Minimally Invasive Options for Salivary Calculi

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The aim of this study was to review the advantages, limitations, and international interdisciplinary expert perspectives and contrasts of salivary gland endoscopy and transoral techniques in the diagnosis and management of salivary gland calculi and their adaptation in North America. The transition from transcervical approaches to strictly sialendoscopic approaches is a broad chasm and often not feasible. Sialendoscopy, sialendoscopy-assisted, intraoral, and transcervical approaches all have surgical value. Diagnostic sialendoscopy, interventional sialendoscopy, sialendoscopy-assisted, and transoral techniques have been a major step forward, not only in providing an accurate means of diagnosing and locating intraductal obstructions, but also in permitting minimally invasive surgical treatment that can successfully manage blockages precluding sialoadenectomy in most cases. A flexible methodology is required. Multiple or combined measured may prove effective.

Key Words: Calculi, submandibular gland, parotid gland, sialendoscopy.

INTRODUCTION

Salivary gland endoscopy and transoral techniques have been a major step forward, not only in providing an accurate means of diagnosing and locating intraductal obstructions, but also in permitting minimally invasive surgical treatment that can successfully manage blockages precluding sialoadenectomy in most cases. The conventional treatment has shifted from open surgical or gland resection procedures to endoscopic, endoscopic-assisted, and transoral gland preservation techniques. Multiple specialties have contributed to the present state of the art. Sialendoscopy has been developed in Europe and Israel, and there has been increased interest in the United States. Extracorporeal shock wave lithotripsy (ESWL) is not approved by the US Food and Drug Administration for management of salivary stones in the United States. Treatment algorithms in the United States must take this into consideration. This evidence-based review of gland preserving methods of treatment options for salivary calculi contrasts includes interdisciplinary (otolaryngology–head and neck surgery and oral/maxillofacial surgery) opinions on treatment algorithms using sialendoscopy, sialendoscopy-assisted, and transoral techniques from London, England (McGurk); Erlangen, Germany (Iro, Zenk, Koch); Ashkelon, Israel (Nahlieli); and an adaptation of their pioneering work in the United States (Witt).

MATERIALS AND METHODS

Expert opinion and literature search was conducted in Ovid MEDLINE, from 1948 to the third week of November 2011, with daily updates. The levels of evidence were 4 and 5.

DISCUSSION

Obstructive sialadenitis, with or without sialolithiasis, represents the main inflammatory disorder of the major salivary glands. The main cause of obstructive disorders are stones (60%–70%), stenosis (15%–20%), and sialodochitis (5%–10%).[1] The discussion in this article will be limited to stones.

Eighty percent of all sialolithiasis cases are in the submandibular glands, 19% occur in the parotid gland, and 1% are found in the sublingual gland. Sialolithiasis is most often found in adults, but it may be present in children.[2] For stones, management depends on the size of the stone, the location (proximal, distal, or intraparenchymal), the number of stones, whether the stone is impacted or mobile, and the surgeon's experience.

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Imaging

The diagnosis and treatment of obstructions and inflammations of salivary glands can be problematic due to the limitations of standard imaging techniques. Satisfactory treatment depends on the ability to reach a precise diagnosis, and in the case of sialoliths, to accurately locate the obstruction and to determine its size and mobility. Treatment of most cases of sialadenitis can be planned by history, physical exam, and ultrasound,[3] potentially performed by the surgeon if feasible. All authors of this manuscript favor ultrasound as the first investigation of choice. If an obstruction is present, its position and diameter of the proximal duct can be revealed on ultrasound by stimulating the salivary flow with a sialogogue (vitamin C tablets). Ultrasound may be limited in the deep portion of the submandibular gland. Computed tomography (CT) imaging can be used where ultrasound fails to identify a calculus by ultrasound. Limitations of ultrasound and CT include distinguishing nonechogenic stones from stricture, the length of stenosis, and the diameter of the duct distal to the obstruction. Conventional sialography and magnetic resonance (MR) sialography can help define these. MR sialography, although avoiding ionizing radiation, has less resolution than conventional sialography, limiting visualization of peripheral ducts but not stenosis.

McGurk and Nahlieli would include an ultrasound and sialogram on initial evaluation to depict duct architecture so that occult strictures that may preclude basket retrieval are known. The Erlangen group advocates ultrasound and MR sialography as the initial clinical investigation.[4]

Brief Historical Review

The approach prior to 1989 (for patients who failed conservative management including sialagogues, massage, heat, fluids, and antibiotics) was transoral duct slitting for submandibular stones up to the first molar and up to the curvature of the masseter for parotid stones, with sialoadenectomy as the alternative. The recent literature (Table I) provides an evidence-based background to current multinational expert opinion.

In 1989, Iro et al.[5] reported the first successful clinical case of ESWL. They proposed piezoelectric rather than electrohydraulic shock waves. In 1990 and 1991, Gundlach et al., Konigsberger et al., and Katz [6–8] published on flexible endoscopy of the salivary ducts using a 0.8-mm miniendoscope. Nahlieli et al.[9] in 1994 reported the use of a rigid endoscope. Zenk et al.[10] in 1998 reported on duct diameters. The mean diameters of normal ducts were 0.5 to 1.4 mm for Stensen's duct and 0.5 to 1.5 mm for Wharton's duct. The minimum width of the duct was at the ostium. In 2001, Marchal et al.[11] found that in 48 consecutive submandibular adenectomy patients with proven stones, 10 had normal histology, 18 had intermediate alterations, and 20 glands had extensive atrophy. The implications were that most glands are near normal except for the ductal calculus, and gland-preserving techniques should be attempted when removing the stones.

TABLE I.
Timeline of the Development of Surgical Techniques.

Year	Surgical Technique
1990	Flexible diagnostic sialendoscopy [6–8]
1994	Rigid diagnostic and therapeutic sialendoscopy[9]
1998	Ductal diameters determined[10]
2001	Gland returns to functionality after removal of calculus[11]
2002	External incision combined endoscopic/open approach[12]
2004	Parotid-sparing combined endoscopic/open approach[13]
2006	>85% of stones removed with sialendoscopy or sialendoscopy-assisted approach[16]
2007	Submandibular combined endoscopic open approach[17]
2009	>90% success rate for endoscopic removal of calculi[19]
2011	Robotic-assisted surgery[33]

The combined approach for parotid stones was reported in 2002 on 12 patients by Nahlieli et al.[12] The endoscope was used as a skin transilluminator to locate the stone and was combined with a 1-cm cheek skin incision over the stone. After stone removal by incising the duct, endoscopy was performed to explore the remaining duct for secondary stones. The duct was closed with 4-0 Vicryl and allowed to heal over a stent (1.7-mm polyethylene tube) for 2 weeks. In 2004, McGurk et al.[13] reported a parotid-sparing combined endoscopic and open surgical approach. The intraductally situated endoscope transilluminated the cheek soft tissues at the stone site, whereas a preauricular incision parotid flap allowed access to the parenchyma overlying the stone. Incising directly through the superficial musculoaponeurotic system and gland overlying the stone down to the duct, the stone could be removed. The duct with a stent in place and gland were oversewn.

In 2004, Zenk et al.[14] reported a 10-year experience with ESWL for submandibular stones. Over 10 years, 191 patients were treated with the Piezolith 2500 (R. Wolf Co., Kittlingen, Germany). Stones were treated at 80 MPa, 3,000 shock waves, and monitored by a B-mode 7.5-MHz ultrasound scanner.

The shock wave treatment was followed by massage, duct bougienage, and Dormia basket extraction. Results showed that of the originally treated group, 71% had some residual stone material in the ducts, of which half had long-term symptoms requiring further therapy such as transoral removal of stones or adenectomy. The sole prognostic criterion for certain shock wave success was being free of stones after treatment. Chossegros et al.[15] in 2006 described entering a tight duct by first placing a guidewire through the working channel of the endoscope, followed by threading the endoscope over the guidewire. Nahlieli et al.[16] in 2006 reported success in sialendoscopy or sialendoscopy-assisted cases in 89% for submandibular stones and 86% for parotid stones out of

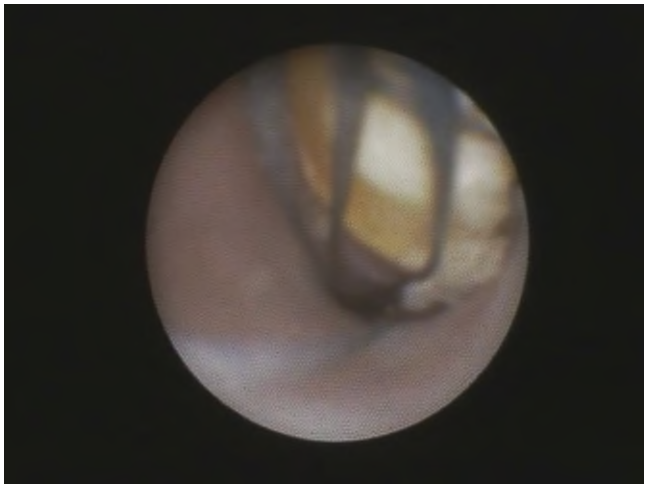

Fig. 1. Basket retrieval of stone.

736 cases. Treatment by Nahlieli et al.[16] showed a 30% to 40% rate of stones that could be managed by sialoendoscopy alone (Fig. 1).

Nahlieli et al.[17] in 2007 reported on the ductal stretching technique for submandibular stones. The endoscope is introduced first to locate the stone, followed by a lacrimal probe. The duct is dissected and isolated; the gland and stone are pushed from below to herniate the stone forward. Incision of the duct follows with lithotomy, then reattachment of the anterior duct to the mouth floor. In 2008, Fritsch[18] reported on decibel levels generated during ESWL with an 80-dB peak found. Because of the acoustic stress of shock waves administered by the thousands, hearing protection was thought advisable.

Iro et al.[19] in 2009 reported on a comprehensive five-group multi-institutional experience of 4,691 patients regarding all diagnostic and therapeutic aspects of salivary calculi over a 14-year period. Submandibular stones outnumbered parotid stones by a three-to-one ratio. ESWL was curative in 51% of patients, partially successful in 25%, and needed repeat ESWL treatment in 23%. Further follow-up treatments included endoscopy, intraoral surgery, and gland removal. For endoscopic basket microforceps retrieval, a 92% success rate was reported.

Anesthesia

In Europe and Israel, most diagnostic sialendoscopies and a significant number of therapeutic sialendoscopic procedures are performed with local anesthesia, including rinsing the working channel with topical anesthetic. Nasotracheal intubation is emphasized when using general anesthesia. Thus, all cases of interventional sialendoscopy by the first author have been performed with general nasotracheal anesthesia. Gillespie et al.[20] described that a failed sialendoscopic or transoral approach can be converted to an immediate transcervical approach, precluding multiple procedures, transitioned more readily with the use of general anesthesia.

SURGICAL TECHNIQUES: DIAGNOSTIC SIALENDOSCOPY

Sialendoscopy can segue the diagnostic assessment to treatment in the same operative session.[21] Available sialendoscopes include flexible endoscopes that can be steered for branch intubation and diagnosis. Stone retrieval is not as effective compared to rigid scopes.[22,23] Rigid and semirigid endoscopes have a larger diameter, greater stability, and can be autoclaved. Instrumentation has differentiated to an array of grasping forceps, baskets, graspers, burrs, balloons, lasers fibers, and stents.

Introduction of the endoscope into the duct papilla, the narrowest portion of the duct,[10] can be challenging. The following methods progressively lead to accomplishing this. Conical dilators and probes of increasing diameter are used under loop magnification, stabilizing the floor of mouth with tooth forceps posterior and superior to the punctum[24] and exposure of the oral cavity with a Denhart or Ferguson mouth prop.[25] Exposure of the oral cavity with a proper mouth prop is emphasized for an unobstructed view of the floor of mouth. Application of methylene blue has been described to enhance visualization of the duct.[26] Guidewire insertion through the working channel assists insertion of the endoscope through a tight papilla.[15] Papilla stenosis of Wharton's duct may require cutdown on the duct dissecting the sublingual gland laterally and exposing the duct and lingual nerve deep to the duct and inserting the sialendoscope.[27] Irrigation with saline to expand the otherwise collapsing duct distally is enhanced by the application of intravenous tubing to the irrigation port attached to a 50- to 100-mL syringe. Healing by secondary intention or a ductoplasty (suture of the duct to the floor of mouth at the end of the procedure) can be performed. Kinks in the duct can be bypassed with the assistance of a guidewire.[27]

SURGICAL TECHNIQUES: INTERVENTIONAL SIALENDOSCOPY

Submandibular Stones, Distal and Proximal Duct

The first author's adaptation of sialendoscopy, sialendoscopy-assisted, and transoral approaches as a part of the surgical array for submandibular stones that have failed conservative management (sialogogues, massage, heat, fluids, and antibiotics) is summarized in Table II and compared to international experts. The most substantial difference in the treatment algorithm is the use of ESWL where available, although for submandibular stones its use is not uniform as it is for parotid stones.

Distal stones treated near the punctum of Wharton's duct (<1 cm from the orifice) can be removed with longitudinal slitting of the duct by a needle tip insulated electrosurgical unit, removal of the stone, followed by sialendoscopy and lavage. A transoral approach is favored by McGurk and Nahlieli.[4,2] The duct heals by secondary intention, and stents are not required to prevent stenosis. Alternatively, primary treatment for distal stones <5 mm favored by the Erlangen group[28] is interventional sialendoscopy. In most cases, however,

TABLE II.
Gland-Sparing Management of Submandibular Stones That Have Failed Conservative Medical Management.

	Distal Stones <5 mm	Proximal Stones <5 mm, Mobile, or Palpable Intraparenchymal	Proximal Stones >5–6 mm, Mobile, or Palpable Intraparenchymal
1st-line approach	Transoral (McGurk, Nahlieli, Witt)	Interventional sialendoscopy (all authors)	Transoral approach, limited duct incision (McGurk, Nahlieli, Witt), duct incision papilla to hilum (Erlangen group)
1st-line approach	Interventional sialendoscopy (Erlangen group)		
2nd-line approach	Transoral approach (Erlangen group)	Transoral approach (all authors), limited duct incision (McGurk, Nahlieli, Witt), duct incision papilla to hilum (Erlangen group)	ESWL (Erlangen group, Nahlieli; McGurk does not advocate ESWL for submandibular stones)

ESWL = extracorporeal shock wave lithotripsy.

papillotomy has to be performed because the narrowest portion of the duct is the ostium.

Interventional sialendoscopy using baskets (Fig. 1), balloons,[26] or graspers allow stone retrieval through the working channel of the sialendoscope for proximal mobile submandibular stones <5mm. Interventional sialendoscopy is the favored approach of all four authors for mobile proximal stones <5 mm. The basket should be opened behind the stone, otherwise the basket runs the risk of entrapment for immobile large stones.[29] Once the stone is engaged in the basket it often cannot be released. New baskets have recently been developed that allow the stone to be grasped and released if it is found the stone is fixed or too large to be drawn down the duct. Balloons favored by Nahlieli[27] can be used to remove small stones, passing the uninflated balloon distal to the stone, then inflating the balloon and withdrawing it. A stone sitting in a diverticulum with a narrow neck may not allow the stone to pass in the main duct system.

Balloons and forceps are designed to be inserted through the working channel of the endoscope. An alternative technique Nahlieli[27] describes is a cutdown approach to Wharton's duct. Here the duct is visualized and opened surgically. Then a balloon or forceps can be placed initially, not through the working channel but along side the endoscope.[27] Another available technique is grasping forceps to hold and extract the stone without bypassing it. Fragmentation of larger stones is possible with drills and forceps (although time consuming). Forceps can only apply low forces and have limited application. Nahlieli[27] applies suction to the working channel to remove dust-like stone fragments in selected cases.

Geisthoff and Maune[30] have described sonographically guided mechanical fragmentation of sialoliths (sonoguide forceps). The main advantage of this technique is the larger-size forceps that can be used under ultrasound guidance without the use of a sialendoscope. The sialendoscope limits the size of the forceps and their force. Distal stones are more effectively treated with the sonoguide forceps technique than stones in the parenchyma.

Calculi >5 mm in the proximal Wharton's duct can be removed by Nahlieli et al.'s ductal stretching procedure and limited duct incision.[17] Modifications described by McGurk[4] crystallize the key ductal and lingual nerve anatomy and safe surgical approach including use of the Ferguson mouth prop and lateral retraction of the sublingual gland with stay sutures passed through the teeth. The Erlangen group[31] differs from the other authors by incising the duct from punctum to hilum. The duct is then sutured to the floor of mouth without incidence of ductal stenosis.

Repair of the duct proximally can be technically challenging, and leaving it open will not likely result in ill effect.[4] Alternatively, Marchall uses a guidewire through the working channel of the sialendoscope passing through a ductotomy. The sialendoscope is withdrawn, and a stent is introduced over the guidewire and sutured to the papilla with nonabsorbable suture, leaving the stent for a recommended 3 weeks.[32]

Proximal submandibular stones >5 mm not able to be removed by transoral techniques will be treated with ESWL followed by sialendoscopy (ESWL + SE) by the Erlangen group[28] and Nahlieli.[27] McGurk does not advocate ESWL for submandibular stones. ESWL is not available in the United States. In the United States, robotic-assisted transoral removal of larger, impacted, and palpable Wharton's duct stones with duct repair offers a potential avenue in selected patients.[33]

Parotid Stones: Distal and Proximal Duct

The first author's adaptation of sialendoscopy, sialendoscopy-assisted, and transoral approaches as a part of the surgical array for parotid stones that have failed conservative management is summarized in Table III and is compared to international experts.

Interventional sialendoscopy and basket retrieval of proximal and distal parotid stones <4 to 5 mm is the

TABLE III.
Gland-Sparing Management of Parotid Stones That Have Failed Conservative Medical Management.

	Distal Stones <4–5 mm	Proximal Stones <4–5 mm or Mobile, Visible, Intraparenchymal	Proximal Stones >5–6 mm and <10 mm
1st-line approach	Interventional sialendoscopy (all authors)	Interventional sialendoscopy (all authors)	ESWL + SE (Erlangen group, McGurk, Nahlieli)
1st-line approach			Combined sialendoscopic/open approach (Witt)
2nd-line approach	ESWL + SE (Erlangen group, McGurk, Nahlieli)	ESWL + SE (Erlangen group, McGurk, Nahlieli)	Combined sialendoscopic/open approach (Erlangen group, McGurk, Nahlieli)
2nd-line approach	Combined sialendoscopic/ open approach (Witt)	Combined sialendoscopic/open approach (Witt)	
3rd-line approach	Combined sialendoscopic/ open approach (Erlangen group, McGurk, Nahlieli)	Combined sialendoscopic/open approach (Erlangen group, McGurk, Nahlieli)	

ESWL + SE = extracorporeal shock wave lithotripsy + sialendoscopy.

treatment of choice by all authors. Distal parotid stones <5 mm not amenable to sialendoscopic removal and stones >5 mm can be removed only if they are at the duct orifice. Any attempt to dissect the parotid duct along its oral origin may lead to troublesome stenosis.

Calculi <4 to 5 mm not amenable interventional sialendoscopy and stones >5 mm are treated with ESWL + SE by the Erlangen group, McGurk, and Nahlieli.[4,27,28] All authors where ESWL is available advocate its use for parotid stones.

In the United States, where ESWL is not available, and a tertiary approach where ESWL is available, a gland-sparing approach for calculi >5 mm in Stensen's duct is advocated. A combined external parotid skin incision with nerve monitoring and sialendoscopy is employed. In selected instances with larger stones, intraoperative ultrasound is helpful. The stone can be identified endoscopically or by ultrasound (when stenosis exists distal to the stone). The duct crosses several branches of the facial nerve. Colored Silastic tubing described by Marchall will help stabilize the duct. An external parotid approach with longitudinal slitting of Stensen's duct is followed with duct closure using 7-0 Prolene. Stenosis can be repaired with a vein graft ductoplasty patch.[32] Transoral back pressure irrigation of Stensen's duct with saline via the irrigation channel of the sialendoscope assures a water-tight closure. Fibrin glue may aid in securing a salivary seal.[32] Sialostenting introduced either from the external approach or via a sialendoscope forwarded on a guidewire is recommended for 2 to 4 weeks.[13] Sialostents are manufactured by Hood Laboratories, Pembroke, Massachusetts (Shaitkin Salivary Gland Cannula) and Sialotechnology Ltd., Ashkelon, Israel.

SURGICAL TECHNIQUES: INTRAPARENCHYMAL NONPALPABLE OR IMPACTED STONES >5 MM

Management of intraparenchymal nonpalpable or impacted stones >5 mm for submandibular and parotid stones is summarized in Table IV. The Erlangen group[28] and Nahlieli[27] advocate ESWL + SE for both submandibular and parotid stones. McGurk favors ESWL + SE only for parotid stones.[4,2] Multiple intraparenchymal symptomatic stones not amenable to conservative therapy are treated with sialoadenectomy by all authors.[4] In the United States, where ESWL is not available, sialoadenectomy is advocated for fixed intraparenchymal stones and stones not amenable to the above gland-sparing techniques. An expertly performed sialoadenectomy carries a low risk of complication to cranial nerves (V, VII, and XII) and is a one-procedure event for the patient without a concern for xerostomia. A balance informed consent in the United States should include sialoadenectomy as an alternative initial approach.

TABLE IV.
Management of Intraparenchymal Nonpalpable or Impacted Stones >5 mm That Have Failed Conservative Medical Management.

	Submandibular Stones	Parotid Stones
1st-line approach	ESWL + SE (Erlangen group, Nahlieli)	ESWL + SE for stones <10 mm (Erlangen group, McGurk, Nahlieli)
1st-line approach	Sialadenectomy (Witt)	Sialadenectomy (Witt)
2nd-line approach	Sialadenectomy (Erlangen group, Nahlieli)	Sialadenectomy (Erlangen group, McGurk, Nahlieli)

ESWL + SE = extracorporeal shock wave lithotripsy + sialendoscopy.

Various lasers have been used for intracorporeal lithotripsy, among them the XeCl-excimer, flash-lamp pulsed dye, the Ho:YAG, and the erbium:YAG laser. One important advantage of most lasers is that the fibers have small diameters, sometimes only 200 mm. These properties allow applying high-watt intensities for fragmentation to stones even in the periphery of the duct system or behind stenotic areas. Vision is often reduced by floating fragments interrupting the case until irrigation, baskets, or forceps are used to remove the fragments. The procedure is time consuming, mainly because of the frequent fragment interruptions, but also to avoid tissue damage.[3] Lasers (intracorporeal lithotripsy) are expensive, time consuming, risk perforation of the duct, and can result in the development of abscesses requiring gland removal, and are not advocated by any of the authors.[6,34]

Complications of sialendoscopy have generally modest impact. They can include duct perforations, basket entrapment, postoperative infections, recurrence of symptoms, duct avulsion, and ductal strictures. Relative contraindication to sialendoscopy is acute sialadenitis. Transoral submandibular approaches have risks that include lingual nerve trauma and bleeding.[24,26,29,35] Transfacial sialendoscopic approaches can result in facial nerve dysfunction in the buccal branches and sialocele that can be managed with BOTOX (Allergan, Inc. Irvine, CA) and anticholinergics, and is best prevented by a water-tight seal and tissue glue.

CONCLUSION

Diagnostic sialoendoscopy, interventional sialendoscopy, sialendoscopy-assisted, and transoral techniques have been a major step forward, not only in providing an accurate means of diagnosing and locating intraductal obstructions, but also in permitting minimally invasive surgical treatment that can successfully manage blockages precluding sialoadenectomy in most cases. A flexible methodology is required. Multiple or combined measures may prove effective. Success is measured by treatment that is efficient, clinically effective, cost effective, and gland sparing in the majority of cases.

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