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# The diagnostic efficacy of ultrasonographically-based measurements of minimum and maximum fascia-tumor distance in differentiating superficial from deep lobe parotid tumors

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## ABSTRACT

**Objectives:** The objective was to calculate the efficacy of ultrasonographically-based measurements of minimum and maximum fascia-tumor distance (MiFTD and MaFTD) of benign salivary gland tumors in identifying tumor location in the superficial or deep lobe of the parotid gland.

**Study Design:** MiFTDs and MaFTDs were measured on preoperative ultrasonographic images of 102 tumors. Tumor location was classified at surgery as superficial or deep based on relation to the facial nerve, with 74 tumors in the superficial lobe and 28 in the deep lobe. The diagnostic efficacy of differences in MiFTD and MaFTD between locations was calculated with the area under the receiver operating characteristic curve (AUC), sensitivity, and specificity. Statistical significance was established at $P < .05$.

**Results:** Mean MiFTD and MaFTD values were significantly smaller in the superficial lobe tumors than in the deep lobe lesions ($P < .001$). Tumors with cutoff values of MiFTD > 2.7 mm or MaFTD > 21.1 mm were considered deep lobe lesions. When using the cutoff values for both MiFTD and MaFTD together, AUC was 0.893 while sensitivity and specificity were .821 and .919, respectively.

**Conclusions:** Ultrasonography can help in pre-operative localization of tumors in the superficial and deep lobes of the parotid gland. This can facilitate selection of the proper surgical treatment and minimize the risk of adverse consequences of facial nerve damage while improving cosmetic outcomes.


**Keywords: Parotid gland, Superficial lobe, Deep lobe, Ultrasonography, minimum fascia-tumor distance, maximum fascia-tumour distance.**

## INTRODUCTION

Salivary gland tumors are relatively rare, accounting for approximately 3% of all head and neck tumors.[1] In 2017, the fourth edition of the World Health Organization (WHO) classification of head and neck tumors listed 11 different types of benign salivary gland epithelial neoplasms.[2] The parotid gland is the site of 80% of these tumors, most of which (80%-90%) are benign.[1] Pleomorphic adenoma (PA), also known as benign mixed tumor, accounts for approximately 60% of parotid neoplasms[3]. Warthin tumor (WT), also known as papillary cystadenoma lymphomatosum or adenolymphoma, is the second most common benign tumor of the parotid gland, and basal cell adenoma (BCA) ranks third.[2] PA has a higher frequency of malignant transformation compared with WT and BCA; the other 8 types have never become malignant [2-5].

Ultrasonography (US), magnetic resonance imaging (MRI), and computed tomography (CT) are the mainstream imaging techniques for the evaluation of parotid tumors. [6] Although CT and MRI have superior quality in distinguishing parotid lesions, they also have some limitations. CT uses ionizing radiation, and MRI is costly, may involve long waiting times, and is contraindicated in patients with internal ferromagnetic devices[7]. In contrast, US is a simple, low-cost and non-invasive procedure, generating real-time imaging without x-ray exposure. It is widely available, easy to operate, and economical, so it is the first choice for the evaluation of salivary gland lesions. In addition, US can provide detailed information about tumor size, boundaries, and echo patterns. [8, 9]

The parotid gland is divided into superficial and deep lobes by the facial nerve, although these are not really "lobes" because there is no fascia to separate them. The purpose of parotid surgery is to completely remove the lesion while preserving the facial nerve anatomically and functionally. The location of the lesion will affect the duration and difficulty of the operation. Superficial lobe lesions can be treated by superficial parotidectomy, but deep lobe lesions sometimes require total parotidectomy [10]. Therefore, it is particularly important to determine whether a tumor is located in the superficial or deep lobe before surgery.

The minimal distance between the parotideomasseteric fascia and the surface of the tumor was first proposed by Higashino et al. [11]as a means of localizing lesions by lobe. To further investigate the validity of this proposal, this study was conducted to calculate the efficacy of US-based measurements of the minimum and maximum distances between the fascia and the tumor in the distinction between the location of benign salivary gland tumors in the parotid gland. We hypothesized that these measurements would lead to acceptable levels of efficacy in classifying tumors in the superficial vs deep lobe.

## MATERIALS AND METHODS

### Patients

This retrospective investigation was conducted in the Department of Oral and Maxillofacial surgery in a comprehensive third-class hospital. US images, case data, and surgical reports of all patients with benign parotid tumors from 2016 to 2021 were collected. Approval was obtained from the institutional review board of our hospital, which waived the requirement for patient informed consent.

Of the original total of 262 cases, we excluded 62 patients with controversial pathological diagnoses, 49 patients without parotid US before surgery, 30 patients with malignant tumors, and 19 patients with unclear or incomplete US images. The remaining 102 patients were enrolled in the study (63 patients with PA and 39 with WT).

### US examination

The Philips EPIQ5 color Doppler US unit (Philips Medical Systems, Amsterdam, Netherlands) was used with a probe frequency of 7-15MHZ. The patient was positioned to completely expose the parotid area. After smearing the appropriate amount of coupling agent, the probe was placed perpendicular to the scanning surface, and the parotid gland was scanned longitudinally (vertically) with minimum pressure applied to the face. The lesions were located and the US features of each tumor were observed, including tumor size, boundary, tumor long and short diameters, and the location of parotideomasseter fascia. The images were saved in the Digital Imaging and Communications in Medicine (DICOM) format in the picture archiving and communication system (PACS) at the hospital.

**Data acquisition**

The parameters measured in our study were the minimum fascia-tumor distance (MiFTD) and maximum fascia-tumor distance (MaFTD) between the parotideomasseter fascia and the tumor surface. (Figure 1) US images were independently measured by a physician who was experienced in US diagnosis and a chief physician in oral and maxillofacial surgery. Both examiners were blinded to the pathologic diagnoses of the tumors. The 2 physicians independently measured the MiFTD and MaFTD of each tumor. In the case of large numerical differences, an agreement was reached through discussion and re-measurement. The mean values of their measurements were used for statistical analysis.

The superficial and deep lobes of the parotid gland were distinguished by the facial nerve plane. According to what was observed in each patient during surgery, the tumors located in the superficial layer of the facial nerve were classified as superficial lobe tumors, while those located deep in the facial nerve plane were classified as deep lobe tumors. The diagnosis of each tumor was determined according to the postoperative histopathological examination. Volumetric DICOM data sets of a superficial lobe tumor and a deep lobe tumor may be examined with the interactive viewer embedded within this article.

**Statistical analysis**

SPSS v25.0 software（SPSS Inc., Chicago, IL, USA) was used for statistical analysis of MiFTD and MaFTD. These measurements were summarized using means and standard deviations The Shapiro-Wilk test was used to test the normality of distribution of MiFTD and MaFTD data. It was found that MiFTD and MaFTD of the superficial lobe tumors did not follow a normal distribution. The Mann-Whitney U test was therefore used to calculate the significance of the differences in distribution between MiFTD and MaFTD.

SPSS v25.0 was used to generate the receiver operating characteristic (ROC) curve, with sensitivity as the ordinate and 1 - specificity as the abscissa. The area under the ROC curve (AUC) is a measure of the ability to correctly distinguish the location of tumors and was calculated to estimate the overall diagnostic outcome of the parameters. On this curve, the closer the point is to the upper-left corner, the higher the sensitivity and specificity.

Diagnostic performance was calculated according to the Youden index, which at its maximum value is used to determine the cutoff measurement values that produce the maximum of (sensitivity + specificity – 1) over all possible decision thresholds. The cutoff values for MiFTD and MaFTD determined by the Youden J index were used to calculate sensitivity and specificity in correctly localizing the lesions. Statistical significance was established at $P < 0.05$.

## RESULTS

Of the 102 patients, 68 were males (PA:30, WT:38) and 34 were females (PA:33, WT:1). There were 74 superficial lobe tumors (PA: 45, WT: 29) and 28 deep lobe lesions (PA:18, WT:10). The mean MiFTD of superficial lobe tumors (1.57 mm, SD = 0.99) was significantly smaller than that of deep lobe tumors (3.03 mm, SD = 1.10, $P < .001$). The mean MaFTD of superficial lobe tumors (18.34 mm, SD = 6.05) was significantly smaller than that of deep lobe tumors (24.34 mm, SD = 6.45, $P < .001$), as stated in Table I.

The ROC curve was constructed to illustrate the ability of MiFTD, MaFTD, and the combination of these parameters to distinguish between superficial and deep lobe tumors (Figure 2). As listed in Table II, AUC values were .889 for MiFTD, .759 for MaFTD, and .893 for the combination of these measurements, which were all significantly greater than the area under the reference line of random chance (.500). The 3 parameters were all effective in identifying the correct locations of tumors. However, there were no statistically significant differences between the 3 AUC values ($P \geq .05$).

According to the Youden index, the diagnostic efficacy was greatest when the cutoff point for MiFTD was 2.7 mm. When tumors with MiFTD > 2.7 mm were considered to be deep tumors, sensitivity and specificity were .714 and .913, respectively. Diagnostic efficacy for MaFTD was greatest with a cutoff point of 21.1 mm. When tumors with MaFTD > 21.1 mm were considered to be deep tumors, sensitivity and specificity were .821 and .703, respectively. When combining the cutoff points of MiFTD at 2.7 mm and MaFTD at 21.1 mm, sensitivity and specificity were .821 and .919, respectively.

## DISCUSSION

The facial nerve is typically used to distinguish the superficial and deep lobes of the parotid gland, but it cannot be well displayed in US, CT, or MRI images, so it is difficult to judge whether a tumor is located in the superficial or deep lobe. This presents challenges in evaluating a parotid tumor before surgery and in choosing the mode of operation. Imaizumi et al [12] used MRI to display the parotid duct in an attempt to distinguish superficial from deep lobe tumors. However, according to the research of Eracleous [13], the success rate of identifying the parotid duct on MRI was only 69%. Therefore, it is very important to find a more effective method to distinguish the tumors of the superficial and deep lobes before surgical treatment.

Higashino et al [11] established an MiFTD of 3 mm as the critical cutoff point to distinguish superficial from deep lobe lesions, and the resulting sensitivity and specificity were 85% and 91%, respectively. The study of Mantsopoulos et al [14] showed that an MiFTD of 2.6 mm was valuable in this task. In the present study, the optimal cutoff point of MiFTD determined by the Youden index was 2.7 mm, resulting in AUC of 0.889 and sensitivity and specificity of .714 and .913, respectively. US examination is known to be operator-dependent; [15] different compression levels of the probe during ultrasound examination may affect MiFTD, which is the main reason for the difference in our research results. We also discovered that a cutoff value for MaFTD of 21.1mm could properly classify the location of the tumor with AUC of .759, sensitivity of .821, and specificity of .703.

However, we were not satisfied with the AUC or the sensitivity and specificity of either MiFTD or MaFTD when used alone. The AUC values for MiFTD and MaFTD were .889 and .759, respectively. A commonly used scale for interpretation of AUC states that values of 0.5 to 0.7 indicate poor ability of the test to discriminate between lesions, 0.7 to 0.8 represents acceptable discrimination, 0.8 to 0.9 is excellent, and values > 0.9 are outstanding.[16] This meant that while the MiFTD cutoff point of 2.7 mm resulted in excellent discrimination between superficial and deep lobe location, the MaFTD cutoff value of 21.1 mm yielded only acceptable ability. The sum of sensitivity and specificity was 1.627 for MiFTD and 1.524 for MaFTD, which barely fulfilled the expectation that the sum of these values should exceed 1.5 for tests to be effective in distinguishing between two conditions.[17]

Therefore, we combined MiFTD and MaFTD and discovered that AUC improved to 0.893, providing excellent discrimination. Sensitivity and specificity were .821 and .919, respectively, and the sum was 1.74, an improvement over the sum values of either criterion alone. The combination of MiFTD and MaFTD to determine the specific location of parotid tumor can provide strong support for preoperative discussion and operation design. This is important because the surgical methods of superficial lobe tumors and deep lobe tumors are different.

The major surgical options for benign parotid tumors are extracapsular dissection (ECD), partial superficial parotidectomy (PSP), superficial parotidectomy (SP), and total parotidectomy (TP) [18]. ECD is a technique that removes the tumor and its capsule together with a thin ring of normal glandular tissue without formally identifying and dissecting the facial nerve [19]. PSP determines the peripheral branches of the facial nerve and dissects in the direction of the main facial nerve. One or more branches of the facial nerve are exposed to prevent injury to the remaining branches, and only a small portion of the healthy parotid tissue around the tumor is removed. [20] ECD and PSP are more popular among surgeons because there are many postoperative complications in the treatment of parotid superficial lobe tumors.

Tumors of the superficial lobe of the parotid gland are treated by SP, including the removal of the entire superficial lobe of the parotid gland and the separation and preservation of the trunk and branches of the facial nerve. Lesions in the deep lobe are usually treated by TP. These methods involve making a skin incision from the root of the zygomatic arch anterior to the tragus, bypassing the earlobe, and extending along the posterior edge of the mandibular ramus to the large angle plane of the hyoid bone.[21,22] The skin, subcutaneous tissue, and platysma muscle in the submandibular region are exposed and the flap is turned along the parotideomasseter fascia to expose the superior, anterior, and inferior margins of the parotid gland. The facial nerve is then dissected and separated to protect it. Finally, the tumor is removed along with the superficial lobe of the parotid or the entire gland.

SP is considered the gold standard for the resection of superficial lobe benign tumors of the parotid gland [23]. However, this surgical method has two problems. First, the probability of intraoperative injury of the facial nerve is greatly increased, resulting in facial paralysis after the operation; and second, the surgical incision is large, often resulting in poor cosmetic appearance.[23]

Albergotti [24] et al reported that the recurrence rates following ECD and SP were similar, but the incidence of facial paralysis after ECD was lower. McGurk et al found that there was no significant difference in the rate of permanent facial paralysis between ECD patients and SP patients,[19] but transient facial paralysis was significantly more frequent following SP.[25]

According to Kilavuz et al [26], the incidence of transient facial paralysis in patients treated with PSP was 6.9%, while the incidence following SP was 13.6%. Permanent facial paralysis did not occur in the PSP group but occurred in 2 patients (1.1%) in the SP group. Temporary facial nerve dysfunction resulted in 11% patients treated with ECD, 18% with PSP, and 26% with SP. The incidence of Frey syndrome was significantly lower after ECD and PSP (3% and 10%, respectively) than after SP (17%).[27] Because ECD and PSP remove less glandular tissue, the incision is smaller than SP and retains more normal glands, so ECD and PSP are more aesthetically pleasing after surgery.

According to our results, when MiFTD > 2.7mm and MaFTD > 21.1mm, it can be considered that the tumor is located in the deep lobe of the parotid gland. In our previous study [28], the ratio of long to short diameter of WT was found to be significantly larger than that of PA in US images, helping identify the types of tumors before operation. In one investigation, the histological features of incomplete capsule, capsule penetration, pseudopodia, and satellite nodules in PA led to a high recurrence rate [29]. The incidence of transient facial nerve injury in ECD is lower than that in PSP, which may be due to the fact that fewer nerves need to be clipped and separated from tumors in ECD [30]. ECD is performed at the edge of the tumor capsule, while PSP is performed in the normal glandular tissue outside the tumor. According to the histological characteristics of PA, however, PSP is more suitable for PA with an incomplete capsule. Accurate location of the parotid benign tumor in the superficial or deep lobe is helpful in selecting the better surgical method, ECD or PSP, and in avoiding the excessive incision of the standard operation when the location of the tumor is unknown. This helps reduce the risk of facial nerve injury, facial paralysis, and Frey syndrome, and provide better aesthetic effects.

Compared with CT and MRI, US is an inexpensive, effective, and safe imaging procedure. It is reported that this technique can fully describe 95% of the common salivary gland lesions [31]. MiFTD and MaFTD can be used to judge whether the tumor is located in the superficial lobe or deep lobe of the parotid gland, which provides important reference value for surgical planning, and is of great benefit in reducing surgical incisions and postoperative complications.

The current research had some limitations. First, this was a retrospective study, so the US findings were not evaluated in real time. The second limitation is that the sample size was small. In addition, MiFTD and MaFTD can be affected by variable grades of compression on the US probe and by different examinations or examiners. Undoubtedly, US examination is highly examiner-dependent, and even if the same examiner had performed all examinations, minor variations might have existed. Finally, although relatively rare, malignant and other benign tumors of the salivary glands were not included in the study.

**CONCLUSION**

Calculation of the minimum and maximum distances between the parotideomasseter fascia and benign salivary gland tumors in the parotid gland by using ultrasonographic images yielded excellent ability to distinguish tumor location in the superficial vs deep lobes of the gland. This knowledge can be helpful in selecting the proper surgical treatment and minimizing the risk of adverse consequences of facial nerve damage while improving cosmetic outcomes.

Statement

Calculation of the minimum and maximum distances between the parotideomasseter fascia and benign salivary gland tumors in the parotid gland by using ultrasonographic images yielded excellent ability to distinguish tumor location in the superficial vs deep lobes of the gland.

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**Legends for Illustrations**

Figure 1: Right parotid mass. The minimum thickness of the normal parotid gland tissue between the parotideomasseteric fascia and tumor (blue arrows) was measured before surgery using ultrasonography. MiFTD: minimum fascia-tumor distance (black line). MaFTD: maximum fascia-tumor distance (red line).

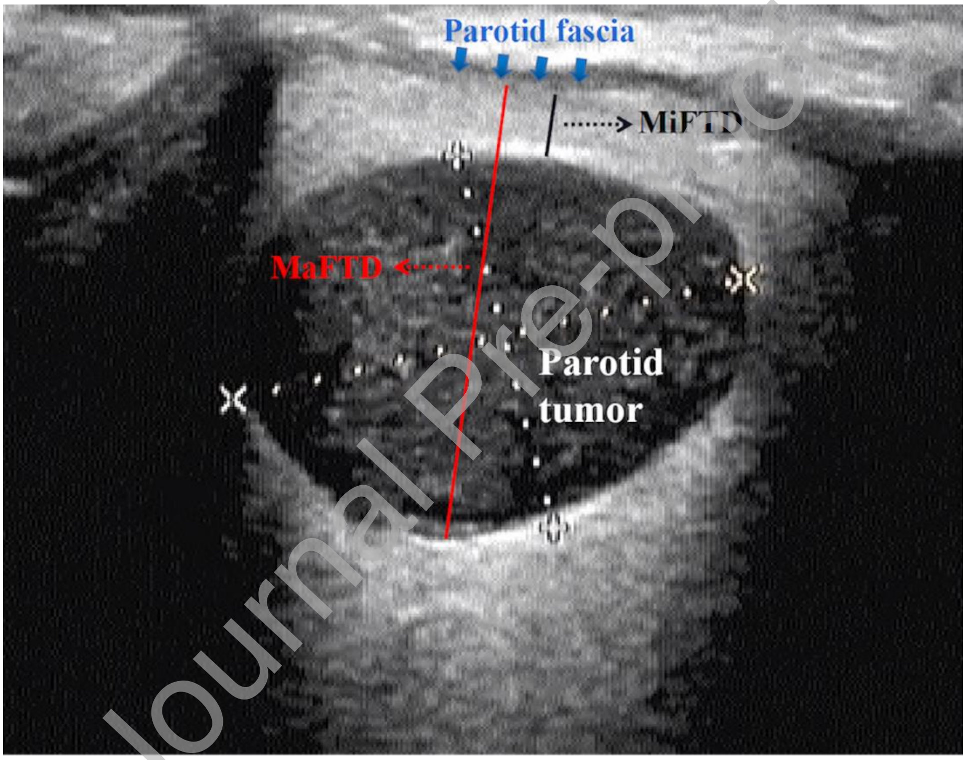

Figure 2: Receiver operating characteristic (ROC) curves for the ability of minimum and maximum fascia-tumor distance (MiFTD and MaFTD) and joint diagnosis model of MiFTD+MaFTD to distinguish superficial and deep lobe tumors in the parotid gland. The ability to distinguish between locations is illustrated by the area under the ROC curves. Reference line, border of the area under the curve that represents random chance in distinguishing between locations.

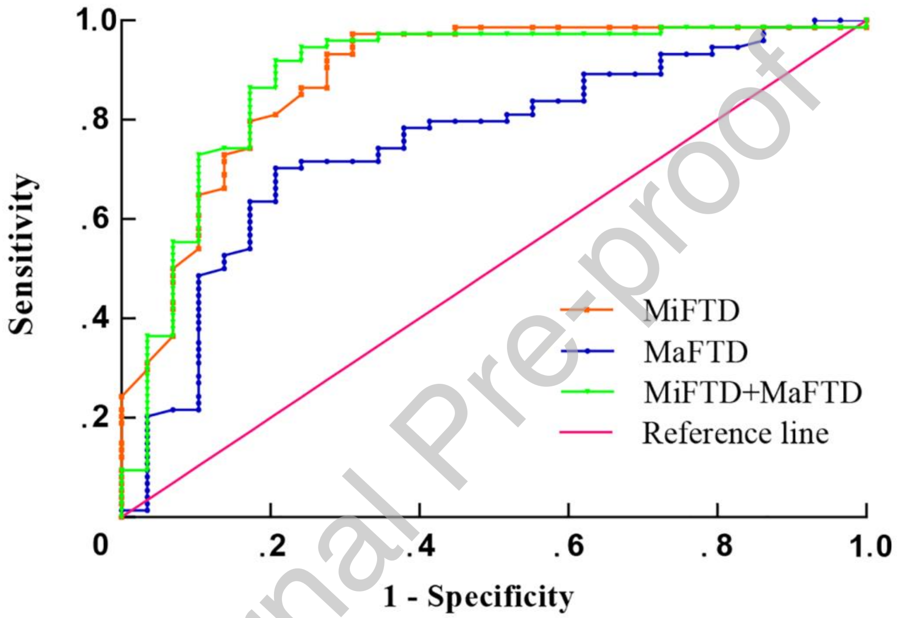

**Table I. Mean ± SD MiDFT and MaDFT of superficial lobe and deep lobe tumors.**

| | Superficial lobe | Deep lobe | Mann-Whitney U statistic | P |
|---|---|---|---|---|
| **MiDFT** (mm) | 1.57 ± 0.99 | 3.03 ± 1.10 | 229.50 | ＜0.001 |
| **MaDFT** (mm) | 18.34 ± 6.05 | 24.34 ± 6.45 | 500.00 | ＜0.001 |

MiFTD, minimum fascia-tumor distance; MaFTD, maximum fascia-tumor distance,

**Table II: Receiver operating characteristic analysis of MiFTD, MaFTD and the combination of MiFTD and MaFTD**

| | AUC | 95%CI | Sensitivity | Specificity |
|---|---|---|---|---|
| **MiFTD** | .889 | .810 -.969 | .714 | .913 |
| **MaFTD** | .759 | .651 -.866 | .821 | .703 |
| **MiFTD+MaFTD** | .893 | .809 -.977 | .821 | .919 |

MiFTD, minimum fascia-tumor distance; MaFTD, maximum fascia-tumor distance; AUC, area under the curve; 95%CI, 95% confidence interval.