Placement of dental implants in the maxillary tuberosity: a systematic review


Abstract. The aim of this systematic review was to identify clinical studies on implants placed in the tuberosity region to determine the survival rate of these implants when compared to implants placed in other regions of the maxilla. A search for data published up until March 2014 was undertaken using the PubMed, Cochrane Library, Embase, and ScienceDirect databases. Eligible studies were selected according to inclusion and exclusion criteria. The first database search revealed 310 titles. After inclusion and exclusion criteria were applied, five studies remained for the detailed analysis. A total of 113 patients were followed for a period of 6–144 months; 289 implants were placed in the patients evaluated. There were eight failures/losses of dental implants in the tuberosity region; the overall survival rate was 94.63% for these implants. In controlled studies, the cumulative survival rates for implants placed in the maxillary tuberosity and other maxillary regions were 96.1% and 95%, respectively. In conclusion, implants placed into the maxillary tuberosity are a predictable alternative for the treatment of patients with insufficient bone volume in the maxillary region. However, randomized trials are needed to assess the effectiveness of this treatment.

Oral rehabilitation with osseointegrated implants is a viable option for the treatment of patients with partial or total loss of teeth, since the use of implants is considered a predictable and reliable treatment.

Implant survival is directly related to primary stability and osseointegration, which are dependent on mechanical aspects and the biological response of tissues, such as bone quality and quantity, anatomical conditions in the area where the implant is to be installed, the implant surface, immediate or delayed loading, prosthesis design, and the occlusal pattern during the healing phase, all of which must be considered.

However, failures in rehabilitation with dental implants should be considered when osseointegrated implants are installed in areas of poor bone quality, such as in the upper molar region, especially in cases of severe bone resorption. According to Lekholm and Zarb, bone quality in the posterior maxillary region is usually type III or IV, characterized by thin cortical bone and low density trabecular bone. Further, in many situations the bone height in this region is insufficient for proper implant placement because of the presence of the maxillary sinus. These factors are detrimental to the achievement of high primary stability. This region tends to show low success rates, not only due to inappropriate primary locking, but also because short implants may present unfavourable biomechanics. The rehabilitation of this
region is therefore a challenge to the dentist.17

Consequently, grafts utilizing the iliac crest have been the most commonly used to increase bone volume in this area. Grafts with Le Fort I osteotomy, bone grafts for sinus lifting, zygoma implants, and implants in the pterygoid region have also been suggested.18–20 However, many of these techniques have long operative times, are surgically complex, and may be physically demanding for the patient, especially the elderly. Furthermore, from an economic standpoint, such procedures may be too expensive for the patient and a burden on health care resources.21 They may also be impractical, such as for patients submitted to severe maxillary surgical resection due to a tumour or neoplasia.22,23

Implant placement in the maxillary tuberosity region, which is the most distal area in the maxillary alveolar process,24 posterior to the maxillary sinus,25 has been suggested as an alternative by many authors.21–23,25–30 In fact, bone tissue in the tuberosity region should be less dense than in other areas of the maxilla18; it is unclear whether very spongy bone quality provides predictable osseointegration.21 However, this alternative relies on the placement of these implants on an incline, without the use of bone grafts, with the implant placed posterior to the maxillary sinus and not invading it (as shown in Fig. 1).1,21,22,26,28,29

All procedures in the tuberosity region should be evaluated carefully, since the tuberosity region may not always be available or may have a low amount of bone available for implant placement. In this region, the bone is mainly types III and IV21,23,25 so firm primary stability should be obtained at the surgical stage.26 In addition, appropriate reverse planning is very important.

Another recommended technique for implant placement in the posterior maxilla is related to the use of a pterygoid implant.20,32 Pterygoid implant placement requires passing through the pillar of bone composed of the maxilla, pyramidal process of the palatine bone, and the pterygoid process of the sphenoid.12,20,26,32,33

Bidra and Huynh-Ba20 stated that implant placement in the pterygoid region involves the tuberosity region; however, implants placed in the tuberosity region are not necessarily fixed in the pterygoid plates. These two techniques have important anatomical differences (Table 1).20,21,23–26,32–35 A systematic review indicated a 92% survival rate (first year) for implants placed in the pterygoid region20; however, evidence-based reviews addressing implants placed in the tuberosity region are scarce.

Clinically, there is evidence that implants positioned in the tuberosity region show suitable outcomes in patients with atrophied jaws21,26–28,36 and in patients with severe maxillary defects.22 In addition, easy access and visibility of the site of the tuberosity26 facilitate the surgical procedure. However, little is known about the long-term results.

**Table 1.** The concept of implants placed in the tuberosity and in the pterygoid region.

<table>
<thead>
<tr>
<th>Points addressed</th>
<th>Tuberosity implant</th>
<th>Pterygoid implant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>Region most distal to the maxillary alveolar process.20,23 Bahat17 indicated that the real posterior structure of the maxillary tuberosity is the pyramidal process of the palatine bone.25 Therefore, these implants may involve the pyramidal process of the palatine bone.20 Finally, Venturelli23 stated that the posterior border of the maxillary tuberosity is defined by the pyramidal process of the palatal bone and the anterior–inferior surface of the pterygoid laminae of the lamellae.</td>
<td>This implant passes through a pillar of bone composed of the maxilla, pyramidal process of the palatine bone, and the pterygoid process of the sphenoid.32–33 Furthermore, it is conceived as implant insertion through the maxillary tuberosity and pterygoid Plate.20,24 Vrielink et al.21 stated that &quot;The pterygoid implant enters in the region of the former second molar, follows an intrasinus trajectory in a dorsal and mesio-cranial direction, where it subsequently perforates the posterior sinus wall and the pterygoid plates&quot;. The pyramidal process of the palatine bone and the pterygoid process of the sphenoid are dense cortical bone.20,23,25</td>
</tr>
<tr>
<td><strong>Bone type</strong></td>
<td>Bahat23 stated that the bone in this area is very cancellous. Different bone types have been reported: III and IV21,23,25,34 II, III, and IV21,23</td>
<td>Internal maxillary artery, posterior or superior alveolar nerve, pterygoid muscles,32 infra-temporal fossa, pterygopalatine fossa, nasopharynx, and sphenoid sinus.20</td>
</tr>
<tr>
<td><strong>Vital structures</strong></td>
<td>The posterior wall of the maxillary sinus20,21 Ridell et al.21 stated that: &quot;Attention must be paid to the region posteriorly and medially to the tuberosity considering the maxillary artery and its branches specifically the greater palatine artery&quot;.</td>
<td></td>
</tr>
<tr>
<td><strong>Angulation of implants</strong></td>
<td>10–20°,17,23 &lt;30°,23 and 15–35°26</td>
<td>45–50° angulations32</td>
</tr>
</tbody>
</table>

*Adapted from Bidra and Huynh-Ba.20*
Therefore, the aim of this systematic review was to analyze relevant clinical studies on implants placed in the tuberosity region of the maxilla regarding the survival rate and recommendations for this technique. The following hypothesis was tested: the survival rate of dental implants placed in the tuberosity region of the maxilla is similar to that for other regions of the maxilla.

Materials and methods

Procedure

This systematic review was executed in accordance with the PRISMA statement and followed models proposed in the literature. The selection of articles was done individually by two of the authors (LFTP/AL and VFS), and there was no disagreement in the selection of articles.

Search strategy

A search for relevant studies published in the English language was conducted using the following databases: PubMed/MEDLINE, Embase, ScienceDirect, and the Cochrane Library. The period covered was 1967 to 23 March 2014. Two pairs of keywords were employed in the search: ‘dental implants’ AND ‘maxillary tuberosity’ and ‘dental implants’ AND ‘maxillary tuber’. The studies were selected by title and abstract and according to the inclusion and exclusion criteria. The full-text articles were evaluated by readers using a pilot text form. There was no discord in the selection of articles made by the independent researchers (kappa = 1). The preparation and discussion of data were performed by JFSJR, SRP, and EPP. In addition, a manual search was conducted during the period February 2013 to 23 March 2014 in the following periodicals: Journal of Periodontology, Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, International Journal of Oral & Maxillofacial Surgery, The Journal of Prosthetic Dentistry, Journal of Prosthodontics, International Journal of Oral & Maxillofacial Implants, and Journal of Craniofacial Surgery. The authors of the articles were not contacted.

Study selection

Clinical studies were chosen based on their titles and abstracts. Prospective and retrospective studies were included. The selected studies reported the clinical monitoring of implants placed in the maxillary tuberosity region. Furthermore, in accordance with the PRISMA statement, participants, interventions, comparisons, and outcomes (PICO) were determined to organize a specific clinical question. ‘Participants’ were patients who had been rehabilitated with dental implants in the posterior maxilla. The ‘intervention’ was dental implants placed in the maxillary tuberosity region (without considering implant placement in the pterygoïd plate – Table 1). ‘Comparisons’ were dental implants placed in other maxillary regions. The ‘outcomes’ studied were the survival rate and recommendations for the effective use of this technique.

Inclusion/exclusion criteria

Inclusion criteria for the studies were as follows: English language; studies reporting clinical series of dental implants installed in the maxillary tuberosity region; minimum of five patients. Moreover, retrospective and prospective studies were included. Implants installed in the tuberosity region were defined as follows: implants involving the most distal aspect of the maxillary alveolar process, behind the maxillary sinus; occasionally engaging the pyramidal process of the palatine bone and located between the posterior–inferior surface of the maxillary bone and the anterior–inferior surface of the pterygoïd laminae of the sphenoid bone

Exclusion criteria were the following: duplicated studies, animal studies, cadaver studies, computer simulation and biomechanical studies, in vitro studies, mini-implants, orthodontic studies, morphometric studies, studies analyzing the maxillary tuberosity as a bone graft donor site, anatomical and radiological studies, clinical studies of implants on humans involving the ‘pterygoïd’ and ‘pterygomaxillary’ regions, clinical cases with small sample sizes (fewer than five patients), clinical monitoring for less than 6 months, theoretical studies, implants not placed in the region of the maxillary tuberosity, and missing data. Systematic reviews were also excluded.

Reliability and quality assessment

A group of researchers conducted the development of this systematic review. The studies were analyzed systematically in order to identify possible biases in the results and conclusions. The studies were classified by category: prospective or retrospective. The assessment of the quality of the methodology was conducted following the requirements of the PRISMA statement. The studies were classified into different levels of evidence. The National Health and Medical Research Council (NHMRC, Australia) hierarchy of evidence was utilized to assess the reliability and quality of the selected studies.

Data analysis

The following data were identified for each article: first author, year, study type, level of evidence, number of patients, number of implants, number of implants in the tuberosity region, implant geometry (length/width), implant placement in other maxillary regions, follow-up, the survival rate in the tuberosity and other regions, and marginal bone resorption in the tuberosity bone and other maxillary regions. Furthermore, qualitative data were analyzed for each article: mean age, imaging examinations, bone quality, implant manufacturer, type of edentulous arch, osseointegration period, and type of prosthesis and opposite arch. The data collected were organized for qualitative and quantitative analysis.

Data synthesis

The studies collected were compared extensively (n = 5). The data were summarized for qualitative and quantitative analysis. The survival rates of implants placed in the tuberosity and other regions were calculated. Failure and survival data were analyzed using tables and graphs. The failure rate was determined as the percentage of implants lost relative to the number of implants inserted for each study. Failures included implants removed regardless of the osseointegration period. Survival represented stable implants without signs of pathology, mobility, resistance to removal torque, pain, or peri-implantitis.

Results

General outcomes

The electronic search of the four databases identified 310 articles. After an analysis of the titles according to the inclusion and exclusion criteria and the elimination of duplicate references, 25 full-text articles were assessed for eligibility. Finally, five studies were included in the qualitative and quantitative synthesis.

Twenty five-texts were excluded for the following reasons: clinical case studies, biomechanical study, orthodontic study, data not localized, morphometric study, in vitro
study, and implants not placed in the region of the tuberosity or missing data. Since there are few studies addressing the topic, relevant excluded clinical studies are summarized in Table 2. These studies indicate a high predictability of implants placed in the tuberosity region; the survival rate was 100%.

The inter-reviewer agreement for all studies (kappa = 1.0) and the abstract (kappa = 1.0) indicated no disagreement. The five studies included in this systematic review were published from 1992 to 2010. Tables 3 and 4 summarize the main data collected in the systematic review.

Qualitative analyses

The selected studies were classified as retrospective and prospective. Non-randomized studies were located in the sample. The levels of evidence for these studies were III-2 and III-3. A total of 113 patients were followed for a period of 6–144 months (mean 52.08 months) (Table 3). The mean age of patients was 55.1 years. All studies presented elderly patients in the sample (Table 4).

A total of 289 implants were placed in the patients evaluated (Table 3); 149 implants were placed in the region of the tuberosity and 140 implants were installed in other regions of the maxilla. The studies predominantly indicated the placement of long implants in the region of the tuberosity.

An important surgical detail observed was the need for angulations of the implants placed in the tuberosity region. However, this inclination was reduced as much as possible. The degrees of angulation were variable: 10–20°, <30°, and 15–35°.

In relation to the diameter, only three studies detailed the use of implants with a regular diameter (3.75–4 mm). Venturelli emphasized that when minimal instability in dental implants was observed during the surgical procedure, the implant was removed (3.75 mm) and replaced immediately with a larger diameter implant (4 mm) without any new drilling.

The region of the tuberosity was categorized predominantly as bone type III and IV. Adequate primary stability of the implants was indicated as an important condition. The minimum period of osseointegration was 4 months.

In relation to the type of prostheses, there was a prevalence of fixed prostheses, one study suggested the use of a reinforced acrylic resin provisional restoration initially (6 months), and after this, fixed partial dentures were made for the patients. The rehabilitation treatment was acceptable to the patients. Krämer et al. reported that the prosthesis could equalize soft tissue and bony defects, resulting in an aesthetically and functionally satisfactory restoration. Riddell et al. asserted that there were no reported complications with the prostheses, no problems related to the components of the implant system, and no inflammatory reactions of the oral soft tissues; other studies did not provide specific information.

Regarding the opposite arch, there was a prevalence of natural teeth and fixed prostheses. Venturelli indicated that no significant difference was related to the type of opposing arch. However, the authors showed that no direct contact was allowed between the distal implant and the opposing arch.

None of the studies analyzed reported implant mobility, a radiolucent area at the implant apex, or prosthetic mobility. The marginal bone loss of implants placed in the maxillary tuberosity remained within acceptable limits. All data above are given in Tables 2 and 3.

Quantitative analyses

A total of 289 dental implants were placed in the 113 patients, and the mean follow-up was 52.08 months (range 6–144 months). From this sample, a total of 149 implants were placed in the tuberosity region and 140 implants were placed in other regions of the maxilla. There were eight failures/losses of dental implants in the tuberosity region and the survival rate was 94.63% (Fig. 3 and Table 5). The lowest interval survival rate was 97.26% due to the loss of four implants during the third period (12–24 months) (Table 5). The main factor related to the failure/loss of these dental implants was a lack of osseointegration (three implants); Krämer et al. related that the reason for these failures was penetration of the maxillary sinus during implantation. In the study of Bahat,
Table 2. Clinical cases of implant placement in the maxillary tuberosity: excluded studies.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Number of patients</th>
<th>Number of implants in the tuberosity region</th>
<th>Number of implants in the tuberosity region (mm)</th>
<th>Length of the implants in the maxillary tuberosity region (mm)</th>
<th>Width of the implants in the maxillary tuberosity region (mm)</th>
<th>Implants in other regions (maxilla)</th>
<th>Length of the implants in other regions (mm)</th>
<th>Width of the implants in other regions (mm)</th>
<th>Follow-up (months)</th>
<th>Survival rate in the tuberosity/other regions (number of failures)</th>
<th>Marginal bone resorption in tuberosity implant/other regions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shirota et al.29</td>
<td>2011</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>4.0</td>
<td>4</td>
<td>35; 40a</td>
<td>Not reported</td>
<td>24</td>
<td>100%</td>
<td>Zygomatic implants showed a marginal bone loss of 3 to 4 threads. Two conventional implants demonstrated a marginal bone shift of one thread or less.</td>
<td></td>
</tr>
<tr>
<td>Leles et al.22</td>
<td>2010</td>
<td>1</td>
<td>2</td>
<td>11; 13</td>
<td>3.75</td>
<td>3</td>
<td>9; 11; 13</td>
<td>3.75</td>
<td>24</td>
<td>100%/66.6% (1)</td>
<td>No radiographic signs of significant bone loss around implants</td>
<td>Follow-up appointment showed acceptable bone levels.</td>
</tr>
<tr>
<td>Alves and Neves28</td>
<td>2009</td>
<td>1</td>
<td>2</td>
<td>14</td>
<td>4.1; 4.8</td>
<td>6</td>
<td>12</td>
<td>4.1</td>
<td>36</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Markt41</td>
<td>2003</td>
<td>1</td>
<td>4</td>
<td>10; 13</td>
<td>3.75</td>
<td>2</td>
<td>–</td>
<td>–</td>
<td>18</td>
<td>50%</td>
<td>Follow-up appointment showed acceptable bone levels. None reported. The patient has worn the prostheses without complications for 18 months</td>
<td></td>
</tr>
<tr>
<td>Nocini et al.36</td>
<td>2000</td>
<td>1</td>
<td>2</td>
<td>–</td>
<td>–</td>
<td>6</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>100%</td>
<td>Follow-up appointment showed acceptable bone levels. Radiographic evaluation was obtained pre- and post-implant placement</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Data summary for the five studies selected reporting dental implants inserted in the tuberosity region.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Study type</th>
<th>Level of evidence</th>
<th>Number of patients</th>
<th>Number of implants in the tuberosity region</th>
<th>Number of implants in other regions (maxilla)</th>
<th>Length/width of the implants in other regions (mm)</th>
<th>Follow-up in months, mean (range)</th>
<th>Survival rate tuberculosis/other regions (number of failures)</th>
<th>Marginal bone resorption in tuberosity region/other regions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Park and Cho26</td>
<td>2010</td>
<td>Retrospective</td>
<td>III-2</td>
<td>7</td>
<td>17</td>
<td>7</td>
<td>11.5–15.0/3.75–4</td>
<td>84 (12–84)</td>
<td>100%</td>
<td>0.93</td>
</tr>
<tr>
<td>Ridell et al.21</td>
<td>2009</td>
<td>Retrospective</td>
<td>III-2</td>
<td>20a</td>
<td>86</td>
<td>22</td>
<td>13.0–20/3.75–4</td>
<td>96 (12–144)</td>
<td>100%/96.87% (2)</td>
<td>1.6/1.9</td>
</tr>
<tr>
<td>Venturelli25</td>
<td>1996</td>
<td>Prospective</td>
<td>III-2</td>
<td>29</td>
<td>42</td>
<td>29</td>
<td>10–20/3.75–4</td>
<td>40 (36–48)</td>
<td>100%/92.3% (1)</td>
<td>Not reported</td>
</tr>
<tr>
<td>Bahat23</td>
<td>1992</td>
<td>Prospective</td>
<td>III-3</td>
<td>45</td>
<td>72</td>
<td>72</td>
<td>Not reported</td>
<td>21.4</td>
<td>93% (5)</td>
<td>Not reported</td>
</tr>
<tr>
<td>Krämer et al.27</td>
<td>1992</td>
<td>Prospective</td>
<td>III-2</td>
<td>11</td>
<td>72b</td>
<td>19b</td>
<td>Not reported</td>
<td>19 (6–60)</td>
<td>84.21% (3)/92.45% (4)</td>
<td>2.4 (M)/2.5 (D)</td>
</tr>
</tbody>
</table>

M, mesial; D, distal.

*One patient died (initial sample = 21).†The study began with 66 implants, but after an initial loss of six implants (three in the tuberosity region and three in other regions), there was further surgery for implant placement (according to Table 1 of the article).
Table 4. Qualitative data from the five studies selected reporting dental implants inserted in the tuberosity region.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Patient age, mean (range)</th>
<th>Imaging examinations</th>
<th>Bone quality</th>
<th>Implant manufacturer</th>
<th>Edentulous arch (partially/fully)</th>
<th>Primary locking</th>
<th>Osseointegration period (months)</th>
<th>Type of prosthesis</th>
<th>Opposite arch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Park and Cho</td>
<td>2010</td>
<td>52.3 (43–65)</td>
<td>Digital panoramic</td>
<td>Not reported</td>
<td>CSM</td>
<td>Partially</td>
<td>25–40 N cm</td>
<td>6</td>
<td>Porcelain fused NiCr alloy fixed bridge</td>
<td>Not specified</td>
</tr>
<tr>
<td>Ridell et al.</td>
<td>2009</td>
<td>63 (42–79)</td>
<td>Panoramic, peri-apical, conventional tomography scans</td>
<td>III and IV</td>
<td>Nobel Biocare, Branemark</td>
<td>Partially and fully</td>
<td>Adequate primary stability</td>
<td>6–8</td>
<td>Screwed prosthesis</td>
<td>Teeth (11), fixed prosthesis (2), lacked occlusion (8)</td>
</tr>
<tr>
<td>Venturelli</td>
<td>1996</td>
<td>50 (38–62)</td>
<td>Not specified</td>
<td>III (12) and IV (16)</td>
<td>Implant Innovations</td>
<td>Partially</td>
<td>Adequate primary stability</td>
<td>6–8</td>
<td>Reinforced acrylic resin provisional restoration; fixed partial denture</td>
<td>Teeth (7), fixed partial dentures (gold occlusal surfaces) (4), fixed partial dentures (ceramic occlusal surfaces) (8), removable partial denture (10)</td>
</tr>
<tr>
<td>Bahat</td>
<td>1992</td>
<td>All &gt;80</td>
<td>Serial parallel radiographs</td>
<td>II (9), III (35), and IV (28)</td>
<td>Nobel Biocare, Branemark</td>
<td>Partially and fully</td>
<td>Not reported</td>
<td>Not reported</td>
<td>Metal-ceramic (29); O-ring</td>
<td>Natural teeth (2), fixed partial denture (39), fixed plus implant (4)</td>
</tr>
<tr>
<td>Krämer et al.</td>
<td>1992</td>
<td>47–68</td>
<td>Not specified</td>
<td>Not reported</td>
<td>Cylindrical IMZ type</td>
<td>Not reported</td>
<td>6–60</td>
<td>Removable partial denture</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Le Gales and Zarb classification.  
b No statistical difference.

Discussion

The survival rate of implants installed in the tuberosity region was high (94.63%). These results are consistent with those reported in other studies (Table 3). There are two main considerations that have influenced the outcomes in the tuberosity region. First, the prevalence of marginal bone loss (9%) in the maxilla and mandible regions (9%) is lower than those reported for implants in other regions of the maxilla and mandible (2.45 mm) during 12 months of follow-up (Table 3).

Regarding marginal bone resorption, two studies did not report these data. Finally, Kämmer et al. [17] showed marginal bone loss of less than 2 mm during 12–14 months of follow-up. Furthermore, four implants in patients with parotid gland tumors were placed in the tuberosity region, with one implant failure (5.88%). Therefore, the prevalence of implant failure is higher in the tuberosity region (6.3%).

Figure 4 shows the number of implants placed in the tuberosity region and the number of failures. The cumulative survival rate for implants placed in the tuberosity region was 96.1% (Fig. 5). Therefore, these data indicate that implants placed in the tuberosity region may be suitable for oral rehabilitation.
trials (RCT) were included. The literature indicates that certain clinical questions in implant dentistry cause difficulty in the development of well-designed studies, for example, type of treatment and limited choice of randomization. However, these systematic reviews can provide a contemporary view of the topic studied, in addition to assisting in the synthesis of data and performance of the treatment utilized. Furthermore, these studies indicate deficiencies in certain areas of implantology and can therefore direct the execution of new well-designed clinical trials.

The inclusion criteria for this systematic review were organized in order to obtain the maximum number of studies. Four databases were searched by independent researchers. Moreover, a manual search was done. The excluded clinical cases are presented in Table 2, adding further information for the reader, since few studies were included in the qualitative and quantitative analyses (n = 5).

The technique of implant placement in the maxillary tuberosity region follows the same basic principles as the installing of conventional implants, through milling or by using bone condensation through osteotomies. All studies presented a high success rate, reaching an average of 100% in three studies.21,25,26 The mean follow-up was 52.08 months, ranging from 12 months21,26 to 12 years.21 showing that this technique was viable in all studies.21,23,25–27

This technique is a conservative choice for restorations in the posterior maxilla with large bone loss, since it does not require the bone grafting usually necessary in the upper molar region, an area with maxillary sinus pneumatization and high bone resorption. Despite the great advantages offered by cone beam computed tomography (CBCT), which is gaining headway in modern dentistry, implant placement in the maxillary tuberosity is a technique that can be performed with panoramic and peri-apical radiographs22,26; however, we encourage the use of CT scans to improve reverse planning.21,26,29

Rigorous planning for implant placement in this tuberosity region is highly relevant, and adequate bone mapping should be considered. CBCT should be used whenever possible.23,30 Moreover, a radiopaque marker placed on a surgical guide or provisional acrylic resin guide at the level of the edentulous ridge will help locate the implantation site.23

Although this region is considered a treatment option, other regions are available for the placement of endosseous implants as an alternative: implants may be placed in blocks of autogenous bone grafts in other areas, as well as the floor of the maxillary sinus, or implants may be placed in the zygomatic and pterygoid regions.18,20,21 Finally, the bone tissue must be evaluated mesiodistally and buccolingually to determine if it can accommodate an implant. Bone defects in the buccal and lingual aspects of the tissue may result in dehiscence and fenestration defects around an implant, increasing the probability of failure.23

The studies included in this review reported a period of osseointegration ranging from 4 to 8 months (Table 4), probably

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**Table 5.** Life-table survival analysis showing the cumulative survival rate of tuberosity implants for the five selected studies.

<table>
<thead>
<tr>
<th>Follow-up intervals of the study, months</th>
<th>Number of implants in each interval in the tuberosity region</th>
<th>Number of failures in each interval in the tuberosity region</th>
<th>Survival rate within each interval (%)</th>
<th>Cumulative survival rate (%)</th>
</tr>
</thead>
<tbody>
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<td>0–6</td>
<td>149</td>
<td>3</td>
<td>97.98</td>
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<td>12–24</td>
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<td>24–36</td>
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<td>36–48</td>
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</tr>
<tr>
<td>48–60</td>
<td>141</td>
<td>0</td>
<td>100</td>
<td>94.63</td>
</tr>
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</table>
due to poor bone quality in the area, which would hinder the primary locking and osseointegration. However, Alves and Neves, in a case report study, indicated immediate loading for tapered implant placement in the maxillary tuberosity but emphasized that more studies should be done to confirm this technique.

Although there was great divergence among the types of opposing dentition presented by the patients in the studies, Ridell et al. stated that 75% of dentate patients presented natural dentition in their opposing arch, which does not attenuate the masticatory forces as for removable prostheses, demonstrating that this technique would also be viable under these conditions. On the other hand, Ventura suggested that no direct contact was permitted between the distal implant and the opposing arch. Thus, it is important to emphasize that adequate planning should be done in relation to the opposite arch for implants placed in the tuberosity region, presenting fixed prostheses with a larger extent.

Unlike other authors, Shirot et al. and Leles et al. in case reports (Table 2), used the technique of implants placed in the maxillary tuberosity associated with other implants for the rehabilitation of patients with severe bone loss caused by tumours; this does not exhibit the best conditions for prosthetic rehabilitation, thus showing the effectiveness of this technique in rehabilitating such patients satisfactorily, both aesthetically and functionally.

In cases of partial fixed prostheses, the splitting of these implants placed in the maxillary tuberosity with another implant installed in the area of the first molar was often reported. Thus this treatment option is suggested for rehabilitating first and second molars adding the third molar along the prosthesis (implant in tuberosity), instead of installing only one implant in the first molar area and rehabilitating the second in a cantilever situation due to the lack of bone tissue for installing an implant in that region; this would generate a lever arm and might even result in failure of the prosthesis over the medium term.

Surgery for the placement of implants in the region of the tuberosity should be performed by experienced surgeons. Moreover, knowledge of the anatomy of the posterior maxilla is essential to the success of this technique, in particular knowledge of the region posterior and medial to the tuberosity, with special consideration given to the maxillary artery and its branches, specifically the greater palatine artery (as shown in Table 1). Thus, Ridell et al. suggest that a possible technique is the preparation of an inspection window in the maxillary sinus to further ensure correct fixture placement.

Studies have indicated the prevalence of types III and IV bone in the tuberosity region. This warrants the use of a more favourable geometry for a primary lock. Furthermore, an appropriate surface treatment is relevant for implants placed in bone of low density. In this regard, the studies did not provide a detailed analysis of the surface type used in these implants. Ridell et al. used turned Bränemark implants and no failures were reported. However, a strict protocol was adopted; the authors used adequate primary stability, careful management of bone tissue, and a minimum length of 13 mm for implants, and finally all implants were fully submerged and allowed to osseointegrate unloaded for 6–8 months. On the other hand, Nocini et al. in a case report, stated that corticalization of an implant with suitable surface treatment reduces the need for bicortical anchorage in the pterygoid processes, thus reducing the risk of tuberosity fracture. Longitudinal clinical studies should be performed in order to analyze the geometry and surface treatment of implants for the posterior maxillary region.

Reverse planning should be utilized in surgery for the placement of an implant in

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**Table 6. Summary of the main points covered for implants placed in the bone of the tuberosity.**

<table>
<thead>
<tr>
<th>Phases</th>
<th>Pre-surgical planning</th>
<th>Surgical planning</th>
<th>Post-surgery planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgery</td>
<td>Correction of pathoses and periodontal lesions</td>
<td>Internally irrigated drills</td>
<td>Enough healing time for maturation of host bone (6–8 months)</td>
</tr>
<tr>
<td></td>
<td>Radiography and CBCT</td>
<td>Reduced speed of instrument</td>
<td>Possible surgery in mucosal tissue</td>
</tr>
<tr>
<td></td>
<td>Detailed study of anatomy/potential site</td>
<td>Minimal use of countersinking</td>
<td>Prevent non-axial loading</td>
</tr>
<tr>
<td></td>
<td>App. 35 mm opening: site/ opposing teeth</td>
<td>Bone compaction, modified osteotomies</td>
<td>Occlusal scheme, avoid overloading</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Achievement of bicortical fixation</td>
<td>Occlusion and oral hygiene periodically</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drilling sequence to maximize stabilization</td>
<td>Access to the posterior oral cavity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum primary stability</td>
<td>Careful manipulation of instruments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Implant diameter larger and length longer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Favourable geometry of implant</td>
<td></td>
</tr>
<tr>
<td>Prosthesis</td>
<td>Opposing arch/load</td>
<td>Elimination of occlusal loading in osseointegration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Parafunction must be controlled</td>
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</tr>
<tr>
<td></td>
<td>Space availability for the implant and crown</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quality and dimensions of the soft tissues</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CBCT, cone beam computed tomography.
the tuberosity region. The angulation of the implant is a factor that increases the stress concentration in bone tissue. In addition, Krämer et al. stated that because of the divergent positions of the implants, it was sometimes necessary to divide the bar in the anterior region with an attachment.

Data related to the extension of the prosthesis are of relevance. The studies included in the sample predominantly showed partially edentulous patients, or partially and fully edentulous patients. In relation to the quality of evidence, studies showed a low level of evidence (Table 3). No attempt was made to blind or mask the process used for the elaboration of these studies. Measurements of bone loss were incomplete or were not reported. Two studies involved a small sample of patients ($n \leq 12$). Thus, more well-designed studies should be conducted to elucidate possible biases.

Finally, in an analysis of all studies, it was observed that these implants showed bone loss within acceptable limits, which is further evidence of the high success rate of this technique. In conclusion, implants placed in the maxillary tuberosity are a predictable alternative for the treatment of patients with insufficient bone volume in the maxillary region. However, randomized trials are needed to assess the effectiveness of this treatment.

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Patient consent
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References

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