Survival and failure rates of orthodontic temporary anchorage devices: a systematic review

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Key words: failure, human, skeletal anchorage, survival, systematic review

Abstract

Aim: The purpose of this study was to systematically review the literature on the survival rates of palatal implants, Onplants®, miniplates and mini screws.

Material and methods: An electronic MEDLINE search supplemented by manual searching was conducted to identify randomized clinical trials, prospective and retrospective cohort studies on palatal implants, Onplants®, miniplates and miniscrews with a mean follow-up time of at least 12 weeks and of at least 10 units per modality having been examined clinically at a follow-up visit. Assessment of studies and data abstraction was performed independently by two reviewers. Reported failures of used devices were analyzed using random-effects Poisson regression models to obtain summary estimates and 95% confidence intervals (CI) of failure and survival proportions.

Results: The search up to January 2009 provided 390 titles and 71 abstracts with full-text analysis of 34 articles, yielding 27 studies that met the inclusion criteria. In meta-analysis, the failure rate for Onplants® was 17.2% (95% CI: 5.9–35.8%), 10.5% for palatal implants (95% CI: 6.1–18.1%), 16.4% for miniscrews (95% CI: 13.4–20.1%) and 7.3% for miniplates (95% CI: 5.4–9.9%). Miniplates and palatal implants, representing torque-resisting temporary anchorage devices (TADs), when grouped together, showed a 1.92-fold (95% CI: 1.06–2.78) lower clinical failure rate than miniscrews.

Conclusion: Based on the available evidence in the literature, palatal implants and miniplates showed comparable survival rates of ≥90% over a period of at least 12 weeks, and yielded superior survival than miniscrews. Palatal implants and miniplates for temporary anchorage provide reliable absolute orthodontic anchorage. If the intended orthodontic treatment would require multiple miniscrew placement to provide adequate anchorage, the reliability of such systems is questionable. For patients who are undergoing extensive orthodontic treatment, force vectors may need to be varied or the roots of the teeth to be moved may need to slide past the anchors. In this context, palatal implants or miniplates should be the TADs of choice.

Anchorage is one of the limiting factors in orthodontics, and its control is essential for successful treatment outcomes. The term ‘orthodontic anchorage’ denotes the nature and degree of resistance to displacement offered by an anatomic unit. According to the intended treatment goals, desired tooth movements should, therefore, be maximized, and undesirable effects should be minimized. Traditionally, orthodontic therapy used teeth, extraoral and/or intermaxillary appliances for anchorage. Since a patient’s cooperation is not always optimal (Nanda & Kierl 1992), temporary anchorage...
Deviation devices (TAD) [Daskalogiannakis 2000] have been introduced. TADs are anchored in bone and removed after completion of the intended orthodontic tooth movement. They are designed to overcome the limitations of conventional orthodontic anchorage devices (COADs). Anchorage by means of TADs allows independence in relation to patient compliance [Creekmore & Eklund 1983] either by supporting the teeth of the reactive unit or by obviating the need for a reactive at large.

Usually, orthodontic patients present a complete dentition or with extraction sites to be closed. No edentulous alveolar bone ridges are generally available for the insertion of TADs. As a consequence, these must be placed in topographical regions distant to the main area of action.

New additional insertion sites have been offered by the introduction of length-reduced mid-palatal orthodontic anchorage devices such as titanium flat screws [Triaca et al. 1992], resorbable orthodontic implant anchors [Glatzmaier et al. 1995], T-shaped orthodontic implants [Wehrbein et al. 1996] [Orthosystem®, Institut Straumann, Waldenburg, Switzerland] and the Graz implant-supported pendulum [Bylof et al. 2000]. Diameter-reduced temporary orthodontic anchorage devices such as miniscrews (<2 mm) in various lengths [Kanomi 1997; Costa et al. 1998] and titanium pins [Bousquet et al. 1996] are inserted into the alveolar bone and L-shaped miniplates with the long arm exposed into the oral cavity [Umemori et al. 1999], and bollard anchors [De Clerck et al. 2002] are fixed by bone screws in supra-apical regions. Another device, the Onplant® [Nobel Biocare, Zurich, Switzerland] [Block & Hoffman 1995], placed subperiostially, was supposed to adhere to bone.

Having used these TADs for more than a decade, numerous case reports and scientific papers have been published documenting the clinical feasibility of the TADs mentioned. In contrast to prosthetic oral implants, the literature exploring the survival and failure rates of orthodontic TADs has not been evaluated systematically.

Therefore, the aim of the present systematic review was to determine the survival and failure rates of palatal implants, mini screws, miniplates and onplants. The focused question to be answered was: ‘What are the survival and failure rates of the orthodontic TADs after a functional period of at least 12 weeks?’

**Material and methods**


Manual searches of the bibliographies of all full-text articles and related reviews, selected from the electronic search, were additionally performed. Furthermore, the following journals were searched manually for the years 2004 to January 2009: *Clinical Oral Implants Research*, *European Journal of Orthodontics*, *American Journal of Orthodontics and Dentofacial Orthopedics, Angle Orthodontist, Journal of Clinical Orthodontics, Journal of Orofacial Orthopedics, Journal of Adult Orthodontics and Orthognathic Surgery and International Journal of Oral and Maxillofacial Implants*.

From these searches, it was obvious that there were no randomized-controlled clinical trials (RCTs) available comparing all the different types of TADs. However, there were two RCTs comparing TADs [Onplants® and palatal implants] with compliance-dependent COADs [Feldmann & Bondemark 2008; Sandler et al. 2008] and one RCT comparing two different miniscrew types [Wiechmann et al. 2007].

**Inclusion criteria**

In the absence of RCTs comparing all different types of TADs with each other, this systematic review was based on the few [three] available RCTs with limited impact and all prospective or retrospective cohort studies. The additional inclusion criteria for study selection were:

- mean TAD loading time of at least 12 weeks;
- publications reported in English;
- included patients had been examined clinically at the follow-up visit, i.e. publications based on patient records only, on questionnaires or interviews were excluded;
- reported details on the screw types used.

**Selection of studies**

Fig. 1 describes the search strategy used to identify relevant studies selected for this review. Titles and abstracts of the Medline searches were initially screened by two independent reviewers (R.M. and M.S.) for possible inclusion. From a yield of 390 titles, 71 were selected for abstract screening (Fig. 1). The agreement between the reviewers using k-statistics was 96.2%. The full text of all studies of possible relevance [34] was then obtained for independent assessment by the two reviewers. Any disagreement was resolved by discussion.

Data were extracted independently by the same two reviewers using a data extraction form.

**Excluded studies**

Of the 34-full-text articles retrieved, seven were excluded from the final analysis. The main reasons for exclusion were a mean observation period of <12 weeks, loading time was not clearly indicated, less than 10 units per modality in the study and multiple publication of the same cohort in different scientific journals at different time points.

**Data extraction**

Information on the proportions of biological and technical complications was retrieved on the 27 studies included. Biological complications included disturbances in the function of the skeletal anchorage device leading to any early removal of the anchorage device before the end of the intended orthodontic treatment or observation period. Healing or incorporation failures were also included in this category. Technical complications were not reported in any of the studies, and therefore could not be assessed separately.

From the 27 included studies, the number and percentage of failures was extracted. Disagreement regarding data extraction was resolved by consensus.

**Statistical analysis**

Failure rates were calculated by dividing the number of events [failures] after at least 12 weeks of orthodontic loading in the
numerator by the total number of each TAD type in the denominator. For further analysis, the total number of events was considered to be Poisson distributed for a given number of TADs, and Poisson regression with a logarithmic link function and total number of TADs per study as an offset variable was used. To assess the heterogeneity of the study-specific event rates, the Spearman goodness-of-fit statistics and associated $P$-value were calculated. If the goodness-of-fit $P$-value was below 0.05, indicating heterogeneity, random-effects Poisson regression (with $g$-distributed random effects) was used to obtain a summary estimate of the event rates. Summary failure rate estimates and 95% confidence intervals (CI) are reported.

To provide anchorage on either side of the maxilla, only one palatal implant or Onplant$^\text{a}$ was needed, whereas at least two fixtures have to be installed if miniplates or miniscrews are used.

To evaluate the possible failure of at least one out of two fixtures, it was assumed that failures of these objects may occur independently. The probability to remain free of failure was therefore calculated by multiplying the probability that each object remains free of failure: $\frac{1}{1 - \text{risk}_{\text{object1}}} \times \frac{1}{1 - \text{risk}_{\text{object2}}}$. Therefore, the probability of encountering at least one failure becomes $1 - \left( \frac{1}{1 - \text{risk}_{\text{object1}}} \times \frac{1}{1 - \text{risk}_{\text{object2}}} \right)$.

The 95% CI limits for survival proportions were calculated using the 95% confidence limits of the event rates. All analyses were performed using Stata, version 10.1 (Stata Corporation, College Station, TX, USA).

## Results

### Onplants

There was only one article fulfilling the inclusion criteria concerning Onplants$^\text{a}$ (Feldmann & Bondemark 2008). In this RCT, five out of 29 onplants or 17.2% (95% CI: 5.9–35.8%) failed (Table 1).

### Microscrews/Microimplants and Miniscrews/Minimplants

Seventeen studies provided data on the survival of 31 different types of miniscrews (Table 2). A total of 2374 miniscrews inserted in 1196 patients with a total of 363 or 15.3% failures could be analyzed (Table 2). Seven studies reported results of prospective cohort studies, whereas the remaining 10 assessed their results retrospectively. Data of only one RCT could be extracted comparing two different screw types (Wiechmann et al. 2007). However, due to the lack of precise data reporting in all these studies no conclusive statement of survival and/or the failure rate of a specific screw type (length and diameter) regarding their favorable indication, insertion location, insertion technique and type of loading could be made.

Some reports provided detailed data on the diameter and length of the inserted miniscrews, while others pooled the results of a specific miniscrew diameter with various lengths (Table 2). The mean follow-up

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**Table 1. Study and patient characteristics of the reviewed study of Onplants$^\text{a}$**

<table>
<thead>
<tr>
<th>Author</th>
<th>Kind of study</th>
<th>Type of TAD</th>
<th>Manufacturer</th>
<th>Diameter</th>
<th>Number of patients</th>
<th>Mean patient’s age (years)</th>
<th>Number of TADs</th>
<th>Number of failures</th>
<th>Percent of failures</th>
<th>Loading time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feldmann &amp; Bondemark (2008)</td>
<td>RCT</td>
<td>Onplant$^\text{a}$</td>
<td>Nobel Biocare$^\text{a}$</td>
<td>7.7 mm titanium disk</td>
<td>29</td>
<td>14 ± 1.53</td>
<td>29</td>
<td>5</td>
<td>17.2%</td>
<td>Completion of treatment</td>
</tr>
</tbody>
</table>

TAD, temporary anchorage devices; RCT, randomized controlled clinical trials.
Table 2. Study and patient characteristics of the reviewed studies of miniscrews/microscrews

<table>
<thead>
<tr>
<th>Author</th>
<th>Kind of study</th>
<th>Type of TAD</th>
<th>Manufacturer</th>
<th>Diameter (mm)</th>
<th>Length (mm)</th>
<th>Number of patients</th>
<th>Mean patient's age (years)</th>
<th>Number of TADs</th>
<th>Number of failures</th>
<th>Percent of failures</th>
<th>Loading time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen et al. (2008)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>Mondeal, Tuttlingen, Germany</td>
<td>2</td>
<td>8–14</td>
<td>194</td>
<td>25.1</td>
<td>57</td>
<td>14</td>
<td>24.6</td>
<td>Within 36 months</td>
</tr>
<tr>
<td>Chen et al. (2008)</td>
<td>Retrospective</td>
<td>Microscrew</td>
<td>Bioray, Taipel, Taiwan</td>
<td>2</td>
<td>5–21</td>
<td>194</td>
<td>25.1</td>
<td>264</td>
<td>25</td>
<td>9.6</td>
<td>Within 36 months</td>
</tr>
<tr>
<td>Chen et al. (2007)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>AbsoAnchor, Dentos, Daegu, Korea</td>
<td>1.2</td>
<td>4–10</td>
<td>129</td>
<td>24.5</td>
<td>72</td>
<td>17</td>
<td>6.5</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Chen et al. (2006)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>AbsoAnchor</td>
<td>1.2</td>
<td>6</td>
<td>29</td>
<td>29.8</td>
<td>18</td>
<td>4</td>
<td>9.8</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Chen et al. (2006)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>AbsoAnchor</td>
<td>1.2</td>
<td>8</td>
<td>29</td>
<td>29.8</td>
<td>41</td>
<td>4</td>
<td>9.8</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Cheng et al. (2004)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>Leibinger and Mondela, Mondeal Tuttlingen, Germany</td>
<td>2</td>
<td>9</td>
<td>44</td>
<td>29.8</td>
<td>21</td>
<td>2</td>
<td>6.5</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Cheng et al. (2004)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>Leibinger or Mondela</td>
<td>2</td>
<td>11</td>
<td>44</td>
<td>29.8</td>
<td>21</td>
<td>2</td>
<td>6.5</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Cheng et al. (2004)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>Leibinger or Mondela</td>
<td>2</td>
<td>13</td>
<td>44</td>
<td>29.8</td>
<td>21</td>
<td>2</td>
<td>6.5</td>
<td>Completion of treatment</td>
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<tr>
<td>Cheng et al. (2004)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>Leibinger or Mondela</td>
<td>2</td>
<td>15</td>
<td>44</td>
<td>29.8</td>
<td>21</td>
<td>2</td>
<td>6.5</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Cheng et al. (2004)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>Leibinger or Mondela</td>
<td>2</td>
<td>17</td>
<td>44</td>
<td>29.8</td>
<td>21</td>
<td>2</td>
<td>6.5</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Cheng et al. (2004)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>Leibinger or Mondela</td>
<td>2</td>
<td>19</td>
<td>44</td>
<td>29.8</td>
<td>21</td>
<td>2</td>
<td>6.5</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Park et al. (2006)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>Stryker/Leibinger, Leibinger, Mühlheim-Stelten, Germany</td>
<td>1.2</td>
<td>5</td>
<td>10</td>
<td>15.5</td>
<td>19</td>
<td>3</td>
<td>15.8</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Park et al. (2006)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>OstoMed, Addison, TX, USA</td>
<td>1.2</td>
<td>6–10</td>
<td>67</td>
<td>15.5</td>
<td>157</td>
<td>10</td>
<td>6.4</td>
<td>Completion of treatment</td>
</tr>
<tr>
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<td>Prospective</td>
<td>Miniscrew</td>
<td>AbsoAnchor</td>
<td>1.2</td>
<td>4, 6, 7, 8 or 10</td>
<td>16</td>
<td>15.5</td>
<td>46</td>
<td>5</td>
<td>10.9</td>
<td>Completion of treatment</td>
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<tr>
<td>Wiechmann et al. (2007)</td>
<td>RCT</td>
<td>Miniscrew</td>
<td>Dual Top, Jeil Medical, Seoul, Korea</td>
<td>1.6</td>
<td>5, 6, 7, 8 or 10</td>
<td>49</td>
<td>26.9</td>
<td>54</td>
<td>7</td>
<td>13</td>
<td>4 months</td>
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<tr>
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<td>RCT</td>
<td>Miniscrew</td>
<td>AbsoAnchor</td>
<td>1.1</td>
<td>5, 10, 8</td>
<td>49</td>
<td>26.9</td>
<td>24</td>
<td>7</td>
<td>9.4</td>
<td>9 months</td>
</tr>
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<td>Miniscrew</td>
<td>AbsoAnchor</td>
<td>1.3</td>
<td>6, 7, 8, 10 or 12</td>
<td>110</td>
<td>22.5</td>
<td>237</td>
<td>42</td>
<td>17.7</td>
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<td>Gebruder Martin GmbH, Tuttlingen, Germany</td>
<td>1.5</td>
<td>9</td>
<td>110</td>
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<td>25</td>
<td>4</td>
<td>16</td>
<td>12 months or completion of treatment</td>
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<td>Kuroda et al. (2007b)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>KeiSei Medical Ind., Tokyo, Japan</td>
<td>2 or 2.3</td>
<td>7 or 11</td>
<td>37</td>
<td>21.8</td>
<td>37</td>
<td>7</td>
<td>18.9</td>
<td>12 months or completion of treatment</td>
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<td>Miniscrew</td>
<td>AbsoAnchor</td>
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<td>6, 7, 8, 10 or 12</td>
<td>40</td>
<td>21.8</td>
<td>79</td>
<td>9</td>
<td>11.4</td>
<td>12 months or completion of treatment</td>
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<tr>
<td>Luzi et al. (2007)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>Ashus-Miniscrew, Medicon, Tuttlingen, Germany</td>
<td>1.5 or 2</td>
<td>9 or 11.6</td>
<td>98</td>
<td>34.3</td>
<td>140</td>
<td>13</td>
<td>9.3</td>
<td>12 months or completion of treatment</td>
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<tr>
<td>Motoyoshi et al. (2006)</td>
<td>Prospective</td>
<td>Miniscrew</td>
<td>Biodent, Biodent, Tokyo, Japan</td>
<td>1.6</td>
<td>8</td>
<td>21</td>
<td>21.4</td>
<td>20.3</td>
<td>34</td>
<td>19.5</td>
<td>Space closure</td>
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<td>Tseng et al. (2006)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>Stryker Leibinger</td>
<td>2</td>
<td>8</td>
<td>25</td>
<td>29.9</td>
<td>18</td>
<td>3</td>
<td>15.8</td>
<td>Completion of treatment</td>
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<td>Tseng et al. (2006)</td>
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<td>Miniscrew</td>
<td>Stryker Leibinger</td>
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<td>25</td>
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<td>15</td>
<td>3</td>
<td>15.8</td>
<td>Completion of treatment</td>
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<td>Stryker Leibinger</td>
<td>2</td>
<td>12</td>
<td>25</td>
<td>29.9</td>
<td>15</td>
<td>3</td>
<td>15.8</td>
<td>Completion of treatment</td>
</tr>
<tr>
<td>Miyawaki et al. (2003)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>Not specified</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>21.8</td>
<td>31</td>
<td>10</td>
<td>100</td>
<td>12 months or completion of treatment</td>
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<tr>
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<td>1.5</td>
<td>11</td>
<td>31</td>
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<td>101</td>
<td>16</td>
<td>15.8</td>
<td>12 months or completion of treatment</td>
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<tr>
<td>Miyawaki et al. (2003)</td>
<td>Retrospective</td>
<td>Miniscrew</td>
<td>Not specified</td>
<td>1.5</td>
<td>14</td>
<td>10</td>
<td>21.8</td>
<td>78</td>
<td>12</td>
<td>15.8</td>
<td>12 months or completion of treatment</td>
</tr>
</tbody>
</table>

TAD, temporary anchorage devices; RCT, randomized controlled clinical trials.
time ranged between 120 days and more than 1 year or completion of the intended orthodontic treatment.

By meta-analysis, the failure rate [Fig. 2] was estimated at 16.4% (95% CI 13.4–20.1%). By analyzing the influence of screw length and diameter, only the data of screws with detailed characteristics were considered. Three groups of diameter were created, which basically separate these three ‘clouds’ of diameter and length types [Fig. 3]. The miniscrews with a diameter of 2 mm or more showed a significantly 1.8-fold lower risk (95% CI: 1.1–3) of failing than miniscrews of a diameter of 1.2 mm or less.

**Palatal implants**

One retrospective and five prospective cohort studies provided data fulfilling the inclusion criteria on the survival and failure rate of palatal implants [Table 3]. Two out of these were RCTs comparing palatal implants with conventional compliance-dependent orthodontic anchorage (CDOA) [Sandler et al. 2008] only or with CDOA and Onplants® [Feldmann & Bondemark 2008]. However, only one report evaluated the clinical outcome of a larger number of palatal implants [Männchen & Schätzle 2008]. Data of a total of 190 palatal implants with a follow-up time of at least 12 weeks up to more than 22 months or completion of the intended orthodontic treatment could be assessed. Nineteen or 10% out of 190 palatal implants did not provide sufficient anchorage and were lost early or before the time point of evaluation. In meta-analysis, the failure rate for the whole group of studies was estimated at 10.5% (95% CI: 6.1–18.1%) [Fig. 4].

**Miniscrews**

Seven studies out of the 27 included reports provided data on the survival and failure rates of miniscrews [Table 4]. Two were prospective cohort studies, and the remaining five evaluated the material presented retrospectively. A total of 586 miniscrews in 406 patients could be followed for at least 120 days up to 1.5 years or completion of the intended orthodontic treatment, respectively. Forty-three or 7.3% out of

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**Table 4. Study and patient characteristics of the reviewed studies of palatal implants**

<table>
<thead>
<tr>
<th>Author</th>
<th>Kind of study</th>
<th>Number of TADs</th>
<th>Number of failures</th>
<th>Mean patient’s age (years)</th>
<th>Loading time</th>
<th>Number of patients</th>
<th>Manufacturer Diameter (mm)</th>
<th>Type of TAD</th>
<th>Number of TADs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jung et al. (2009)</td>
<td>Prospective</td>
<td>30</td>
<td>2</td>
<td>18.7</td>
<td>6 months</td>
<td>30</td>
<td>Straumann 4.1 4.2</td>
<td>Palatal implant</td>
<td>30</td>
</tr>
<tr>
<td>Sandler et al. (2008)</td>
<td>RCT</td>
<td>24</td>
<td>6</td>
<td>15.7</td>
<td>25.8 months</td>
<td>26</td>
<td>Straumann 3.3 or 4</td>
<td>Palatal implant</td>
<td>26</td>
</tr>
<tr>
<td>Feldmann &amp; Bondemark (2008)</td>
<td>RCT</td>
<td>30</td>
<td>2</td>
<td>14.6 ± 2</td>
<td>Completion of treatment</td>
<td>30</td>
<td>Straumann 3.3 or 4</td>
<td>Palatal implant</td>
<td>30</td>
</tr>
<tr>
<td>Männchen &amp; Schätzle (2008)</td>
<td>Prospective</td>
<td>70</td>
<td>4.7</td>
<td>22.5 ± 10.8</td>
<td>18.8 months</td>
<td>70</td>
<td>Straumann 3.3 or 4</td>
<td>Palatal implant</td>
<td>70</td>
</tr>
<tr>
<td>Criscione et al. (2007)</td>
<td>Retrospective</td>
<td>14</td>
<td>2.1</td>
<td>&gt;20</td>
<td>22.8 months</td>
<td>14</td>
<td>Straumann 3.3 or 4</td>
<td>Palatal implant</td>
<td>22</td>
</tr>
<tr>
<td>Arcuri et al. (2007)</td>
<td>Retrospective</td>
<td>20</td>
<td>3.2</td>
<td>26.4</td>
<td>22.8 months</td>
<td>20</td>
<td>Straumann 3.3 or 4</td>
<td>Palatal implant</td>
<td>20</td>
</tr>
</tbody>
</table>

**Table 3. Study and patient characteristics of the reviewed studies of palatal implants**

<table>
<thead>
<tr>
<th>Author</th>
<th>Kind of study</th>
<th>Number of TADs</th>
<th>Number of failures</th>
<th>Mean patient’s age (years)</th>
<th>Loading time</th>
<th>Number of patients</th>
<th>Manufacturer Diameter (mm)</th>
<th>Type of TAD</th>
<th>Number of TADs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jung et al. (2009)</td>
<td>Prospective</td>
<td>30</td>
<td>2</td>
<td>18.7</td>
<td>6 months</td>
<td>30</td>
<td>Straumann 4.1 4.2</td>
<td>Palatal implant</td>
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<td>20</td>
</tr>
</tbody>
</table>

TAD, temporary anchorage devices; RCT, randomized controlled clinical trials.
these did not remain stable and had to be removed early. In meta-analysis, the failure rate (Fig. 5) was estimated at 7.3% (95% CI: 5.4–9.9%).

On comparing miniplates, palatal implants and miniscrews with each other, none of them showed statistically significantly higher survival rates than the other due to the wide scattering within the groups. However, when miniplates and palatal implants representing torque-resisting TAD were grouped together, they showed a statistically significant 1.9-fold (95% CI: 1.1–2.8, \( P = 0.005 \)) lower clinical failure rate than did miniscrews.

To achieve the same clinical anchorage on both sides of the arch as with a palatal implant (10.5% failure rate, 95% CI: 6.1%–18.1%), two miniscrews or miniplates have to be inserted. The probability of having at least one failure, when two of these TADs are installed in the maxilla, was 14.1% (95% CI: 10.5–18.8%) for miniplates and 29.4% (95% CI: 24.3–36%) for miniscrews, respectively.

Discussion

The purpose of this systematic review was to evaluate the survival and failure rates of skeletal TADs such as Onplants®, miniplates, palatal implants and mini- or micro-
screws after a loading time of at least 12 weeks. No RCTs were available comparing all types of these TADs. RCTs comparing these four treatment modalities may be difficult to conduct both from a logistic as well as an ethical point of view since this anchorage is usually chosen on specific patient indications. In the absence of these kinds of RCTs, a lower level of evidence, i.e. RCTs comparing some TADs with COAD and prospective and retrospective cohort studies were included in this systematic review. TAD survival and failure rates are only meaningful if anchorage is provided at least for the major part of orthodontic therapy. Hence, a minimal period of 12 weeks of functional anchorage was chosen in the evaluation.

Before the use of TADs, COADs offered the only possibility for sufficient anchorage to control undesired tooth movements. The main disadvantage of many of these devices was the fact that treatment outcomes depended to a high degree on patient compliance [Nanda & Kierl 1992]. Hence, the comparison of survival and failure rates of the different types of TADs is of great prognostic value in future orthodontic treatment planning. But it has to be remembered that TADs are usually inappropriate in growing patients in whom influencing the skeletal growth is additionally indicated.

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There were only two RCTs [Feldmann & Bondemark 2008; Sandler et al. 2008] comparing the efficacy of COADs with TADs [palatal implants or Onplants®] within the same patient cohort. One of these studies reported significantly higher proportions of failed palatal implants than the other [Sandler et al. 2008]. Most of the failed palatal implants had been placed during the initial phase of the investigation, representing the results of a learning curve of the surgeons involved with this ‘relatively new’ technique. Similar problems were encountered in one retrospective study [Arcuri et al. 2007].

In contrast to conventional oral implants, the orthodontic anchorage implants of the time such as palatal implant yielded an emergence profile with a 90° shoulder. This bore the danger of ‘over-winding’ the implant during installation [Orthoimplant®, Straumann AG, Basel, Switzerland]. To date, only one prospective cohort study is available on this new generation of palatal implants [Jung et al. 2009] reporting very favorable survival rates [93.3%] [Table 3]. Furthermore, a recently published experimental human study on palatal implants with this novel design [Schätzle et al. 2009] yielded a high primary stability and a 100% survival for the whole observation period. Considering all studies on palatal implants, the meta-analysis presented a mean failure rate of 10.5% [95% CI: 6.1–18.1%,] rendering this treatment a reliable option with sufficient predictability for routine clinical use [Fig. 3].

Compared with COAD [headgear, transpalatal arch], palatal implants provided equal [compliant patients, Sandler et al. 2008] or statistically significantly better clinical anchorage reinforcement [Feldmann & Bondemark 2008]. There were more technical problems and a significantly higher failure rate with the Onplant® system and hence the palatal implant may be considered the anchorage system of choice for TAD [Feldmann & Bondemark 2008]. Palatal implants were better tolerated than Onplant® devices as well as extraction of premolars in terms of patient-centered outcomes [pain intensity, discomfort and analgesic consumption] [Feldmann et al. 2007].

After an observation period of at least 12 weeks, miniplates showed a slightly higher success rate of 92.7% than palatal implants (89.5%). It has to be realized, however, that this difference was mainly caused by early surgical failures in two studies mentioned above [Arcuri et al. 2007; Sandler et al. 2008]. A direct comparison of the efficacy of miniplates with that of palatal implants with respect to survival has not been performed. Considering the fact that two miniplates have to be installed instead of one palatal implant to achieve the same anchorage in the maxilla, the presumptive risk for failure for the miniplates has to be assumed at 14.1% [95% CI: 10.5–18.8%] for the miniplates.

<table>
<thead>
<tr>
<th>Study</th>
<th>Percentage of Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen CH et al. 2007</td>
<td>7.3% (95% CI: 5.4% - 9.9%)</td>
</tr>
<tr>
<td>Chen CH et al. 2008</td>
<td></td>
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<tr>
<td>Cheng SJ et al. 2004</td>
<td></td>
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<tr>
<td>Choi et al. 2005</td>
<td></td>
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<tr>
<td>Cornelis et al. 2008</td>
<td></td>
</tr>
<tr>
<td>Kuroda et al. 2007b</td>
<td></td>
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<tr>
<td>Miyawaki et al. 2003</td>
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</table>

Fig. 5. Failure rates of miniplates and summary estimate from meta-analysis and their 95% confidence intervals [95% CI] by study.
making in orthodontic treatment planning. The Kaplan–Meier analysis of Wiechmann et al. (2007) showed that the major miniscrew failures occurred within 100–150 days after the start of orthodontic loading. At this point, a change in the treatment plan may be difficult or impossible. With respect to palatal implants, reports indicate that implant loss occurred predominantly in the unloaded healing period (Arcuri et al. 2007; Männchen & Schätzle 2008, Sandler et al. 2008). This in turn means that once a palatal implant is osseointegrated, no implant loss is to be expected.

It is clear that the placement and removal of a miniscrew or a palatal implant is a more complex procedure than that associated with the installation of a miniscrew. The surgical intervention for both devices is generally well tolerated by the patients (Kuroda et al. 2007b; Cornelis et al. 2008) and pain intensity after surgical installation of a palatal implant is less than that after premolar extraction (Feldmann et al. 2007). It seems that the greater flexibility and torque resistance provided by palatal implants and miniscrews provides an advantage.

For example, during ‘en-masse’ movement of an entire dental arch of >2 mm, placing a palatal implant in the maxilla or two miniscrews in the mandible would be preferable to choosing miniscrew anchorage. Palatal implants as well as miniscrews offer safe and effective anchorage possibilities with a high survival rate (>90%), with few side effects or problems during treatment. Palatal implants as well as miniscrews might simplify orthodontic treatment and enhance the possibility of treatments that might have been considered unfeasible without skeletal anchorage. However, the relative effectiveness, efficiency and indication list of all different TADs used for various clinical problems need to be evaluated further in prospective controlled studies.

Acknowledgements: This study has been supported by the Clinical Research Foundation for the Promotion of Oral Health, Brienz, Switzerland. The authors acknowledge the continuous support of Prof. Odont. Riitta Suuronen, REGA Institute for Regenerative Medicine, University of Tampere, Finland, and Prof. Dr Timo Peltonäkki, University of Zurich, School of Dental and Oral Medicine. Likewise, the stimulating encouragement of Prof. Dr Urban Hägg and Prof. A. Bakr M. Rabie, The University of Hong Kong, is highly appreciated.

References


