Clinical Effectiveness of the Lateral Approach of the Maxillary Sinus Floor Augmentation using Different Gadgets with Simultaneous Implant Placement: A Systematic Review with Meta-Analysis

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Abstract

Objectives: Help the clinician to choose between the newly introduced, specifically designed instruments for this procedure.

Methods/Statistical Analysis: after thorough search of Cochrane CENTRAL and PubMed databases, the analysis was limited to clinical studies of the lateral approach sinus augmentation with simultaneous implant placement. Statistical Analysis: Comprehensive Meta Analysis version 2.2.048 software was used.

Results: Eight articles were included in the review. Analysis of the formatted tables shows that the type of tool used in sinus lateral approach might affect the success of the procedure.

Findings: There was a statistical significance difference of using the ultrasonic tips over the conventional use of rotary tips but it is not usually to be clinically significant; especially if a highly trained surgeon could perform the lateral osteotomy by any tool but the previous studies were highly supporting the ultrasonic tips over the rotary tips in reference to less traumatic surgery with minimal operative and postoperative complications.

Application/Improvements: Randomized clinical trials are needed to compare the newly presented tools like DASK and SLA reamers to properly assess their clinical effectiveness. Studies of patient reported outcomes are needed to clearly evaluate the cost effectiveness of each tool.

Keywords: Augmentation, Implant, Lateral Approach, Maxillary Sinus, Simultaneous

1. Introduction

Damage of the membrane lining the maxillary sinus is the most common problem of the lateral approach sinus floor augmentation techniques which used as a corrective surgery to the upper posterior atrophic ridge with height problem that contradict implant placement at this site. Perforations were most likely accompanied with the use of traditional rotary tips and saws.

Recently different tools designed to minimize the possibility of sinus membrane tear. Piezoelectric tips are ultrasonic auscultation tips that selectively cut the bone without damage of soft tissue and teeth.

Many reamers presented nowadays in the market which minimally invasive to the sinus membrane likes (Biomet 3i) but it was advised to be used with extreme caution. LS and C reamers (SLA KIT, Neobiotech) are other types of drills of a conical trunk and specific penetration depth that selected for each case from the pre-operative cone beam volumetric tomography. Moreover, it favors good accessibility to the surgical site; lessen the time of surgery when compared to the conventional rotary tips, also it considered of low cost when compared to the piezoelectric tips.

Altered type of reamers was presented that based on cutting the bone on the lateral surface of the maxillary
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sinus by thinning it gradually\(^4\). Also, there are new drills called Artificially Intelligent (AI- Water Lift System) that stops cutting the bone when they reach the membrane lining the sinus cavity by pressure sensitivity\(^2\).

Implant placement could be simultaneous with the sinus floor augmentation or in staged approach, the former provides the advantages of shortening the time of treatment and less surgical entries, but it requires minimal residual preoperative bone height of 5mm that guaranties implant primary stability\(^10\).

2. Material and Methods

2.1 Focus Question
Which is the best tool to be used in lateral sinus augmentation technique and to help clinicians choose between the newly introduced tools in the market? It established by PICO (Population, Intervention, Comparison And outcome).

Population: Patients with upper posterior edentulous area with insufficient bone height for implant placement.

Intervention: piezoelectric ultrasonic tips and reamers.

Comparison: Conventional rotary burrs.

Outcomes: implant survival and bone height changes

2.2 Type of Intervention
New tools which specifically designed for the lateral approach sinus floor augmentation technique.

2.3 Outcome Parameters
Outcomes to be assessed were membrane perforation, postoperative sinusitis, graft loss, implant survival rate, graft height reduction and postoperative bone height.

3. Study Type and Follow Up
Randomized clinical trials on patients (sample size = minimum 4 patients) need restoration of upper posterior edentulous area which complicated by sinus floor pneumatization; with residual bone height (at least 8 mm) requiring sinus floor augmentation via the lateral approach and simultaneous implant placement and at least follow up of 6 months after implant placement.

4. Exclusion Criteria
- In vitro studies.
- Case reports and case series studies.
- Implants survival rate not assigned in the paper or implant success not one of the outcomes.
- The technique of sinus augmentation not clearly described.

4.1 Search Strategy
A computerized systematic search strategy was conducted in Cochrane CENTRAL and PubMed searching for human studies with no language restrictions. The full text articles were obtained from reviews on sinus floor augmentation published to date. Additional publications were identified from the reference lists of the retrieved articles. No individual journal search was conducted but rather depending on reputable journals already indexed in the searched databases.

4.2 Search Combination
Search terms were ((((((sinus lift lateral) OR sinus lift lateral window) OR lateral sinus lift) OR external sinus lift) OR open sinus lift)) AND (((simultaneous implant) OR implant placement) OR implants dental) OR implants)

4.3 Selection of Studies
Independent screening of all papers by the authors based on the inclusion criteria. The selected articles were then obtained in full text. Disagreements were resolved by discussion. PRISMA flow chart presented in Figure 1.

4.4 Data Extraction
The reviewers independently extracted the data using data extraction tables. Any disagreements were resolved by double-checking the original data and by discussion.

4.5 Quality Assessment
Retrospective studies were excluded because they are highly susceptible to recall bias so they considered of a low grade of evidence. Cochrane tool for risk of bias assessment was used to assess the quality of included clinical studies regarding sequence generation, allocation concealment, blinding, incomplete outcome data and selective outcome reporting.
Figure 1. PRISMA flow chart.

Table 2. Study design and basic patient data and exclusion characters

| The author | Design of study | No. patients | No. sinuses | Age (years) | Mean of age | Smokers | Systemic disease | Sinus pathology | Others                      |
|------------|----------------|--------------|-------------|-------------|-------------|---------|------------------|-----------------|---------------------------|
| 25         | Randomized clinical trial | 10 | 15 | 35-58 | No | Yes | Yes | periodontitis |
| 24         | Retrospective | 17 | Not specified | Not specified | 51 | > 10 cigarettes per day | Yes | Yes | previous maxillary sinus surgery |
| 14         | Randomized clinical trial | 12 | 13 | 20–50 | Not specified | Yes | Yes | Limited mouth opening |
| 11         | Retrospective | 33 | Not specified | Not specified | 55 | Not specified | Yes | Not specified | Not specified |
| 13         | Retrospective | 49 | 49 | | Yes | Yes | Yes | Not specified |
| 26         | Retrospective | 73 | 81 | 29 to 78 | 53.79 +/- 9.92 | No | Yes | Yes | previous sinus surgery |
| 27         | Not specified | 10 | 12 | Not specified | Not specified | Not specified | Yes | Yes | Replacement of the bone window not possible |
| 12         | two-arm and split-mouth randomized controlled clinical trial | 104 and 5 | 135 | 39 to 81 | 64.9 | No | Yes | Yes | Pregnancy |

5. Results

105 articles were identified by electronic searching. Eight original articles fulfilled the inclusion criteria as in (Figure 1). After reading the full text (Table 1): Three articles were excluded because implant placement were in two stages after augmenting the sinus, two articles were excluded also
Table 3. Characters of surgical procedures

| The authors | Residual bone height | Simultaneous/Staged implant placement | Membrane use | The lateral osteotomy characters | Tool used for the lateral approach | Healing | Grafting | Implants |
|-------------|----------------------|--------------------------------------|--------------|----------------------------------|-----------------------------------|---------|----------|----------|
| 25          | >5mm                 | Simultaneous                          | platelet-rich fibrin (PRF) | Not specified                     | Ultrasonic tips                    | Loading after 6 months, 1 year postoperative CT | (MBCP) Biomatlante Inc., Vigneux de Bretagne, France | In-Kone TEKKA implants |
| 24          | 3.32 to 8.14mm       | Simultaneous                          | No           | bony window was used to cover the osteotomy site | a Piezo surgical tip or a number 4 diamond round bur | Follow up at 2 weeks, 4 weeks, and 4 months after the surgery for post-surgical evaluation. Second stage surgery was scheduled at 5- to 6-month post sinus lift | calcium phosphate silicate (CPS) putty bone substitute (Novabone Dental Putty; Novabone Products, Alachua, FL) | (BioHorizons, Birmingham, AL) |
| 14          | >5mm                 | Simultaneous                          | collagen membrane | Window                           | 3mm diameter round bur             | Loading was 6 months after placement of implants. | Alloplastic bone graft (Bioactive glass putty) | Self-threaded, Tapering, Double thread, Acid etched and sand-blasted, selective Integrated surfaced Implants |
| 11          | 5mm                  | Simultaneous                          | Not specified | trap-door, open-window electric-motor drill | The prosthetic procedures of both 1-stage or 2-stage systems were started at 7 to 8 months and with initial force loading at about 9 months after sinus lifting-combined implant surgery. Follow up up to 2 years | Not specified | -(ITI; Straumann, Waldenburg, Switzerland, and SwissPlus; Centerpulse Dental, Carlsbad, CA) | -(Friate-2; FriadentGmbH, Mannheim, Germany) |
| 13          | >3mm                 | Not specified                         | Collagen     | Window                           | hand and piezo surgery burs        | 12 months of follow up after delivery of crowns. | (MinerOss, BioHorizons, Birmingham, allograft) | (Nobel Biocare, Zurich-Flughafen, Switzerland) |
| 26 | <6 mm | simultaneous or by staged approach | Collagen used only to seal over perforations | Not specified | Piezo-surgery burs | delayed implant loading | bone allograft (PUROS, Zimmer Dental Inc., Carlsbad, CA, USA) |
|----|-------|-----------------------------------|--------------------------------------------|--------------|------------------|------------------------|----------------------------------------------------------------|
| 27 | Mean = 3.07 +/- 1.35 mm | Not specified | replaceable bone window | oscillating saw (Aesculap®, B. Braun Melsungen AG, Germany) | Abutment connection surgery was performed after 6 months of healing | Not specified | (Bränemark System™, TiUnite™, Nobel Biocare AB, Gothenburg, Sweden) |
| 12 | range, 4–10 mm | When residual bone height was ≥4 mm, implants were placed simultaneously n = 61 | Porcine collagen (control group) | Boyne & James (1980) and Tatum (1986) | Not specified | Loading after 6 months after placement.. | (Bio-Oss; Geistlich Pharmaceutical AG, Switzerland) |

**Table 4. Complications**

| The authors | Implant survival rate | Graft height reduction | Post-operative bone height | Sinus perforation | Postoperative sinusitis | Graft loss | Other |
|-------------|-----------------------|-----------------------|---------------------------|-------------------|------------------------|-----------|-------|
| 25 | Not specified | 1.7mm³ Volume of bone graft material used, mean Correlation to new bone formed 0.079 mm³ | The volume of the new space created was 2.94 mm³, 0.70 ml in the lateral sinus lift group and 3.40 mm³ 1.30 ml in the sinus infiltration technique group Height of the membrane elevation, mean =13.5 mm, Volume of new bone formed mean=2.94 mm³ | no | no | No | moderate edema |
| 24 | survival was 96.67% (29/30) during a mean follow-up of 15.74 months post loading | Not specified | Mean 13.34 mm (61.74 mm) Difference 8.43 +/- 2.08 | no | Not specified | Not specified | Not specified |
| 14 | 100% | 0.3–0.7 mm 1 year after loading 0.2–0.3 mm 2 years after loading | Increase in residual ridge height ranged from (71.43 to 133.33 %) 3.7–6.1 mm (on an average 4.5 mm). | One perforation, sealed by bio-absorbable membrane. | One patient | Not specified | Not specified |
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because the augmentation were from the crest of the ridge and one article was excluded because it was a case report.

5.1 Included Studies

Eight articles were included in this review and presented in Tables 2-7. Most of the excluded patients in the included studies were the patients with history of sinusitis, immune system disorders, and uncontrolled systemic diseases; also most of the included studies excluded the smoker patients (Table 3). The surgical technique was by trap door technique or an access hole (Table 4). In the included studies, all patients underwent the lateral approach sinus floor augmentation with simultaneous implant placement.

5.2 Quality Assessment (Risk of Bias Assessment)

One randomized clinical trial was of low risk of bias, one randomized clinical trial was of unclear risk of bias because of unclear sequence generation, allocation concealment, blinding, incomplete outcome data and selective outcome reporting, one randomized clinical trial was of high risk of bias. (Table 5).

5.3 Statistical Analysis

Meta-analysis is the last step in systematic review formulation which aimed for analysis of the studies by Comprehensive Meta Analysis version 2.2.048 software, after measuring the heterogeneity to decide on the fixed or random effects approach by Cochran’s Q, which provides P-value of the studies, but I² is more reliable in assessing inconsistency between studies, with values of 25%, 50% and 75% corresponding to low, moderate and high heterogeneity respectively11.

Meta-analysis done for changes in bone height used the Standard Difference in Means (SDM) as the effect measure, while meta-analysis for survival rates used the rate as the effect measure.

The publication bias was checked by Funnel plot. Egger’s test of the intercept was used to quantify the display of the funnel plot.

6. Results

6.1 Survival Rate

Heterogeneity measures in Table 6 showed non-statistically significant Cochrane Q value (P-value = 1.000). I²
value was 0.0% indicating no heterogeneity. So we can conclude that homogeneity hypothesis is not rejected and the fixed effects model will be used.

The fixed effects model (Figure 2) showed a survival rate (effect size) of 0.990 (99.0%) using conventional rotary tips and a survival rate of 1.000 (100.0%) using Ultrasonic tips. The overall survival rate is 0.993 (99.3%) and the effect size is statistically significant with \( P \)-value < 0.001.

The relative weight of the included studies, was the highest weight (30.9%) while showed the lowest weight (7.9%).

Funnel plot analysis for the included studies showed no publication bias. This was confirmed by Egger’s regression intercept which showed non-statistically significant result (\( P \)-value = 0.548). As the results were not statistically significant, we concluded that there is no publication bias.

6.2 Changes in Bone Height

Heterogeneity measures shown in (Table 7) were statistically significant as Cochrane Q value (\( P \)-value < 0.001). \( I^2 \) value was 97.4% indicating high heterogeneity. So we can conclude that homogeneity hypothesis is rejected and the random effects model will be used.

The random effects model (Figure 4) resulted in standardized mean difference (effect size) of 0.376 using conventional rotary tips and 0.433 using ultrasonic tips. The overall change in bone height was in the direction of increase and the overall effect size was 0.410. The effect size was statistically significant with \( P \)-value < 0.001. So, we can conclude that there was a statistically significant change in bone height.

The relative weight of the included studies was the highest weight (50.6%) while showed the lowest weight (32.7%).

Funnel plot analysis for the included studies showed a publication bias. This was confirmed by Egger’s regression intercept which showed a statistically significant result.
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As the results were statistically significant, we concluded that there was a publication bias.

![Funnel plot for survival rate.](image)

**Figure 3.** Funnel plot for survival rate.

| Tool used      | The Author | Rate | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
|----------------|------------|------|----------------|----------|-------------|-------------|---------|---------|
| Rotary         |            | 27   | 1.000          | 0.289    | 0.083       | 0.434       | 3.464   | 0.001   |
| Rotary         |            | 12   | 1.000          | 0.146    | 0.021       | 0.714       | 6.856   | 0.000   |
| Rotary         |            | 25   | 1.000          | 0.213    | 0.045       | 0.582       | 4.690   | 0.000   |
| Rotary         |            | 24   | 0.933          | 0.249    | 0.062       | 0.444       | 3.742   | 0.000   |
| Rotary         |            | 14   | 1.000          | 0.277    | 0.077       | 0.456       | 3.606   | 0.000   |
| Rotary         |            |      | 0.990          | 0.095    | 0.009       | 0.803       | 10.389  | 0.000   |
| Ultrasonic     |            | 15   | 1.000          | 0.192    | 0.037       | 0.623       | 5.196   | 0.000   |
| Ultrasonic     |            | 24   | 1.000          | 0.258    | 0.067       | 0.494       | 3.873   | 0.000   |
| Ultrasonic     |            |      | 1.000          | 0.154    | 0.024       | 0.698       | 6.481   | 0.000   |
| Overall        |            |      | 0.993          | 0.081    | 0.007       | 0.834       | 12.245  | 0.000   |

*P-value = 0.030). As the results were statistically significant, we concluded that there was a publication bias.

![Forest plot for change in bone height.](image)

**Figure 4.** Forest plot for change in bone height.

Table 7. Heterogeneity measures of meta-analysis for change in bone height (Group 2)

|                | Value  | Df  | P-value |
|----------------|--------|-----|---------|
| Cochrane Q     | 154.9  | 4   | <0.001* |
| I²             | 97.4%  |     |         |

*: Significant at P ≤ 0.05, df: degrees of freedom (n-1)

7. Discussion

Many surgical tools designed recently aimed for minimizing the sinus trauma possibilities. In the contrast, some studies showed non-significant difference between piezo-electric tips and conventional rotary tips, also some authors claimed that membrane perforation not correlate with implant survival.
Figure 5. Funnel plot for change in bone height.

When comparing the piezoelectric tips with the conventional rotary tips, regarding the incidence of perforation was lowered from 7%\textsuperscript{14} to 3.8%\textsuperscript{20} while by conventional rotary tips was from 11%-56%\textsuperscript{21}. Investigating the effect of the piezoelectric patch length on the required control voltage was the interest of recent engineering research\textsuperscript{22}.

Regarding the operative time it was increased using piezoelectric tips and the rotary tips. Other studies used the new reamers didn't measure the time, so more randomized clinical trials are needed which measure the time one of the outcomes. Post-operative sinusitis as an expected complication after the lateral approach sinus floor augmentation was not founded when ultrasonic tips used\textsuperscript{23}, it was founded in one patient by using 3mm round burr\textsuperscript{24} and not specified in the rest of the included studies.

Regarding the implant survival rate which is the primary patient related outcome was 96.67% (29/30) during a mean follow-up of 15.74 months post loading, 95.3%, 100% when round burr used or electric motor drill or either use of hand or piezoelectric rotary tips or by using oscillating saw which means that survival implant rates not correlate to the tool used for the sinus augmentation and was not specified in the rest of studies\textsuperscript{25}.

Graft loss was seen in four patients, not found when ultrasonic tips used, and was not specified in the other included studies\textsuperscript{26} on the contrast the reduction of graft was 0.3–0.7 mm in height 1 year after loading and 0.2–0.3 mm 2 years after loading when 3mm round burr used but it was not clearly specified or calculated in the rest of the included studies\textsuperscript{27}.

8. Conclusions

The retrieved evidence provides a statistical significance difference of using the ultrasonic tips over the conventional use of rotary tips but it is not usually to be clinically significant; especially if a highly trained surgeon could perform the lateral osteotomy by any tool also the perforation of the sinus could be managed easily especially if it of small size by covering it by collagen barrier or by suturing if it was of large size and accessible one, but the previous studies were highly supporting the ultrasonic tips over the rotary tips in reference to less traumatic surgery with minimal operative and postoperative complications. Clear reasons identified that should prompt the clinician to prefer ultrasonic tips or rotary tips or any other type of tools. Randomized clinical trials are needed to compare the newly presented tools like DASK and SLA reamers to properly assess their clinical effectiveness. Studies of patient reported outcomes are needed to clearly evaluate the cost effectiveness of each tool.

9. Conflict of Interest

The authors declare no conflict of interest. The authors don't have financial interests in the products or tools listed in the review.

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