017 [22]	479	59	0	0	0	0	59	12%
Zhao et al., 2020 [8]	514	0	11	7	0	0	18	4%
Overall	1467	76	24	10	2	6	118	8%

Table 7 Number and percentage of stone location in cases treated by combined sialendoscopic-assisted surgery in the included studies

Study	Sample size	Hilar	Intra-parenchymal	Hilo-parenchymal	Hilar, %	Intra-parenchymal, %	Hilo-parenchymal, %
Ziegler et al., 2004 [12]	17	17	0	0	100%	0%	0%
Nahlieli et al., 2007 [13]	172	131	41	0	76%	24%	0%
Su et al., 2010 [15]	18	18	0	0	100%	0%	0%
Wallace et al., 2010 [16]	5	4	1	0	80%	20%	0%
Kopec et al., 2013 [17]	21	21	0	0	100%	0%	0%
Gallipoli et al., 2013 [18]	18	0	0	18	0%	0%	100%
Liu et al., 2013 [19]	70	70	0	0	100%	0%	0%
Xiao et al., 2016 [21]	8	0	8	0	0%	100%	0%
Capaccio et al., 2017 [22]	479	233	57	189	49%	12%	39%
Zhao et al., 2020 [8]	514	311	146	57	61%	28%	11%

A retrospective chart review was performed to identify the factors that may influence successful retrieval of salivary stones and concluded that submandibular stones larger than 4 mm may be amenable to endoscopic removal provided their largest dimension is orientated favorably along the length of the duct [5].

A prospective controlled study was performed to describe a combined sialendoscopic and trans-oral approach to remove large parenchymal submandibular sialoliths of median diameter of 18 mm (range 9–22 mm) in 18 patients and to assess functional results after stone removal. Parenchymal stones were successfully removed using the combined approach in all cases. Fifteen patients (83.5%) were symptom free after 6 months of follow-up. Two out of 3 still symptomatic patients showed residual sialolithiasis at post-operative ultrasonography [18].

Capaccio et al. [22] evaluated the efficacy of sialendoscopy assisted trans-oral approach retrospectively in retrieval of symptomatic, large (>7 mm), fixed and palpable proximal and hiloparenchymal submandibular stones from 479 patients under general anesthesia. Stones were successfully removed from 472 patients (98.5%); the seven failures (1.5%) concerned pure parenchymal stones. They concluded that sialendoscope-assisted trans-oral removal of large hiloparenchymal submandibular gland stones is a safe, effective, conservative surgical procedure,

and functional preservation of the main duct and parenchyma of the obstructed gland allows sialendoscopic access through the natural ostium in case of recurrence. Combining a trans-oral approach with other minimally invasive, conservative procedures ensures symptomatic relief and salivary duct system clearance in most patients.

A retrospective study was performed for the treatment of sialolithiasis in the submandibular gland via combined approach sialendoscopy. Most sialoliths (56.5%) were over 10 mm in size and were hilar (56%). The success rate of the combined approach was 87%. No significant complications were documented. Symptoms resolved in 75.7% of patients; however, this did not correlate with placement of an intra-ductal stent or steroid irrigation. An overall gland preservation rate of 94.9% was achieved [11].

The most common complication following sialendoscopy assisted trans-oral approach is recurrent sialadenitis because of restenosis or due to postoperative infections especially in cases of proximal sialoliths or retained sialoliths after an unsuccessful removal attempt: Out of 172 patients, 1 developed recurrent stone and 6 developed recurrent sialadenitis because of restenosis [13]. Four out of 9 patients suffered of recurrent sialadenitis (***5***). Three out of the 18 cases underwent sialendoscopy assisted trans-oral approach suffered of recurrent sialadenitis [18]. Thirteen out of 70 patients suffered of persistent sialadenitis, and 2 of them were because of recurrent stones [19]. Fifty-nine out of 479 cases underwent sialendoscopy developed recurrent sialadenitis [22].

Other complications confronted were transient lingual nerve paresthesia, ranula formation, and reduced salivary flow. Permanent lingual nerve paresthesia after trans-oral submandibular sialolith removal, as well as lingual nerve damage during purely intra-ductal endoscopic procedures, are very rare [5, 11, 13, 15, 16, 19, 22]. In addition, hemorrhage has been reported in one case out of 172 cases and fistula in the floor of the mouth has been reported in 2 studies [13].

Based on the pooled analysis, the pooled success rate for combined sialendoscopic approach in management of submandibular stones was 95.5. A low incidence of major complications was reported.

The inherent weakness of our study is secondary to the heterogeneity that is introduced when pooling studies with non-uniform populations and methodology. Variability in the use of instrumentation and ancillary devices both between and within studies where instruments changed or evolved over time contributes to this weakness. Further studies using same instruments and techniques on large number of patients are recommended.

Conclusion

Combined sialendoscopic-assisted surgery is efficient and safe in management of submandibular sialolithiasis.

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Not applicable.

Authors' contributions
Study concept and design: AMA and TAY. Acquisition, analysis, or interpretation of the data: AMA, TAY, MMN, and PMM. Drafting of the manuscript: AMA, TAY, MMN, and PMM. Critical revision of the manuscript for important intellectual content: AMA, TAY, and MMN. Statistical analysis: MMN and PMM. Administrative, technical, or material support: AMA, TAY, and MMN. Study supervision: TAY and AMA. The authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the present study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Approved by an ethical committee of Faculty of Medicine Ain Shams University before the start of the study (FMASU M S 565/2022).

Consent for publication
Not applicable.

Competing interests
Prof Tamer Youssef is a co-author of this study and an Editorial Board member of the journal. He was not involved in handling this manuscript during the submission and the review processes. The rest of the authors have no conflict of interest to declare.

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