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Review on submandibular gland stone surgical techniques and new advances

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Abstract

This review delves into the complexities and advancements in the surgical management of submandibular gland stones, a prevalent condition within sialolithiasis, with a particular focus on the submandibular gland which is most frequently affected. Traditional surgical interventions, such as submandibular sialoadenectomy, though effective, come with significant risks and postoperative complications including gland deficiency, scarring, and digestive issues. The emergence of minimally invasive endoscopic techniques marks a significant advancement, offering a less traumatic alternative for stone removal without sacrificing gland functionality. Despite these advances, challenges remain with endoscopic techniques, particularly in the complete removal of calcified stones and in cases involving large stones, leading to extended surgery times and increased costs. The review highlights a novel transoral endoscopic technique aimed at improving the removal of deep lobe stones, showing promising results in terms of efficacy, reduced trauma, and lower complication rates. This study underscores the ongoing evolution in the management of submandibular gland stones, emphasizing the importance of innovation and the adoption of new technologies to enhance patient outcomes and reduce healthcare burdens.

Keywords: Sialolith; Stone; Calcium; Submandibular Gland; Surgery

1. Introduction

Sialolithiasis is one of the most common diseases involving the salivary glands. Among the three paired major salivary glands, the submandibular gland is the most frequently affected site. The recurrence rate after treatment is around 10-40% regardless of technique, which not only leads to great discomfort to patients but also increases the economic burden to tertiary hospitals. Various surgical techniques have been proposed to remove stones depending on the stone size or condition of the duct.

Conventional submandibular sialoadenectomy can effectively remove all stones in the gland but incurs the greatest risk of surgical complication and is associated with more severe postoperative sequelae, including salivary gland deficiency, an unsightly scar, and digestive problems. Extraoral sialoadenectomy provides a better visual field for deep-seated stones but is more traumatic. Intraoral sialoadenectomy is less invasive but leaves a blind area to remove distally embedded stones.

With the advancement of endoscope technology, minimally invasive endoscopic techniques have been developed to remove a vast majority of stones without sacrificing the gland. However, there are certain limitations in the endoscopic technique, including difficult identification of the duct, inability to completely remove calcified fibrous stones, and extended surgery time for large stones. Although laser lithotripsy can fragment even very dense stones, it requires time-consuming morcellation and is more costly than other traditional techniques.

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Herein, a literature review of submandibular gland sialolithiasis is provided, with a focus on pathophysiology, clinical presentation, diagnosis, surgical techniques, and notably, advances in the surgical technique for submandibular stones.

1.1. Background and Significance

Salivary gland stone (sialolithiasis) disease remains a persistent health concern globally, with the submandibular gland being the most frequent site. Recent explorations have aimed for more effective treatment modalities, fostering the interest in new technologies and novel minimally invasive techniques. Sialolithiasis can lead to the proliferation of benign gland tumors. The majority of submandibular stones arise in the deep lobe, where they might cause gland swelling and obstruction. The classic surgical technique for deep lobe stones involves a transcervical approach, which poses potential complications for facial nerve injury. Various technologies, such as extracorporeal shock wave lithotripsy (ESWL), sialendoscopy-assisted laser lithotripsy, and robotic procedures, have been applied to remove stones, with varying effects. However, for the submandibular deep lobe, sialendoscopy has severe limitations and extractions are not recommended. Sialendoscopy is also more challenging for the submandibular gland due to its functional and anatomical structure. More importantly, managements like ENDO still heavily rely on sialendoscopes. As a widely used and successful technique in other fields, the transoral approach has never been used for removing deep lobe stones in the submandibular gland.

The study aimed to help in innovating a new transoral technique to facilitate the removal of submandibular gland deep lobe stones under endoscope assistance. The transoral approach offers better exposure and better handling.

All patients with deep lobe submandibular stones who underwent removal by transoral endoscope-assisted technique between 2019 and 2022 were taken into account. The stone removal procedure includes the following steps: first, the duct orifice was expanded through the lingual flap incision. Then, the stone location was confirmed by injecting saline fluid or hyoscine butylbromide. Next, an incision was made on the duct and the stone was grasped and removed through the duct incision. The stone removal is all done under endoscope assistance.

This new technique's effectiveness is indicated through clinical outcomes and illustrative cases. All stones were successfully removed through the transoral route. No post-operative complications were reported. The transoral technique allows for less trauma and a higher success rate is suggested. Moreover, for stones that cannot be removed through the duct, alternative approaches can be adopted.

2. Anatomy and Pathophysiology of Submandibular Gland Stones

The submandibular gland is one of the major salivary glands in humans and plays an important role in the maintenance of oral health. These glands are pea-sized salivary glands that are located under the lower jaw of the mouth. There is one submandibular gland on either side of the jaw. These glands open into the mouth at the floor of the mouth beneath the tongue. The submandibular gland's ducts (Wharton's ducts) take a serpentine course into the oral cavity. The duct system is composed of an intraparenchymal duct system that is surrounded by glandular tissue, a mucosal duct, and an orifice at the sublingual caruncle.

The submandibular gland has a peculiar anatomical arrangement. First, the gland is situated on an isolated muscle (mylohyoid) and is therefore surrounded by extra glandular tissue and fascial coverings. Second, its duct descends deeply into the neck and passes under a longitudinally oriented muscle (hyoglossus) and under the lingual nerve. Third, the distal end of the duct opens at an elevated position, just beneath the base of the tongue. These anatomical features likely play roles in the pathogenesis of sialolithiasis, such as being prone to trauma and salivary stasis.

The formation of stones in the submandibular gland occurs due to a combination of anatomical factors, altered salivary secretion, and microbial adherence. These stones can create obstructions and lead to secondary infections in the affected salivary glands. Sialolithiasis predominantly affects the submandibular glands, with a ratio of 3 to 1 compared to the parotid glands and 10 to 1 when considering the major glands together. Under normal conditions, saliva is secreted in the form of a low-viscosity isotonic fluid, which has a high water content. Certain inflammatory conditions can alter this homeostasis of salivary secretion, decreasing water content and increasing mucin and protein levels, which in complex with calcium precipitates to form stones. Salivary stones can also consist of 66% calcium phosphates and 34% calcium carbonates. These stones can then become the sites of microbial colonization and lead to secondary infections of the gland.

2.1. Anatomy of Submandibular Gland

The submandibular glands, or submaxillary glands, are the second pair of major salivary glands and are classified as mixed, producing both serous and mucus secretions. However, the majority of the glandular tissue is serous. Each gland is located below the mandible, in the submandibular triangle and occupies a space above and below the mylohyoid muscle. A parotid duct runs from each gland, opening into the floor of the mouth at the submandibular papilla, near the midline, and posterior to the lingual frenulum. The ducts are commonly obstructed by calculi, resulting in a painful collection of fluid, salivary sialadenitis, and, in some cases, abscess formation. Judging from its location and course, disease in the submandibular gland requires a thorough understanding of its anatomy.

Two distinct parts can be made out, as seen in a submerged specimen: a superficial (or external) part, which is ovoid and convex externally; and a deeper, or internal part, which is flat, and is propped on the mylohyoid muscle. Each submandibular gland has two main components: the glandular parenchyma composed of serous acini and ducts and the ductal system, which consists of intercalated ducts, striated ducts, and excretory ducts. The excretory duct, or Wharton's duct, runs forward and medially in a groove on the submandibular fossa of the mandible, parallel to the lower border of the bone. After a course of about 5cm, it emerges from the posterior border of the gland, and makes a turn upward behind the mylohyoid muscle to reach the floor of the mouth. Associated with the Wharton's duct is the submandibular ductal salivary gland (of Rivinus), which lies between the lower border of the mandible and mylohyoid muscle. Several short ducts run parallel to the main duct and open into the mouth by small openings behind or beside the lingual frenum. Flow of saliva from the submandibular duct is slower than under stimulation by the parotid duct. At rest, 67% of the whole salivary secretion is from the submandibular gland.

2.2. Formation of Submandibular Gland Stones

The exact mechanism of the formation of submandibular gland stones (SG stones) is still poorly understood. Salivary gland stones have been reported with a conspicuous difficulty in oral cavity hygiene, indicating a close association with oral bacteria. Similarly, acid pH has been associated with the formation of calcium oxalate stones in previous studies. Stone composition analysis has shown hydroxyapatite as the main component of the majority of SG stones, which is one of the main components of mineral precipitation in the oral cavity induced by microbes.

This experimental study aimed to fabricate an in vitro biomimetic model in which hydroxyapatite could be induced by oral bacteria. With the use of the model, the oral biofilm formed in the salivary pool simulating pellicle formation, calcium and phosphate precipitation in a supersaturated environment, and hydroxyapatite precipitation in an acidic environment could be attained. Further, the resulting biofilm exhibited a morphologically thick pellicle layer, characterized by a significantly higher attachment of crystalline CTAB-extracted proteins than control. The findings confirm that oral biofilm on the pellicle layer on salivary condition plays an important role in the mechanism of SG stone formation with an oral microbial origin.

Salivary gland stones (SG stones) are the most prevalent pathology in salivary glands, and accordingly, have been a hotly debated issue for decades. Recent studies have highlighted the close associations of SG stones with anatomical abnormalities and oral cavity hygiene, leading to controversial theories regarding the non-migrating obstruction. The histological investigation proved that calculus and duct stricture coexisted around the site of separate duct orifice in a porcine model, implying a similar calcific process in juxta-focal salivary duct stricture. Calcification centers were prominent with oral microbe colonization in SG stones. In addition, numerous Ca2+ and PO4- clusters and precipitated minerals, with an evident increase of pH value, were obvious in the duct epithelial surface near the juxta-focal stricture. All these findings suggest that the urolithiasis-like obstructive mechanism might explain the formation of SG stones.

The components of SG stones were analyzed, and all the SG stones were found to consist of the complex mixture of calcium phosphate, mucin glycoproteins, and non-calcium minerals. Hydroxyapatite (77.1% ± 5.1%), i.e., $Ca10(PO4)6(OH)2$, was demonstrated to be the major component of 35 examined SG stones, conforming to the previous studies regarding the high ratio of hydroxyapatite in human salivary stones. Salivary gland stones comprised a complex matrix, and mineral deposits were often accompanied by protein precipitates, which in turn were also coated by salts. Interestingly, similar microscopic observations and mineral composition results of human SG stones have also been found in other studies, indicating that the composition of human SG stones is similar regardless of race and salivary gland type.

3. Diagnosis of Submandibular Gland Stones

A submandibular gland (SMG) stone (sialolithiasis) is the most common cause of salivary gland swelling and pain, accounting for 80-90% of all salivary stones. After optimal treatment, symptoms of submandibular gland stones can

often completely disappear. Submandibular gland stone disease is common in adults aged 30-60 years, with a male-to-female ratio of 2:1. When diagnosing submandibular gland stones, doctors can identify abnormalities by taking a history and performing a physical examination. Typical clinical presentation of submandibular gland inflammation due to salivary stones includes waxing and waning symptoms, intermittent swallowing, and swelling before meals. Physical examination may reveal tenderness and palpation of the stone in the floor of the mouth 2-3 cm from the midline. Chronic typical presentation includes dropping of the tongue and mouth-side external incisions to relieve swelling of the contralateral floor of the mouth.

Various imaging modalities were used to exclude or identify morphology, number, location, and complications of submandibular gland stones. Plain X-ray film is used mainly in the selection of patients for duct exploration and is useful to diagnose calcified stones. Computed tomography displays exquisitely the duct system and parenchyma of the submandibular gland, and could depict the stones accurately. MR-sialography could visualize the duct system and hilar area, being helpful for the diagnosis of chronic sialadenitis. Era of Crescent Transoral Minimal Invasion can achieve removal of a high stone through a lower second molar approach without damaging lingual nerve and salivary duct.

3.1. Clinical Presentation

Submandibular gland stone patients usually have complaints of unilateral, recurrent salivary gland swellings and postprandial pain, which may be of only a few hours duration. Though these acute symptoms usually subside after a while, this may be associated with chronic swelling, which may be of longer duration. These chronic swellings are mistaken for other conditions like sialadenitis, enlarged lymph nodes, etc. These patients may present with recurrent attacks and scarring of the gland. On chronicity, the swelling may become firm and may not be tender, and positive signs of inflammation may be absent. It is advisable to have a suspicion of stone disease in all cases of recurrent wheezing or scarring of salivary glands. Chronic injuries are rarely examined properly, and the incidence of stones may be underestimated. As chronic stones affect the entire duct system, they are difficult to diagnose and treat. In the last few years, there has been a revival of interest in diagnosis and treatment owing to better diagnostic and surgical methods.

Salivary gland stones in the submandibular gland occur in a peculiar arrangement because of certain anatomical, salivary, and functional features. It occurs predominantly in men, with the usual age being 30 to 60 years, and the lower socioeconomic group particularly because of the absence of hygienic habits. Salivary gland stones in the submandibular gland form almost 30% of the total salivary stones. Most of these stones have a huge size of 8 mm or more with a firm outline, as compared to those in the parotid or sublingual glands, which are small and with a warty outline. The stones in the submandibular glands are often associated with strictures, which is rare in the parotid glands. Submandibular gland stones rarely occur in children. Stones form preferentially in glands with alkaline pH, as is the case with submandibular saliva. The taste of the stones, if one can have this highly imaginative thing, is sweetish and acerbic. These stones present with swelling and pain, which occurs during meals and is considered pathognomonic of stones and not generally seen in tumors or glandular sclerosis. However, in submandibular stones, the patient may remain asymptomatic, and hence there is a possibility of misdiagnosing stone disease as other things. Supervising and careful examination usually can provide the answer.

3.2. Imaging Modalities

The role of imaging in the diagnosis of submandibular gland stones is imperative, particularly in the case of an asymptomatic stone found in a routine imaging study. Therefore, due to its high sensitivity, multiple imaging modalities have been a subject of development and investigation. However, clinical presentation remains an important aspect of investigation.

Plain radiography plays a crucial first-line role in the diagnosis of submandibular gland stones, and several studies have conducted comparisons of plain radiography with other imaging modalities. However, plain radiography remains the first imaging modality in the diagnosis of submandibular gland stones. In addition, the sensitivity and specificity of plain radiography have been reported to be 64% to 98% and 75% to 100%, respectively, depending on stone size and type. Plain radiography can detect both radiopaque and borderline stones.

The introduction of ultrasound provided a non-invasive and radiation-free option for the evaluation of salivary duct diseases. Various ultrasound criteria have been established over time; newly developed modalities have also been invented and tested. However, it remains difficult to evaluate deep portion stones with this modality. The sensitivity and specificity of ultrasound have been reported to be 60% to 98% and 41% to 97% in different studies. First reported by Bergstrom and relatively widely used for the salivary gland stone evaluation, it is a safe imaging modality that provides a two-dimensional image with high sensitivity. However, most of the focal lesions are detected in this semi-invasive technique, and stones in the duct can be overlooked. The technique reported up to this point on IRMBA has

been performed with a 1.5T system, and stone detection sensitivity has been reported to be 71% to 100%. Recently, IRMBA has been investigated with a 3.0T system, reporting a stone detection sensitivity of up to 100%. Interpretation of the scan image is well established with predictable findings and a better finding detection profile. However, the equipment cost is expensive; additionally, MRSA is relatively tedious and less widely available than CT in clinical practice.

Although CT might be advantageous over the other modalities in terms of the capability of detecting non-calcified stones, nevertheless, to the best of the author's knowledge, no study has been performed in stone detection or any comparative studies. Advantages of this modality are its rapid and easy examination nature; additionally, it can examine bone status simultaneously. However, carefulness should be taken in performing CT in a more radiation-sensitive group of patients. Evaluating these categories of patients, alternative imaging modalities or a repetitive examination protocol should be arranged. Overall, the aforementioned imaging modalities all have their advantages and limitations, and discrimination of the involved disease should be performed cautiously. Moreover, recently invented and developed modalities are worthy of attention for future possibilities in the diagnosis of this common disease.

4. Conservative Management of Submandibular Gland Stones

In recent decades, endoscopic surgical treatments have flourished, particularly for salivary gland stones, and a variety of endoscopic instruments have been invented. However, methods other than surgical treatment are preferred for initial management. For very tiny stones, conservative treatment such as salivary gland massage or sialogogues is recommended. Generally, salivary stones less than 2 mm in size can be managed conservatively. Stones of size less than 1 cm are indicated for conservative treatment. Simple submandibular duct stone removal by intra-oral approach is performed where stones are in Wharton's duct or the hilum of the gland or stones of diameter less than 1 cm or stones totally embedded in the gland. Stones located at the proximal duct are treated by extra-oral duct stone removal. If previous techniques failed or recurrent stones were found, submandibular gland excision can be performed.

Digital massage of the salivary glands is recommended to promote the passage of the stone into the mouth where it can be removed. In all cases of massage therapy, compliance with home care instructions is essential to increase the chance of expelling the stone. Digital massage of salivary glands is an existing treatment for both submandibular gland stones and parotid stones. Salivary gland massage relieves symptoms, allows passage of smaller stones and, importantly, avoids surgical interventions. For smaller stones, where no obstruction is detected at the lower duct, vigorous massage of the parotid gland should be attempted since the stone may traverse to the duct. Stones in parotid duct or gland can be approached via a combination of sialogogues, massage, umbilical cord blood transfusion, intra-oral irrigation, and incision at orifice or duct. Stones obstructing parotid duct or gland for six months can be managed by parotid duct diversion to buccal vestibule or duct cannulation and flushing.

Sialogogues enhance salivary flow and promote spillage of stone in duct and prevent complaints associated with obstruction for initial stone size of less than 1.5 mm or at lower duct having a chance to be expelled. Chewing sialogogues enhances and hoists salivation, dilutes saliva concentration, and retrocedes smaller stones. Peppermint or menthol mouthwash enhances salivation by central vagal stimulation. To circumvent rancid taste of acyclic stimulation, sour juice swishing is advocated. To explore antifungal and smooth muscle controlled oral sialogogues, green tea, menthol 0.1%, and citric acid 0.2% mouthwash were investigated. Citric acid acts in line with sialagogic hormone secretin releasing pancreatic secretion for eight mins. After citric acid mouthwash, bicarbonate concentration in parotid saliva increases for ten mins and flow rate increases by 271%.

4.1. Salivary Gland Massage

With its deep location, tortuous course, and large mucous content, the submandibular gland is predisposed to stasis, leading to the formation of stones. Most stones are not large (from a few mm to 2 cm), unilateral, and composed of calcium salts and organic materials, with high concentrations of sodium and uric acid. Multiple stones are rare. Location can affect treatment and clinical presentation. Stones in the hilum or in the proximal duct may be more likely to cause obstruction, leading to recurrent parotitis. In contrast, stones located in the long segment of the duct may be asymptomatic until they grow large enough. If closely located to the orifice, patients may feel discomfort during meals as the orifice dilates and brings the pressure to be higher than the stone's.

A history of recurrent episodes of pain, swelling, and tenderness is common with parotid gland stones. Stone attacks typically occur within 1-2 hours after food intake as salivation increases. Pain may radiate to the ear and is often throbbing. Other symptoms include dryness of mouth and tongue, bad breath, fever, malaise, and fatigue. As the stone grows larger, swelling becomes chronic, firm, and non-mobile, with dry ipsilateral mouth, tongue, and lower lip.

Salivary gland massage has been used to treat sialolithiasis for more than 2300 years. Ancient practitioners believed that stone removal can be facilitated by inducing retrograde flow of saliva through the duct. Using a simple technique of passive drainage of the affected gland, light pressure should be applied posterior to the stone in a downward manner in order to push the stone to the duct orifice, where its dislodgement is granted by stimulation with sour candies or electrogustatory stimulation. Pressure should be released to let the saliva flow outside, repeating the sequence multiple times. This treatment is suitable for stones smaller than 5 mm and is efficient and safe. Since 6% of totally treated stones became more than 5 mm after failed attempts, it is better to refer the patient to surgical removal within 4 weeks of diagnosis.

A simple and effective technique of passive dilation suitable for sialolithiasis of the submandibular gland, innovative in Japan, is suggested. When saliva from a healthy side spontaneously flows out of the mouth, chips of tissue can indicate the presence of sialolithiasis at that side, etc. Detailed precautions and procedures to avoid severe complications are described.

4.2. Sialogogues

Sialogogues can be classified as artificial or natural and are believed to act on the parasympathetic secretomotor nerve endings of the gland. The former group includes medicines such as pilocarpine and cevimeline. The latter group includes lemon juice, citric acid, and vinegar, which stimulate the release of salivary secretions by inducing the secretion of saliva from the parotid, submandibular, and sublingual glands, motivating the expulsion of stones and debris. Salivary secretions may dilute any irritants present in the duct, preventing inflammation and obstruction. Sialogogues can be administered through the oral cavity or other routes for proper functioning.

Additional factors, including the upper esophagus irritation also known as the "pharyngeal reflex," would be effective during the first stage of the swallowing act, as this zone is directly contacted by the sialogogue agent when thrown into the mouth. This region is innervated by fibers of the glossopharyngeus as well as the vagus nerve. The final efferent pathway for the secretory response is the autonomic parasympathetic nerves to the submandibular, sublingual, and parotid glands. The central nuclei and pathways for augmentation of salivary secretion due to irritation of the upper esophagus and other gastroesophageal structures have also been identified.

A dilemma arises concerning the best choice of sialogogue. Many physicians employ prickly pear fruit juice, orange juice, cellulose and honey, peach and plum juice, vinegar, ginger, natural vitamins A and E, carrot, onion, cranberry, and fish egg extract with a good success rate. The combination of these natural substances would be useful in obstinate cases.

5. Surgical Techniques for Submandibular Gland Stone Removal

Historically, the structured management of salivary gland stones in the submandibular gland has evolved. Surgical approaches to treat sialolithiasis can be broadly categorized into intraoral approaches such as sialendoscopy and/or transoral sialolithotomy and extraoral approaches such as transcervical approaches or intraoral-extracervical combined techniques. Every surgical technique has its own advantages and drawbacks with respect to stone localization, size, location, symptoms, and patient compliance.

Sialendoscopy is a minimally invasive technique used to treat salivary duct or gland diseases. Old findings regarding ductal autoregulation and the internal draining of retained saliva are now critically analyzed and challenged. The diagnosis is done with a rigid scope or a flexible endoscope under local anesthesia. In radiolucent cases, the procedure is mainly performed blind and the stone unreachable. Other options consist of marsupialization, ductal dilation, milking, catheter drainage, at best followed by sialendoscopy. Other advanced techniques include laser lithotripsy and basket retrieval. The long-term success rates are around 80%. Post-operative complications are infrequent, depend greatly on the experience of the team, and do include bleeding, pain, stricture, or failure to remove the stone. The complication rate in simple sialendoscopies ranges between 0% and 4%. The indication for sialendoscopy is easy and well accepted. In case of failure after sialendoscopy, other approaches can easily be combined or performed later on.

Transoral sialolithotomy is a less invasive alternative for the removal of sialoliths of the submandibular glands. The technique was applied in 179 patients from 1997 to 2009, and satisfactory results were obtained. Success rates were 91.7% for all stones and 94.0% for stones smaller than 15 mm. The recurrence rate was 8.4% (15 of 179). All recurrences were caused by new stones. Patients expressed a high degree of satisfaction with the results. The main advantages of transoral stone removal are that it can be performed when the intra-oral access is free of stricture, it's less invasive, and it avoids visible external scars. The water through incisional approach is shown to be a powerful adjunct to transoral sialolithotomy.

Salivary duct stones (sialoliths) are the most common cause of obstructions of the salivary gland and/or ducts. They are most commonly located in the Wharton's duct and can cause partial or complete obstruction. Techniques for accessing impacted stones have evolved from open surgery to multifunctional approaches. These include transcervical sialolithotomy and intraoral sialolithotomy. This technique was refined at the same time complementary technological advances like digital sialendoscopy, basket retrievals, and laser lithotripsy were introduced. It became a minimally invasive modulo with a stone removal success rate of 69% to 98%.

5.1. Sialendoscopy

Sialendoscopy, a minimally invasive technique, has become an important adjunct for treating submandibular gland stone disease. The technique was first described by Caton in the early 1990s and used rigid optical scopes. Since then, incremental improvements in technology have allowed this technique to become widely adopted. Although sialendoscopy seems to be highly effective for treatment of parotid glands, data on directly treating submandibular stones are absent.

In this approach, the submandibular duct is cannulated with a sialoscope, and ductal obstruction is treated by removal of mucus plugs, milking dilated ducts, and dilating strictures. There is a learning curve to this technique, and various stones may be more or less difficult to treat. For treatment of symptomatic submandibular stones masses >4mm, there are 10% treatment failures; when the stone is directly visualized and 5mm with experienced surgeons, the treatment failure rate falls to 5%. There are multiple technological advances that would help improve the success rate of sialendoscopy. Despite this being a less invasive option than fibrotomy, there still exists a sizable patient population that will require gland excision, and sialadenectomy remains the gold standard.

A 15-month patient population cohort was evaluated for initial patient treatment, date of initial presentation to the ENT clinic, and referral to a tertiary care center. The inclusion criteria state that patients must have submandibular stones that are symptomatic. The study size ranges from 430-566 patients and observed a significant stone migratory effect with 20-30% of them apparently moving in size or location. Mills et al. also demonstrated that stents may be very effective in symptomatic stones >6mm in size, with a success rate higher than ductal dilation alone. Broadbent et al. proposed group therapy for patients with recurrent stone disease, where each patient is counseled about the etiology, preventative measures, dietary recommendations, oral hygiene, and both surgical and nonsurgical management of these stones. However, there is only one such study currently in the literature using this model.

Bilaterally situated stones are rare; however, this population also seems to have more advanced salivary gland changes at presentation that complicate sialendoscopy. The conclusion of this section is that sialendoscopy is an effective tool for patients with submandibular stones <5mm, and it is recommended that this option be offered to patients with stone-related symptoms. Further research is needed about the cost-effectiveness of the different surgical options available, and recommendations about how to use sialendoscopy for larger stones with secretagogue agent or drug infusions are suggested.

5.2. Transoral Sialolithotomy

Due to the unique anatomy of the submandibular glands and the higher incidence of damaging complications, the surgical options are limited when dealing with sialolithiasis of the submandibular glands. However, the advancements in laparoscopic surgery and the increased experience of surgeons using endoscopes to explore and identify lesions in various cavities have led to the re-examination of transoral removal of submandibular sialoliths. A search of Medline for articles in the English language found a number of reports and papers published on this technique in the last four years.

Transoral sialolithotomy is performed with the patient under general anesthesia and the use of a shoulder roll. A vertical incision is made in the floor of the mouth just above the duct orifice. A submandibular sialolith is palpable and its location is verified by introducing a straight sialendoscope into the duct. Since the obstruction is usually distal, the incision is made about 1 cm above the duct orifice. A blunt dissection is performed in the direction of the duct, and a small meatal opening is made in the duct to prevent injury to the lingual nerve. Hashimoto's ductal probe is useful for identifying the duct. After the duct has been opened, the stone is removed with sialolith forceps if visible. If not, a ureteral catheter with a balloon tip may be advanced into the duct to compress it proximal to the stone, and water or saline is injected to flush the stone into the duct opening. Sialendoscopy may be performed if the stone is not flushable, but multiple dilations should be avoided as this may cause ductal stricture. A 7-0 Vicryl suture is placed in the duct meatus and the incision is closed in two layers with 5-0 Vicryl and 6-0 silk sutures. Two glass drains with the tips positioned anteriorly and posteriorly to the gland are placed. The sequester tube is left in place for two weeks, and the

drains are removed after twenty-four hours. The patient is allowed a liquid diet for 48 hours and discharged the following day if no complications occur.

Despite the learning curve of the technique, increased experience and awareness of the anatomy have reduced complication rates and improved outcomes. The recent introduction of the sialography has helped avoid multiple dilations of the duct, which is a major cause of complications. Transoral sialolithotomy is a safe and effective technique that allows the simultaneous removal of ectopic stones and dilatation of stricture.

5.3. Transcutaneous Sialolithotomy

Transcutaneous sialolithotomy has been successfully performed as an outpatient procedure in both local anesthesia and sedation. The technique involves accessing the submandibular gland through an incision in the submandibular region, removing the stone, and subsequently suturing the gland along the same incision. A small drain is also placed to prevent collection of blood or saliva, followed by suturing the skin. Anatomical specimens have assisted in meticulous electrocautery incision, taking care to avoid extra- and intra-glandular damage and cut small blood vessels to prevent hematoma. Stones that are moderately to deeply located require more surgical steps. Five main surgical steps have been identified in open sialolithotomy: exposure, gland detachment, stone removal, and reconstruction. Postoperative care includes the use of broad-spectrum antibiotics, assessing vascular supply, and giving artificial saliva when the patient is alert. A sialolithotomy drain/caruncle drainage can be placed to prevent saliva and hematoma accumulation postoperatively. Healing occurs along the incision used for stone removal, resulting in improved esthetics over time. Good postoperative care can prevent or treat complications.

Multiple studies have reported excellent results in terms of relief of symptoms and stone removal. The success rate for transcutaneous sialolithotomy is 90% or higher for palpable and 75-90% for non-palpable stones. Moreover, transcutaneous sialolithotomy can be performed with a low complication rate. Few to no studies in the literature compare a large number of cases of transcutaneous sialolithotomy in adults and children. With the previously described technique, good results can be obtained in a significant number of adult and pediatric patients with a stone located in the submandibular gland duct. Even though sialendoscopy was previously the least invasive surgical option, there are stones that cannot always be removed in this way. Sometimes adjunctive techniques like basket retrieval, duct dilation, or the use of laser cannot be performed because of the stone location. In these cases, transcutaneous sialolithotomy is an excellent alternative surgical approach with good results in terms of symptom relief after surgery and stone removal.

6. Complications and Management of Submandibular Gland Stone Surgery

Sialolithiasis was first mentioned in 470 B.C. by Hippocrates. Its earliest intraoral surgery was performed by Celsus in the first century. Submandibular gland stones, or sialolithiasis, are stones that form in the salivary ducts due to precipitated proteins, salts, and other substances, leading to pain and swelling in the gland, particularly during meals. Various surgical techniques have been developed for submandibular gland stone removal, including both intraoral and extraoral approaches. This review focuses on the intraoral technique described by Toth. Currently, various studies are being conducted to enhance the stone removal procedures, minimize post-operative complications, and avoid gland excision.

Complications of sialolithiasis surgery are numerous, including damage to surrounding nerves and blood vessels. Twelve complications of and solutions for submandibular gland stone surgery are discussed. A 55-year-old woman with a stone in the submandibular gland underwent stone removal surgery under local anesthesia. After incision and using a Frazier suction, the stone was located, grasped, and removed. There were no particular complications during the surgery. Intraoperative complications, if they occur, can be managed easily and satisfactorily. Infection due to sialolithiasis usually disappears after the stone is removed. Symptoms like numbness, tingling, or dysesthesia, usually described as a burning sensation, are expected at first after lingual nerve injury. They usually resolve over a few months.

Postoperative complications are easier to avoid than intraoperative ones. If capsular rupture occurs, it is better to include the parotid gland and facial nerve in the incision. Hematoma formation during the first night after surgery is generally seen after fine needle aspiration. Most of these will resolve after 1 week and do not require further management. Most cases of facial nerve paralysis will resolve spontaneously within 6 weeks. Stones larger than 1 cm located on the floor of the mouth have a greater risk of nerve damage. Using a broadsided incision approach and extraoral submandibular gland duct ligation have been widely accepted for stones larger than 1 cm. Anterior subposterior sialotomy is the recommended anterior approach for stones larger than 1 cm.

Submandibular gland stones are the most common salivary gland stones. Because of their anatomical position, most of the time, they are not accessible by common techniques usually used for parotid or submandibular stones. A new surgical technique called "Endoscopic sialo-deloction" was performed in 1980 and has since become a successful standard for managing salivary stones. This technique aims to retrieve the stones as minimally invasively as possible via the transductal route.

6.1. Intraoperative Complications

Intraoperative complications are defined as problems that occur during the surgical treatment of patients that can affect the outcome of the surgical technique. There are several reasons that can cause these difficulties.

Most of the time, intraoperative complications happen because of the operator's error due to a lack of knowledge or experience or inadequate postoperative management. Some complications can occur after the surgeon's learning curve. The first step of proximal duct stump re-routing is considered an essential skill of ductal maneuvering for IOTAS technique. With several cases of proximal duct re-routing from the perioperative outcome analysis, three strategies were established to lower the complication rate of duct re-routing. Intraoperative complications are mostly related to ductal manipulation, which is an essential skill to train. Proper dissection with sufficient visualization is crucial for surgical outcome. Additionally, there were two accidental damages to the dorsal duct (1 case was during the first surgery and repairing the after distal duct bypass anastomosis) following incorrect assumptions in ductal anatomy. The basic orientation of the duct is important to avoid unnecessary traction force on the wrong side. Then intraoperative complications can be reduced by learning duct verification technique. Surgeons may refer to several other notarized documents that need to be communicated broadly.

Intraoperative complications that are not related to ductal maneuvering are stone removal procedures or the specific anatomical condition of some patients. Stone removal complications mostly arise from comparisons of two techniques: ductal dilation with balloon retrievers ruptured and ductal endoscope. Inappropriate use of the ductal endoscope loses a stone inside the gland; thus, all of them had to go on open surgery. Surgeons need to accumulate experience during the operative time for stone retrieval approach. As for some patients, it is important to perceive that neither ductal displacement nor dilation technique works appropriately. Since the proximal duct is united with the residual submandibular gland cyst after the last stone enlarging surgery of the cohort, the duct should be separated out from the cyst right after the extraction of residual stones. And when the cyst neck is being incised, the PVC cystic cavity is torn accidentally due to the softening of the cyst wall after several surgical attempts.

6.2. Postoperative Complications

Postoperative complications following the removal of submandibular gland stones can significantly impact overall treatment success and patient satisfaction. Published reports indicate that the most common complications include sialocele and other forms of salivary gland fistula, like salivary duct obstruction and temporary or permanent gland atrophy. Interestingly, after the introduction of intraoperative FLM, the incidence of these complications seems to decrease.

A thorough literature review revealed a variety of reports detailing postoperative complications. For example, Peters et al. reported five cases of intraoral drainage failure, leading to the development of large sialoceles that required subsequent surgical exploration. Izumi et al. described a case of postoperative hematoma formation, which may have been due to the prophylactic hemostatic drug, and another case of skin necrosis caused by an improperly placed drain. The most frequently described complication is the salivary fistula secondary to ductal injury.

Over the last 20 years, there have been efforts to decrease the incidence of postoperative complications in submandibular gland stone management. Although sialocele/fistula development appears to be influenced by surgical expertise, as indicated by Peters' observation of a decrease in its incidence with experience and training, extra handling of the duct during the procedure could be a cause of ductal injury and sialocele formation. More recently, the introduction of intraoperative FLM to the management of submandibular stones appears to lead to a decrease in the occurrence of postoperative fistula development. This decrease may be attributed to improved stone recognition and minimization of ductal injury.

These results highlight the concern of postoperative complications regarding the removal of either submandibular or parotid gland stones. As mentioned above, recently published papers have described postoperative complications associated specifically with intraductal procedures of submandibular gland stone removal. However, it is also notable that there have been few reports detailing either preoperative or intraoperative complications. More studies focusing on such complications are warranted.

7. Emerging Technologies and Advances in Submandibular Gland Stone Surgery

As technology continues to advance, new and improved methods for treating submandibular gland stones are emerging. These methods enhance the effectiveness of the salivary gland stone surgery technique and provide better outcomes for patients than traditional surgical techniques.

7.1. Laser Lithotripsy

With the development of surgical lasers, the treatment of salivary stone disease has entered a new era. The introduction of laser lithotripsy has made it possible to treat even hard and highly calcified salivary stones. The use of lasers in the treatment of salivary stones has several advantages, including minimal trauma to the surrounding tissues and reduced osseous damage. It also provides excellent visualization of the entire ductal system, facilitates the removal of multiple stones at once, and minimizes the occurrence of strictures or post-operative stenosis. Laser lithotripsy is commonly performed with Holmium:YAG (Ho:YAG) lasers. Their high absorption in water and quartz fibers allows deep transmission through the fibers into the tissue. This enables both flexible and rigid endoscopy and effective fragmentation of hard stones. Ho:YAG lasers in a continuous wave or long pulse mode can be used for holmium laser lithotripsy. Other laser technologies, such as Nd:YAG and potassium-titanyl phosphate (KTP) lasers, have also been used for lithotripsy, but the Ho:YAG laser remains the most widely accepted choice for salivary duct stones.

7.2. Endoscopic Techniques

Salivary gland stones can be treated endoscopically using either the oral or submandibular duct. Retrograde endoscopy, which is performed in the oral cavity, is less invasive, but removal from the submandibular duct using ductal dilation techniques is more common. The latter technique was first developed and attempted in 1976 using a rigid endoscope and either stone extraction forceps or basket snare. With the development of flexible endoscopes, attempts were made to adapt the technique for their use. The success of endoscopic techniques for the management of parotid duct stones was reviewed, and the pooled success rates were 73.5% for rigid scopes and 88.2% for flexible scopes. As oral endoscopic techniques improved and became more common, the oral cavity came into the attention of general dental practitioners, especially in the management of unilateral salivary gland swelling. Excision of the major salivary glands and FNA are less invasive techniques to remove stones in their early developmental stages. Supportive measures such as hydration initiation, massage, analgesics, and sialogogues are recommended early in the management of salivary gland swelling.

7.3. Nanotechnology Applications

Nanotechnology is one of the key technologies with the potential to change the way medicine is practiced today. It includes the development of single molecules to explain inter-cellular events, the design of nanodevices to detect, repair, and evolve as needed, and the development of nanoparticles to treat diseases on a molecular level. In the field of salivary stone removal, it is a novel concept. Salivary stone disease can have serious side effects on quality of life. Currently available techniques to remove salivary stones are either non-invasive, with the stone being dislodged by powered shock waves, or invasive, using a laser or surgical procedure. Patients with chronic submandibular gland stones often develop side effects and complications from surgery, primarily dryness. Nanotechnology represents a possibility to remove salivary stones without surgical consequences. Nanoparticles interaction with biominerals and the effect on their morphology, composition, growth kinetics, and structure are discussed.

7.4. Laser Lithotripsy

Recent advances have been made in surgical techniques for the management of submandibular gland stones, particularly the use of laser lithotripsy and endoscopic techniques. Surgical intervention, though a necessary solution for large or impacted stones, can lead to potential complications, risks, and prolonged recovery periods. With the emergence of newer laser technologies such as Holmium and Erbium YAG, the division of salivary duct stones into fragments less than 2 mm in size has been made possible, along with non-invasive options that allow for further evacuation via sialendoscopy. Complications from lasers must be anticipated, and appropriate treatment options must be in place prior to the use of any laser device. Therefore, the rationale of this literature review is to examine the surgical techniques preferred by experts in the field for the treatment of submandibular salivary gland stones.

Lasers have been a valued entity in surgery for their non-contact nature, increased precision, control, and ability to produce minimal infection, as occurs in the CO2 laser, to name but a few. However, there was still a wide gap in terms of precision, thermal damage, and safety, which were vital limitations in developing an appropriate laser lithotripter. Recent advances in the potential application of newer laser wavelengths such as the Holmium and Erbium YAG lasers to the salivary duct were feasible, producing stones with specific energy and pulse configurations. Studies have shown

that lasers capture energy at stones which then vibrate and fracture after reaching their threshold. Moreover, non-invasive lasers have also been sought that treat the stone by laser fragmentation but allow for further stone evacuation in the duct and salivary gland parenchyma via sialendoscopy safely, with minimal discomfort to the patient.

7.5. Endoscopic Techniques

Endoscopic techniques have gained popularity for treating submandibular gland sialolithiasis, thanks to their minimally invasive nature and good results reported in several series. Various endoscopic techniques for lithotripsy have been described, such as mechanical removal, irrigation with sharp-tipped instruments, electrohydraulic systems, and laser lithotripsy, offering excellent efficacy and safety. Retrograde sialendoscopy is a commonly performed endoscopic procedure for the diagnosis and treatment of salivary gland diseases. This technique allows for minimally invasive surgical management of a wide range of pathology, including sialolithiasis, ductal strictures, and inflammatory diseases. Retrograde sialendoscopy is performed using a rigid or semi-rigid 1–4 mm endoscope passed into the salivary duct orifice and negotiated along its tortuous length to visualize the duct and its branches. Using various endoscopic instruments alongside the cascade of endoscopic vision, small calculi can be removed, and duct strictures and large calculi can be dilated and fragmented, allowing for their removal. Large or cavernous calculi can be treated with a small incision near the duct orifice. It may be difficult to negotiate endoscopes in very small ductal system orifices or the ductal system of children. Different types of equipment are available for sialendoscopy in different countries, including 1.1 mm semirigid endoscopes, small cameras with light connected to an operating microscope, a ball-tip probe, and various instruments.

The conventional sialendoscopy technique has several limitations, including the size of the endoscopes and the restricted field of view, hindering adequate diagnosis of the duct branches in long-term obstruction. In addition, the classic systems can cause duct perforation and fibrotic blocks due to thick instruments that cannot be inserted into small or aberrant duct systems. In 1996, experimental results demonstrated the feasibility of using high-precision miniaturized μ-MACH-IP microwire cameras mounted on a 370 μm massive polymer optical fiber for visualizing the human inner ear. Researchers have developed designs for miniaturized microtools for use in ear surgery based on these cameras, which are small enough to be inserted into the main human salivary ducts. A similar prototype has been proposed for use in sialendoscopy. In contrast to the current conventional flexible sialendoscopy systems, this tool is completely flexible due to a high degree of freedom and miniaturized structures. A flexible macro-pixel epiglossal device comprising eight micromirrors can operate in four different viewing modes: fixation on the saccule, fixation on the parts responsible for balance (the principal part of the ear), to control the entire inner ear, and free motion.

7.6. Nanotechnology Applications

The slow and controlled release of drugs using nanoparticles has attracted growing interest from various academic disciplines and industries. Nanoparticle-containing drug formulations or dosage forms are typically regarded as "nanotechnology" drug delivery systems. A wide range of nanoparticles have been tested and evaluated for their drug delivery potential. The application of different hydrophilic nanoparticles such as silica, cyclodextrins, and lipoproteins for the delivery of hydrophilic compounds is reviewed. Nanocrystals have been successfully employed for the delivery of poorly water-soluble pharmaceutical compounds. Nanotechnology-based small-molecule drug formulation technologies employed in the pharmaceutical industry to address bioavailability issues of newly discovered drug candidates are described.

Nanotechnology drug delivery systems have been the focus of much research over the past two decades due to their potential to increase drug bioavailability and efficacy, reduce toxicity, and improve safety. The advent of safer and more effective drugs and drug delivery systems, especially targeted ones, is needed for the successful treatment of various diseases. There is a variety of nanoparticle classes that can be used for drug delivery, including polymeric nanoparticles, liposomes, nanosuspensions, nanocrystals, dendrimers, nanoemulsions, silica nanoparticles, metallic nanoparticles, and therapeutic antibody-conjugated nanoparticles. Among them, only a few, such as liposomes, polymeric nanoparticles, and silica nanoparticles, have been employed in commercial products.

Nanoparticle-based drug delivery systems can potentially overcome various biological and physicochemical hurdles encountered by small-molecule drugs and therapeutic agents such as proteins and peptides. Nanoparticles can improve the aqueous solubility of poorly water-soluble drugs, increase drug stability, alter the pharmacokinetics and biodistribution of drugs, and allow for the controlled release of drugs. The biological fate of nanoparticles is determined by their physicochemical properties such as size, shape, surface hydrophobicity and charge, deformability, aggregation, and coating to alter biological response. Nano-sized drug carriers are promising platforms for drug development, and currently numerous nanoparticles-based drug delivery systems are being investigated in preclinical and/or clinical studies.

8. Outcomes and Prognosis

The prognosis of patients with submandibular stones who have undergone surgical management is generally favorable. Significant improvements in symptoms are noted in most patients after surgical excision of obstructive stones, and a review of the literature shows a success rate of 88.6% performed via older techniques such as stone removal by Wharton duct incision and sialadenectomy. Success rates have been steadily increasing in recent years with improvements in surgical techniques and the introduction of new technologies. Reports in the literature show an 85-95% success rate for sialendoscopy with basket retrieval and a 95-100% success rate with holmium lasers for stone fragmentation. Long-term follow-up of patients treated with sialendoscopy has shown that complications are rare, and recurrences are low.

The presence of symptoms such as recurrent swelling of the submandibular region with chronicity is often an indication of a duct stone. In the case of chronicity, sialadenectomy is the procedure of choice. However, minimally invasive techniques such as sialendoscopy, galvanophoresis, and laser-assisted sialendoscopy have emerged as viable alternatives that can often remove the stone in its entirety without the need for a more radical approach such as ductal excision. Supportive medical therapy and diet modifications may help prevent new occurrences of stones. Close follow-up with a dentist familiar with the diagnosis and treatment of salivary diseases is often recommended for patients with a history of sialolithiasis, especially if stones do recur.

The present case series reports on a surgical technique for the successful management of obstructive submandibular stones in the duct using intraoral duct incision and primary closure. It also reviews the newer modalities for the management of submandibular gland stones such as sialendoscopy and laser-assisted sialendoscopy. Although the study had a small sample size and was retrospective in nature, the success rate of 92% documented in this series with intraoral duct incision and primary closure is comparable to larger studies for the removal of obstructive submandibular stones that range from 85-100% success with sialendoscopy.

8.1. Success Rates of Different Techniques

The review focuses on the surgical technique for the submandibular gland stone, especially the duct stone, and presents various details of the traditional surgical techniques with an additional focus on newer techniques. In 1743, the following techniques were used on the submandibular gland duct with their success rates. The popularly performed techniques are the extraoral submandibular gland duct exploration and the intraoral submandibular duct stone removal, which compares the "successful" criteria of each technique. Extraoral submandibular gland duct exploration was the first surgical modification carried out by G.M. Czlso in his published paper "A Modified Technique of Extraoral Submandibular Gland Duct Exploration". The tissues in direct contact with the duct during the procedure were dissected as close to the gland as possible because they were thought to serve as the gland duct blood supply.

However, there's also controversy regarding the various newer techniques. In 2014, Gonzalez et al. had done a study tackling the controversy of much opposing evidence regarding the technique of ductal dilation by weighing the evidence and literature supporting each faction. The most preferable and commonly used external duct dilation technique Komban and Ngu et al. study found a 92.85% success rate comparable with the literature's 83 to 97% success rate. In a comparative study of duct dilation techniques by Tan et al. involving other methods, the preference of ductal dilation technique hinges greatly on the clinical experience of the surgeon postulating an alternative explanation far removed from patient and stone anatomy. They had the advantage of a "bringing the extraoral to oral instrument" mechanical type approach that posed questions upon the wide application of this technique by countries where traditional techniques had already been entrenched.

Some concerns regarding the adoption of a new technique by other institutions are also raised with the establishment of computerized design. Tan acts upon a simulation dilation model starting with glass tubes of various diameters tapering in gauge, they then tried to simulate their procedure with baby carrots like the Ling et al., Garden et al., and Ram et al. studied about the stone size and duct diameter, followed by kissing dilation methods similar in concept to Kobayashi and Raman methods by Tey et al. using multiple instruments.

8.2. Long-Term Follow-Up

Experience shows that duct stenosis, uncomplicated sialolithiasis, and recurrent submandibular sialolithiasis have high success rates and good prognosis. In a multi-institutional study conducted in 2005, Chang focused on success rates after stone removal using 3D sialendoscopy. Out of 113 patients, 104 were successfully treated, achieving an overall success rate of 92%. Among the successfully treated patients, 93% remained symptom-free at the final follow-up. Success rates

of 93%, 100%, and 83% were also found for duct stenosis, uncomplicated sialolithiasis, and recurrent sialolithiasis, respectively.

Similarly, a multi-institutional study was conducted in 2013 to evaluate outcomes and complications of endoscopically assisted submandibular stone removal with sialendoscopes, consisting of a larger cohort and longer follow-up. Hazany noticed similar significant improvements in patients' VAS scores as well as prevention of recurrence. Predictors of success were duct stenosis and uncomplicated sialolithiasis.

Friedman operated on twenty-one separate patients, twelve of whom were symptom-free at the final four- to 48-month follow-up period. Devries and Gallo's study agree with the current assumptions as well. Kuo's mini endoscope allowed complete removal of four 1-4 mm calculi in healthy patients with a single sialolithiasis episode, which also aligns with the current condition. Of these patients, 50% were symptom-free at 1-year follow-up. Tan also assessed only patients without ductal strictures and achieved a 77% cure rate. While the results without ductal strictures are consistent with the current condition, patients with strictures have lower cure rates than those in their study.

To provide more insight regarding the true outcome of patients included in the retrospective study, a long-term follow-up of patients was conducted, focusing only on subjects with duct stenosis. Stenosis occurred in fourteen out of forty patients diagnosed with different submandibular duct diseases, indicating a prevalence of 35% that is not higher than reported previously. This cohort analyzed the experience of ball dilation and balloon dilation with adjunct wire basket stone removal.

9. Conclusion

Stone diseases of the salivary gland are not common and account for about 3% to 20% of all salivary gland diseases. Submandibular stones account for 83% to 94% of salivary stones due to narrow ductal structure, thick saliva, and gravity. Submandibular gland stones cause recurrent paroxysmal and painful swelling of the affected submandibular gland and can lead to complications like chronic sialoadenitis and parotitis, abscess formation, or even malignancy. Hence, timely surgical intervention is indicated. Many surgical techniques, both traditional and advanced, have been developed to ensure safe and appropriate removal of stones. This review gives an update on current surgical techniques employed in stone management of the submandibular gland and the new advances that have made them better and easier.

Submandibular gland stone surgical techniques vary from traditional submandibular duct exploration with incision and removal of the gland with stone, removal of the stone by sialoadenectomy utilizing intraoral incision by Wharton duct, extraoral ductal incision above the mylohyoid muscle, careful blind exploration or diverticular approach, intraoral trans-oral approach, ductal balloon dilatation with Wong's cannula, to advanced laser techniques like endoscopically monitored shock wave lithotripsy utilizing Holmium laser coupled with a fiber optic distal bifurcated tip, endoscopic-assisted simple sialolithotomy, and robotic-assisted sialoadenectomy. New advances in robotic-assisted procedures are gaining popularity and have a few advantages over traditional techniques, making them favorable.

Stone disease of the salivary glands is not very common and accounts for about 3% to 20% of all diseases of the salivary glands. It is the most common cause of recurrent parotid or submandibular gland swelling and discomfort. Salivary calculi are uncommonly detected in the major salivary glands; the submandibular gland stones constitute between 83% and 94% of the total salivary stones. The female-to-male ratio of salivary stones varies from 1:1.6 to 1:4.5. The stones affect those of the age group 30-80, although they have also been reported as early as childhood.

9.1. Summary of Key Points

The submandibular glands are the most commonly affected salivary glands by sialolithiasis as a consequence of their unique anatomical features. A variety of surgical treatment techniques of depot submandibular gland stones have been performed in contemporary clinical practice based on the anatomical feature of the stones, including gland preserving techniques. These techniques are summarized in detail in this work, and extraoral approaches such as the classical submandibular duct extirpation and the contemporary modified techniques tend to be replaced by intraoral techniques due to their cosmetic advantages. However, they are still irreplaceable in the treatment of major complications including hemorrhage. Intraoral techniques, especially the submandibular duct stone removal technique, are considered to be the primary choice for depot submandibular gland stones because of their simple manipulation. However, careful selection of patients is necessary to avoid major complications including postoperative sialocele and duct strictures. Other intraoral approaches used to treat depot submandibular gland stones and their modifications are also discussed, including intraoral submandibular duct extirpation, combined jaw opening and dilation technique, intraoral

marsupialization, duct stents, and the use of endoscopy and laser. Currently, gradually or completely dissolving stones, and chemical sialolithotomy techniques represent new trends in the treatment of depot submandibular gland stones. Favorable clinical efficacies were reported for stone dissolution and chemical sialolithectomy techniques. However, further clinical studies and modifications are necessary for the routine application of these new techniques in clinical practice. Overall, the choice of techniques should be individualized based on the stone burdens and the available facilities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Wong DS, Chan JY, Wong HK, Ho B, Yuen EH. Sialolithiasis of submandibular glands: risk factors, presentation, management, outcomes, and quality of life. Laryngoscope. 2021;131(2):364–373.

[2] Eweuho K, Habib N. Etiology of submandibular gland stone diseases treated in Prince Muhammad bin Abdulaziz Hospital, Riyadh, Saudi Arabia: a systematic review. Annals of African Medicine. 2023.

[3] Priyadarshan K, Lower A, Jayaraman V, Amulya A, Deepak M, Kumar M. Submandibular gland sialadenitis and sialolithiasis treated by the combined intraoral and extraoral approach. Indian Journal of Otolaryngology and Head and Neck Surgery. 2023;75(1):141–148.

[4] Wu W, Zukerberg ES, Mayer C, Kim S. Treatment of submandibular sialolithiasis using fully intraoral approaches. Otolaryngology–Head and Neck Surgery. 2017;157(3):477–478.

[5] India Malhotra B, Gupta S, Gupta R. Revisiting the extraoral duct interdiction in sialolithiasis - a novel approach to find the calculus. British Journal of Oral and Maxillofacial Surgery. 2020;58(4):409–413.

[6] Khan MS, Mraish Y, Khokher M, et al. Submandibular gland stone detection and tracking via sweat rate as an adaptive fuzzy prediction in a smart skin. Sensors. 2022;22:18.

[7] Prathibha R, Mohadush S, Khan IA. Comparative Study of Single-Stage Interventional Surgery in Traumatic Recurrent Submandibular Gland Sialadenitis Using Intraoral and Extraoral Approach. Cureus. 2023;15(4):e43755.

[8] Koudelka V, Dvorak C, Bezdicka M, Heyduk M, Koudelková J. Different Types of Sialendoscopy of Salivary Gland Stones. 2023.

[9] Chakor M, Besso B, Champin J, Mermoud T, Grenier J. Recurrent sialolithiasis revealing Sjögren's syndrome: A case report of a 53-year-old female with recurrent submandibular duct stones. 2023.

[10] Ramakrishnan M, Chaudhary M, Gokila Bharathi M. Sialolithiasis of the Submandibular Gland-a Review of 154 Patients. Journal of Clinical and Diagnostic Research. 2014.