Jung et al. Head & Face Medicine (2025) 21:3
https://doi.org/10.1186/s13005-024-00479-1

Head & Face Medicine

RESEARCH

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Enhanced precision in stone localization and intraoral removal in sialolithiasis: the role of preoperative computer tomographic scanning in surgical planning

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Abstract

Background The precise localization of stones within the submandibular duct is crucial for the successful intraoral removal in sialolithiasis. Customizing surgical approaches based on the stone's ductal location is imperative. Particularly challenging are stones beneath the lingual nerve, requiring a landmark-guided approach due to their non-palpable nature. This study aimed to comprehend stone positioning, location-specific characteristics, and develop suitable surgical approaches. We conducted a thorough analysis of numerous preoperative computed tomography (CT) scans for this purpose.

Methods We performed a retrospective review of the medical records of patients who underwent intraoral stone removal between 2006 and 2022. Two different surgical approaches were applied based on the stone location as determined by preoperative CT scans. The mediolingual approach was used for superficial stones, while the laterogingival approach was reserved for deeper stones. Patient demographics, sialolithiasis features, and postoperative complications were analyzed. T-test was performed to compare stone characteristics between different locations, and a receiver operating characteristic curve analysis was used to identify the critical size threshold for predicting stone location.

Results Medical records of 465 patients were reviewed. Out of 616 stones, 614 were successfully removed with two distinct surgical approaches guided by preoperative CT scans. Two patients reported retention, and 11 experienced postoperative tongue sensation changes. The hilum was the most common stone location, and deeper stones, approached laterolingually, were generally larger. Analysis identified a 4.25 mm width as the most sensitive and specific threshold for deep stones. Stone volume showed no statistically significant difference between smokers and non-smokers, alcohol consumers and non-consumer.

Conclusion The result of the study underscore the significance of precise stone localization and endorse the efficacy of landmark-guided surgical approaches in managing sialolithiasis.

Keywords Salivary duct calculi, Submandibular gland, Anatomic landmarks, Intraoral, Computed tomography

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Background

Sialolithiasis is a common condition characterized by the formation of stones within the salivary glands, often causing obstruction and subsequent symptoms, such as pain, swelling, and infection [1]. Effective management of sialolithiasis necessitates the selection of appropriate treatment methods tailored to the individual case. A single submandibular gland stone that is easily palpable and located < 2 cm from the ductal orifice can be removed by a direct incision above the palpable stone under local anesthesia [1, 2]. However, small stones located under the lingual nerve and near the submandibular gland (SMG) are difficult to palpate, making it difficult for surgeons to determine their precise location. For these stones, general anesthesia is required, and in the past, SMG resection was performed via the transcervical approach [1, 3]. However, this approach has several drawbacks, including scarring, permanent damage to several nerves, and resection of the functioning salivary glands [4].

The size, location, and number of stones can be accurately determined by performing computed tomography (CT) on patients. However, it is challenging for surgeons to identify the precise location of stones during surgery and subsequently remove them, when they are located in the proximal region of the duct or if they are not palpable. Although endoscopy and ultrasonography have been introduced for this purpose, they may not always be available or feasible in all hospitals [5, 6]. We had presented the anatomical landmarks defined as the triangle formed by the sublingual gland, mylohyoid muscle, and lingual nerve for accurate stone localization, which allowed for successful intraoral stone removal without the need for endoscopic or ultrasonographic assistance [7]. Following a comprehensive preoperative review of CT scans, we confirmed the precise location of the salivary stone in the whole duct. Utilizing the landmark that we reported, we were able to localize and remove the stone even when it was in the proximal part of the duct, which was not palpable.

In this study, we analyzed a substantial volume of patient data collected over 16 years to evaluate the feasibility of intraoral stone removal using surgical landmarks. Additionally, we analyzed the correlation between stone size and location, which is the most important factor in determining the surgical approach for intraoral stone removal. The aim of this study was comprehensive understanding of stone positioning, their location-dependent characteristics, and the development of appropriate surgical approach according to the stone location by using long-term surgical and CT data.

Methods

Patients and study design

We retrospectively reviewed 496 consecutive patients who underwent intraoral submandigular stone removal at a single medical center from January 2006 to December 2022. Patients who underwent a revision surgery for sialolithiasis and those diagnosed with SMG neoplasm were excluded. Patients who did not have preoperative CT scans were also excluded from this study. Among the 496 patients, 31 individuals were excluded, and 616 stones from 465 patients were retrospectively analyzed. Demographic factors (sex, age, alcohol consumption, and smoking status), anesthesia, and features of sialolithiasis (number and total volume of stones per patient) were analyzed. Postoperative complications, such as tongue hypoesthesia, hematoma, and ranula, were evaluated by patient's symptom report and physical examination at the first outpatient clinic visit 7–14 days after surgery. Long-term follow-up was not routinely conducted, but in cases of symptom recurrence, a CT scan was performed to differentiate between residual stones. The location, number, and size of each stone were evaluated based on CT images. This study and the written consent waiver were approved by the Institutional Review Board (IRB no. 2021-08-031-006).

The categorization of stones by location and size in computed tomography images

The stone location was categorized into five parts: two superficial parts (distal and middle) and three deep parts (proximal, hilar, and intragland). An imaginary line from the orifice of Wharton's duct to the SMG was drawn on a CT image at the level of the geniohyoid muscles and the upper half of the SMG. The line from the orifice of Wharton's duct to the posterior border of the mylohyoid muscle (defined as the broadest part of the mandible) was equally divided and defined as "the distal" and "the middle." The remaining part was defined as "the proximal." The "intragland" was defined as the location of a stone in the middle of the gland. The stone was defined as "the hilum" if it was located across the duct and gland. This categorization is illustrated in Fig. 1. The length of the stone was measured as a line parallel to the duct, and the width was measured as a line perpendicular to the duct. Height was measured in the coronal view of the CT scanner. We calculated the area (the perpendicular plane area to pass the duct) using the width and height, and calculated the volume considering the stone as a sphere.

Two types of surgical procedures (mediolingual and laterogingival approaches)

The type of approach was selected as follows: The stones located in the superficial part (distal and middle) were removed via the "mediolingual approach," while the

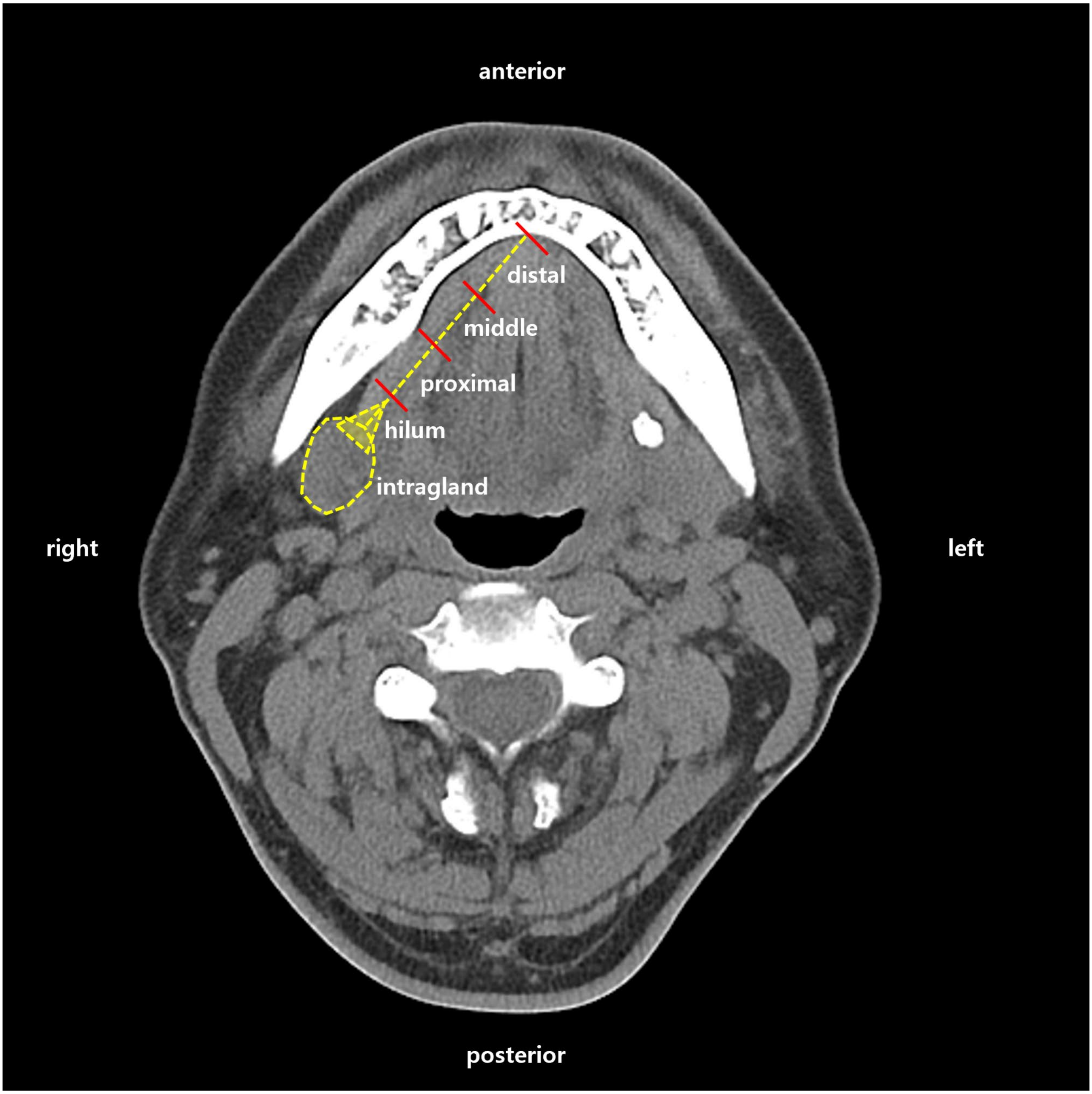

Fig. 1 The stone location. The location of the stone was categorized using the preoperative computed tomography scan axial image

stones located in the deep part (proximal, hilar, and intraglandular) were removed via the "laterogingival approach." (Fig. 2). These two approaches were designed considering the anatomy of the SMG duct to avoid injury to the sublingual gland (SLG), which may cause ranula formation, and the lingual nerve, which may cause post-operative hyposensation of the tongue.

The distal part of Wharton's duct runs under the SLG and is easily identified on the lingual side of the SLG. Therefore, when the stones were located in the distal and middle parts, a mucosal incision was made between the medial side of the SLG and the tongue. After the mucosal incision, the SLG was exposed and pushed laterally to identify Wharton's duct (mediolingual side approach). A laterogingival approach is preferred to remove stones in the proximal portion. The lingual nerve runs across Wharton's duct from the lateral to the medial side. Therefore, a mucosal incision should be made more laterally to prevent injury of the lingual nerve when approaching the proximal part of the duct and gland. After mucosal incision, the lingual nerve is easily identified under the connective tissues and can be pushed medially with a cotton

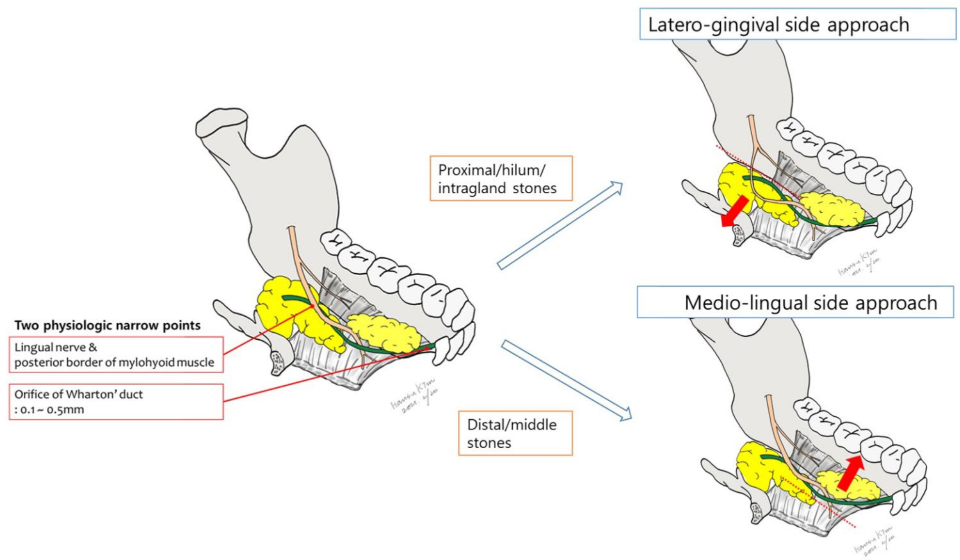

Fig. 2 Two surgical approaches. The stones in the superficial part (distal and middle) were removed via the "mediolingual approach," and the stones in the deep part (proximal, hilar, and intraglandular) were removed via the "laterogingival approach"

swab (laterogingival approach). "The surgical triangle" is substantially useful to expose the gland and hilum. The boundary of "the surgical triangle" was the medial border of the mandible, the posterior border of the mylohyoid muscle, and the lingual nerve [7]. After the SLG was shifted to the side, the posterior border of the mylohyoid muscle and lingual nerve were exposed. The lingual nerve was pushed medially, and the surgical triangle was completely opened. A dilated duct was often observed at the center of the landmark.

After cleaning the oral cavity with iodine solution, the mouth was opened using a lip retractor. Denhardt mouth gag can be used together in the case of general anesthesia. The patient's tongue was pushed in the opposite direction using a cotton swab, and a mucosal incision was made on the floor of the mouth, depending on each approach. After mucosal incision, the SLG and lingual nerve were identified and pushed away from Wharton's duct with a cotton swab. An incision in the duct should be made just above the stone, which can be easily identified by palpation or visual suspicion. After stone removal, the floor of the mouth mucosa was sutured without marsupialization using 4 – 0 polyglactin (Vicryl; Ethicon, New Brunswick, NJ, United States).

The type of anesthesia was selected according to the stone location. General anesthesia was usually administered when the stones were located in the gland, hilum, or proximal duct. All distal and middle stones were removed under local anesthesia. For general anesthesia, the patient was anesthetized via nasotracheal intubation.

Statistical analysis of stone size in relation to stone location

To evaluate the potential influence of demographic factors on stone volume, we compared the total stone volume between patients with and without a history of alcohol consumption and smoking using independent t-tests.

We classified the stones across the five locations into two categories based on the criteria for applying the two surgical methods: distal, medial (mediolingual approach) and proximal, hilar, and intraglandular stones (laterolingual approach). For the purpose of comparing stone sizes between these two categories, we utilized independent t-tests for each of the five size parameters. We performed a **receiver operating characteristic (ROC) curve** analysis to establish a threshold for distinguishing between superficial and deep stones. For each potential cutoff value of stone width, sensitivity (the true positive rate) and specificity (the true negative rate) were calculated to assess the discriminatory ability. The ROC curve was constructed by plotting sensitivity against 1-specificity, with each point on the curve representing a specific threshold value. we evaluated all five size parameters—length, width, height, volume, and surface area—to identify which parameter was the most effective in distinguishing between superficial and deep stones. All statistical analyses were performed using SPSS version 25 (IBM Corp., Armonk, NY, USA) with statistical significance considered $p < 0.05$.

Table 1 Characteristics of patients with sialolithiasis originating in the submandibular gland ($n = 465$)

Features	Number (%)
Sex	
Male	238 (51.2)
Female	227 (48.8)
Alcohol	
Nondrinker	292 (62.8)
Drinker	124 (26.7)
No response	49 (10.5)
Smoking	
Nonsmoker	290 (62.4)
Smoker	132 (28.4)
No response	43 (9.2)
Anesthesia	
General	282 (60.6)
Local	183 (39.4)
Stone numbers	
Single	359 (77.2)
Multiple	106 (22.8)
Complications	
No	452 (97.2)
Yes	13 (2.8)
Remained stone	2 (0.4)
Tongue numbness	11 (2.4)

Table 2 Characteristics of submandibular stones (616 stones)

Features	Number (%)
Site	
Right	309 (49.8)
Left	307 (50.2)
Location	
Superficial	349 (56.7)
Distal	219 (35.6)
Middle	63 (9.8)
Deep	
Proximal	67 (10.9)
Hilar	250 (40.6)
Intraglandular	17 (2.8)
Size[a]	
< 4.25 mm	274 (44.5)
≥ 4.25 mm	342 (55.5)

[a]According to the width of the stone

Results

Patient' demographics and results of the surgical approaches

In total, 465 patients (age, 5–84 [mean, 38.12 ± 16.406] years) were included in this study. The demographic data are shown in Table 1. The mean follow-up period was 10.81 ± 1.74 days. There was no difference in total stone volume between smokers and nonsmokers. The patients with alcohol consumption demonstrated higher volume of the total stone than those without alcohol consumption, but with no statistical significance (nonalcohol drinker, 230.19 ± 403.86; alcohol drinker, 388.42 ± 853.58 mm^3; $p = 0.05$). Among the 465 patients, only two reported removal failure, including one with a 3-mm-sized intraglandular stone and the other with an infection that formed an abscess near the hilum. Eleven patients reported postoperative changes in their tongue sensation on the operation side. Of these, two (0.45%), four (0.23%), one (1.59%), and four (1.36%) patients had a stone located in distal, middle, proximal, and hilar parts, respectively. Among them, 10 recovered the sensation in < 1 month, and only one reported long-term discomfort after a year. Surgical injury to the lingual nerve was not reported in the surgical notes. Postoperative ranula was not reported.

Correlation between stone size and location

A total of 616 stones from 465 patients were analyzed (Table 2). The stones were most frequently located in the hilum (40%). Regarding the surgical approach, 45.4% of the stones were located in the superficial part and removed via the mediolingual approach, and 54.6% of the stones were located in the deep part and removed via the laterolingual approach.

When we analyzed the size of the stones in the superficial and deep parts, the stones removed via the laterolingual approach were significantly larger than those removed via the mediolingual approach in all dimensional variables (Table 3). Among the various size parameters analyzed, stone width (specifically stones measuring 4.25 mm) demonstrated the highest sensitivity and specificity for identifying stones located in the deep part (Fig. 3). In other words, this indicates that 4.25-mm-width stones are particularly effective at indicating the presence of stones in deeper areas.

Table 3 Size of submandibular stones (616 stones)

Features	Width	Length	Height	Area	Volume
Total stone	5.23 ± 3.05	6.51 ± 4.00	6.07 ± 3.42	30.59 ± 38.15	200.57 ± 437.88
Site					
Superficial	4.40 ± 2.73	5.79 ± 3.91	4.94 ± 2.56	20.00 ± 21.93	111.84 ± 211.93
Deep	6.30 ± 3.11	7.46 ± 3.93	7.54 ± 3.83	44.43 ± 48.95	316.55 ± 600.60
P-value	0.000*	0.002*	0.000*	0.000*	0.000*

*P-value < 0.05

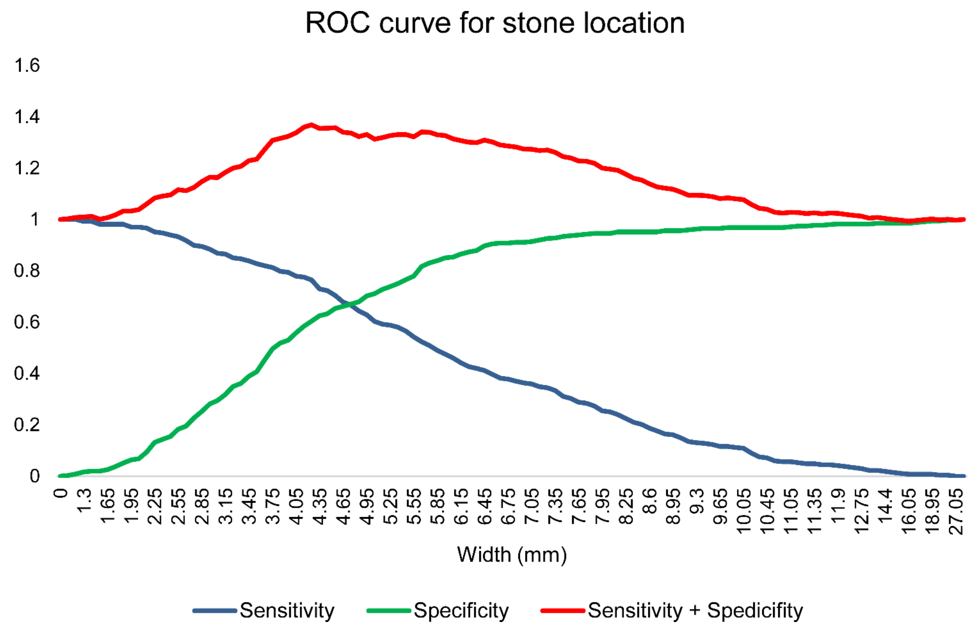

Fig. 3 Receiver operating characteristic (ROC) curve for stone size and location. A 4.25-mm-width stone showed the highest sensitivity and specificity in the ROC curve

Discussion

An intraoral approach for the removal of deep part stones was used to avoid transcervical excision of the SMG in cases of deep silolithiasis. While sialendoscopy and intraoperative ultrasound have been used to precisely locate stones during operations [6, 8], we previously introduced anatomical landmarks that facilitate accurate stone localization without the need for endoscopic or ultrasonographic assistance, thus enabling successful intraoral stone removal. While this approach has proven effective, we aimed to further validate its utility by reviewing a large number of patient data. The utilization of sialendoscopy offers potential advantages over transoral incisions, particularly if it allows for the avoidance of duct incisions. Nevertheless, these devices are not universally accessible in all healthcare facilities and may increase the financial burden on patients when used [9, 10]. Therefore, if the accurate stone localization and precise surgical techniques are achievable without the need for these supplementary devices, intraoral stone removal can be effectively performed without these additional devices [11].

We successfully removed 614 stones from 463 patients using preoperative CT, and the surgical approach was decided depending on the location on the CT scan. Deeply located stones were successfully removed using the surgical landmarks (the sublingual gland, the lingual nerve, and the mylohyoid muscles). The location, size, and number of stones did not significantly affect the success of surgery when an appropriate surgical approach was selected according to the location of the stone. Only two stones could not be removed. One was a 3-mm stone located in the intragland part. In another case, stone removal was performed after abscess formation because of inflammation around the hilum, and precise location of the stone was difficult to be identified. Adhesion of the surrounding tissue may cause bleeding, which can disrupt the visualization of the surgical field and its meticulous management.

Regarding the complications after the SMG duct stone removal, we recommend assessing for injury to the lingual nerve and SLGs during surgery. Eleven patients reported transient postoperative paresthesia in the tongue, such as tingling and numbness, which could be the result of lingual nerve dysfunction; these symptoms disappeared within 1 month in 10 of the 11 patients. Only one patient reported the presence of this discomfort after 11 months; however, this patient did not complain of loss of sensation, solely abnormal sensation around the tongue. No direct injuries, such as cutting or direct application of electrical devices to the lingual nerve, were reported in the surgical records. Postoperative ranula formation was not reported in any patient. This indicates that the SLGs were well-preserved without damage during surgery. When we approached the stones in the deep part, we used the surgical landmarks (the lingual nerve, the SLG, and the mylohyoid muscle) [7]. As the lingual nerve was easily visualized when we made the incision, surgeons were fully aware of the course of the lingual nerve, enabling them to avoid damaging it during the surgical procedure.

The reason for adopting different approaches based on the location of the stone was to consider the anatomical relationship between the duct and the SLG. When the stone was superficially located, the duct was observed to course more medially than it was in the SLG. Conversely, when the stone was deep, the duct was observed to course more laterally than the SLG. By employing precise approaches based on stone location, we minimized the risk of the SLG damage during surgery. Furthermore, no cases of seroma or postoperative infection without the need for an the SMG duct incision and subsequent closure of the duct or sialodochoplasty were reported. Supporting evidence for this rationale has been described in previous studies [12, 13]. Roh and Woo reported that symptom recurrence and the recovery of salivary function after stone removal were unaffected by the presence or absence of a neo-ostium. In addition, they found that sialodochoplasty had no effect on postoperative outcomes, suggesting that the presence of a neo-ostium may have a minimal effect on preventing symptom recurrence after complete stone removal [12, 13].

The results indicate that the stones are significantly larger in the deep part. This is believed to be a result of the anatomical dimensions of the duct and narrowing of the passage. The reported diameter of most ducts is 0.5–2.7 mm [14, 15]. When the lingual nerve and the SMG duct intersect, a narrowing occurs owing to compression by the nerve, with the narrowest point being the ductal orifice. Thus, small stones can migrate along the elastic the SMG duct and reach the orifice, however, large stones that have already formed in the deep parts encounter difficulties passing through the duct to reach the orifice. Therefore, in this study, stone size was analyzed based on their location using ROC analysis. The statistical threshold for the difference in stone size between the two locations was determined to be a width of 4.25 mm.

Although the study demonstrated promising results, the restricted outcome measures and missing data derived from a retrospective chart review pose constraints on the strength of the findings. Specifically, the study lacks information regarding smoking and alcohol consumption in some patients, as well as precise data on the quantity of alcohol consumption and frequency of smoking. Further prospective studies with larger sample sizes and comparative data are required to validate the correlation between the patient factors and stone size.

Studies on intraoral stone removal have been extensively conducted, however, no studies have classified stones into two locations using different classification methods. This study also involved the enrollment of patients over a long duration at a single institution. The utilization of CT scans revealed that actionable information could be obtained even in cases where the stone was non-palpable, by using the surgical landmarks. Moreover, our investigation pioneers the establishment of critical size thresholds for stones situated in deeper regions, achieved through complete CT analysis.

Conclusions

This study conclusively demonstrated that CT data accurately determine the stone's exact location within the duct, facilitating informed decisions regarding the most appropriate surgical approach. This approach offers a cost-effective and accessible alternative for cases where advanced imaging techniques may not be readily accessible. The meticulous examination of preoperative CT scans for precise stone localization and selection of an optimal surgical approach renders transoral stone removal a comprehensive treatment for sialolithiasis of the SMG duct.

Abbreviations

SMG	Submandibular gland
CT	Computed tomography
SLG	Sublingual gland
ROC	Receiver operating characteristic

Acknowledgements

Not applicable.

Author contributions

SYJ collected the patients' data, including CT images, and interpreted the data. SYJ wrote the manuscript. MSC, YJG, and JHY collected and analyzed the patients' demographic data. HSK designed the study and devised the surgical approach. All authors read and approved the final manuscript.

Funding

This work was supported by the Ewha Womans University Research Grant of 2021 and Basic Science Research Program (NRF-2020R1C1C1011612) through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT, and Future Planning, Republic of Korea. Korean Fund for Regenerative Medicine (KFRM) (23B0101L1) funded by the Ministry of Science and ICT, and Ministry of Health and Welfare (Republic of Korea).

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study and the written consent waiver were approved by the Institutional Review Board (IRB no. 2021-08-031-006).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 11 April 2024 / Accepted: 30 December 2024
Published online: 31 January 2025

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