Rupture length of the sinus membrane after 1.2 mm puncture and surgical sinus elevation: an experimental animal cadaver study

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Objectives. To evaluate the rupture length of the sinus membrane after applying a defined 1.2 mm defect comparing 3 different techniques: Summers lift, balloon-assisted technique (BASL), and hydrodynamic ultrasonic cavitational sinus lift (HUCSL).

Study design. Thirty fresh sheep heads (60 maxillary sinuses) were investigated. The sinus membrane was ruptured using a 1.2 mm pilot drill. Then Summers lift, BASL, and HUCSL were each performed on 20 sinuses, creating a 5 mm vertical lift of the sinus membrane. The length of the ruptured sinus membrane was measured before and after the experiment. The results of the different sinus lift techniques were compared using t tests.

Results. The t test showed that the Summers lift leads to a significantly higher rupture length (P = .05) than BASL. The comparison between Summers lift and HUCSL showed a significantly higher rupture length with the Summers lift (P < .005). The same significance (P < .005) was found when BASL was compared with HUCSL. Comparing the increasing rupture length of the sinus membrane during the experiment, the t test showed a significantly greater rupture using BASL or the Summers lift compared with HUCSL.

Conclusions. The HUCSL technique yielded the lowest increase of rupture length compared with BASL and Summers lift. The technique therefore shows the lowest risk of a growing rupture of the sinus membrane in case of an iatrogenic puncture during preparation of the transcrestal approach. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011; 112:568-572)

Bone loss in the maxilla due to failure in periodontal therapy, orthodontic treatment, or general bone diseases is a very common problem. Furthermore, decreased vertical bone height is the result of advancing periodontal diseases and additional pneumatization of the sinus following maxillary posterior tooth removal. The success rate of sinus floor elevation is reported to be higher than onlay grafting. Several techniques using a lateral approach or a transcrestal approach are described in the literature. The lateral approach allows more rupture control, but is more invasive and interrupts bone nutrition by dissecting the peristeum from the bone. In the literature, the lateral approach is reported to show a failure rate of 11%-56%. The transcrestal approach approach allows less control regarding ruptures of the membrane. The most described transcrestal techniques are the balloon-assisted technique (BASL) and the Summers lift. All described lateral and transcrestal approaches lead to tearing forces on the sinus membrane, which is associated with a high risk of ruptures of the membrane. The success rate of the Summers lift is reported in the literature to be 94%, and the success rate of BASL is reported to be ~92%-100%.

Hydraulic procedures are reported to avoid any tearing forces on the sinus membrane. Recent investigations showed that the average pressure for lifting up the sinus membrane is significantly lower using hydraulic pressure instead of pneumatic pressure. The hydrodynamic ultrasonic cavitational sinus lift (HUCSL) was designed to elevate the sinus membrane without any tearing forces by using the Acteon Piezotome equipment. This technique (Intralift) uses an ultrasonic oscillating water stream to lift up the sinus membrane from the bone. The aim of the present study was to evaluate the rupture length of the sinus membrane after applying a defined 1.2 mm defect to the membrane using the Summers lift, BASL, and HUCSL methods and to compare the results of these 3 techniques.

MATERIALS AND METHODS

Thirty fresh sheep heads (60 maxillary sinuses) stored at 5°C and 100% relative humidity were used for
this investigation. Only healthy sinuses (free of inflammation) were used for the investigation. Before the experiment, the heads were warmed up to 22°C at 100% relative humidity. Twenty heads were used for each of the 3 sinus lift techniques.

The thickness of the sheep’s sinus floor bone is 1-2 mm, which was measured by using a ruler with a round and flat tip to initially protect the sinus membrane. The initial osteotomy was prepared to a diameter of 2.8 mm in all 3 techniques. Then the defined circular rupture of the membrane was applied by using a 1.2 mm pilot drill (Figs. 1 and 2). The roof of the maxillary sinus was removed before the experiments. The punctured area of each sinus was lifted to exactly 5 mm in each technique to get comparable results. The achieved height of the sinus lift was measured with a ruler from the top of the maxillary sinus cavity. The Summers lift was performed using Friatec tapered osteotomes with a concave tip. The BASL was performed with the Meisinger system (balloon lift control). The balloon was filled with 0.5 mL saline to achieve a lift of 5 mm.

The HUCSL (Intralift) was performed by using the published standard procedure. The cavity was prepared by using the oscillating diamond cylinders TKW 1 (diameter 1.35 mm), TKW 2 (diameter 2.1 mm), TKW 3 (diameter 2.35 mm), and TKW 4 (diameter 2.8 mm). After preparing the cavity, the sinus lift was performed with the TKW 5 “trumpet” using a flow rate of 40 mL/min 2 × 5 seconds (Fig. 3). The height of the sinus membrane was measured with the ruler mentioned above where the sinus membrane was not ripped completely by the elevation process.

After the sinus lift, the size of each rupture was measured and documented. The results of this study were evaluated in 2 different ways. First, the total rupture lengths, including the 1.2 mm puncture, were considered, and second, the increases of the ruptures excluding the initial puncture were evaluated.

The statistical evaluation by SPSS (Chicago, IL) included the calculation of mean, standard deviation, and variation. To determine the correlation of the different methods of sinus floor elevation, a t test was used. We considered a result to be significant if the P value was <.05.

RESULTS
Evaluation of the total rupture lengths including the 1.2 mm punctures

The Summers lift showed an average rupture length of 4.7 mm with a range of 1.2-12 mm, median 4 mm, and SD 3.15 mm. In 16 cases (80%), the initial puncture was increased during the lifting procedure (Fig. 4).
Using BASL, the sinus membrane showed an average rupture length of 7.1 mm with a range of 1.2-14 mm, median 6.5 mm, and SD 4.01 mm. In 17 cases (85%), the puncture was increased (Fig. 5).

The Intralift technique showed an average rupture length of 1.25 mm with a range of 1.2-2 mm, median 1 mm, and SD 0.44 (Table I). In 5 cases (25%), the size of the initial puncture was increased. In 15 cases, the initial puncture of 1.2 mm did not change its size (Fig. 6).

The comparison of the results by the t test (Table II) showed that the Summers Lift leads to a significantly higher rupture length ($P = .05$) than BASL. The comparison between Summers lift and Intralift showed a significantly higher rupture length with the Summers lift ($P < .005$). The same significance ($P < .005$) was found when BASL was compared with Intralift.

Thus, both conventional sinus lift techniques (Summers lift and BASL) showed a significantly higher risk of increased rupture length of the sinus membrane than the Intralift technique.

**DISCUSSION**

Tearing forces which are inevitably applied to the sinus membrane when performing lift techniques lead to a high risk of ruptures. There exist several anatomic reasons for an increased rate of ruptures of the sinus membrane, such as multilocular sinuses, septa, and involutions of the membrane. The reason these anatomic variations lead to a higher rupture rate is the tearing force applied to the membrane. Especially, the region around the tip of a septum leads to such an increased tearing force. Every transcrestal approach has the disadvantage that no visual control is possible. Therefore, the avoidance of tearing forces reduces the risk of ruptures of the membrane. When the bony fragments are lifted up by the Summers lift or BASL, tearing forces are applied to the sinus membrane, especially because the balloon does not fit exactly into the created space. The risk rate of a rupture of the sinus membrane is reported in the literature as 11%-56%, whereas the Summers lift shows a success rate of 94% and BASL shows a success rate of 92%-100%. Although these figures give an indication, an analysis of the failure rate of these techniques shows that a com-
parison is very difficult, because the study designs differ greatly. Some studies evaluate the success rate by using the survival rates of the placed implants\textsuperscript{9,10,19,25} and some studies evaluate the rupture rates of the sinus membrane.\textsuperscript{13,22,26,31}

Recent studies showed that the application of pneumatic pressure requires significantly higher pressure than hydraulic pressure to lift up the sinus membrane.\textsuperscript{28-30} These results led to the development of the Intralift technique, which uses oscillating water pressure to lift up the sinus membrane.\textsuperscript{31} The present investigation was performed to compare the Intralift technique with 2 commonly used transcrestal sinus lift techniques. The sheep’s sinus is a well known model\textsuperscript{33} to evaluate different techniques of sinus floor elevation, because the roof of the sinus can be removed easily for evaluation of the different elevation methods.

The problem of all internal sinus lift elevation methods is the difficulty to control the lifted volume and to investigate the membrane for ruptures. Former investigations regarding the Summers lift\textsuperscript{15,16,20} and BASL\textsuperscript{26,32,34} report very different failure rates, augmented volumes, and augmentation heights. The achieved augmentation heights vary from 5 to 10.9 mm and the failure rates from 0\%\textsuperscript{19} to 34\%.\textsuperscript{20} One publication\textsuperscript{34} uses pigs as an animal model, and the other references report only clinical cases. Therefore, a comparison of the results of the present study with the existing literature is difficult.

It has to be pointed out that in the current investigation, the Intralift technique showed a very small difference between the initial puncture (1.2 mm) and the median rupture rate (1.25 mm; Table I), whereas BASL and Summers lift showed a much higher increase of the rupture, with median rupture rates of 4.5 mm and 6 mm, respectively. By interpreting the increase of the rupture rate with the t test, BASL and Summers lift show a significantly higher increase of the rupture length than Intralift. This means that Intralift has almost no effect on a ruptured sinus membrane, although BASL and Summers lift lead to further rupturing of the membrane even if only a small 1 mm defect occurs initially.

A ruptured membrane decreases the prognosis of a successful transcrestal sinus lift procedure significantly. On the other hand, the literature shows that only ruptures with a size <2 mm have to be covered.\textsuperscript{24} Leaving these small defects uncovered does not affect the clinical outcome.\textsuperscript{24} A complete rupture of the membrane prevents an augmentation of the cavity and leads to the interruption and failure of the surgical procedure, because the material would end up loose in the maxillary sinus. The present results show that the initial rupture increased in 80\% of the cases when the Summers lift technique was applied and in 85\% of the cases when BASL was used. Intralift showed ruptures only up to 2 mm. Compared with the literature, which reports a need of covering only defects which are >2 mm, it can be concluded that Intralift could decrease postoperative complications after augmentation, because the percentage of ruptures is low and their size does not extend the critical defect size of 2 mm.

The results of the t test allow a ranking of the different sinus floor elevation methods. BASL showed significantly higher rupture lengths of the punctured sinus membrane than the Summers lift and Intralift. Intralift yielded significantly better results than the Summers lift.

The conclusion of the current investigation is that the Intralift technique showed the best results of the 3 investigated methods, and that it yielded the lowest risk of an enlarged rupture of the sinus membrane in case of an iatrogenic puncture during preparation of the tran-

Table II. Statistical comparison by t test (P values) between Summers lift, balloon-assisted sinus lift, and Intralift (using the absolute values of the rupture length)

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<th>Summers lift vs. Balloon lift</th>
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<th>Balloon lift vs. Intralift</th>
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<tr>
<td>P value</td>
<td>.046</td>
<td>&lt;.005</td>
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Table III. Statistical comparison by t test (P values) between Summers lift, balloon-assisted sinus lift, and Intralift (using the increased length of the rupture)

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<tr>
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<tbody>
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<td>P value</td>
<td>.041</td>
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screstal approach. Further clinical studies have to be performed to gain more information about Intralift.

REFERENCES


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