A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years

II. Combined tooth–implant-supported FPDs

Key words: biological complications, combined tooth–implant-supported fixed partial dentures, implant dentistry, complication rates, failures, fixed partial dentures, longitudinal, peri-implantitis, success, survival, systematic review, technical complications

Abstract

Objectives: The objective of this systematic review was to assess the 5- and 10-year survival of combined tooth–implant-supported fixed partial dentures (FPDs) and the incidence of biological and technical complications.

Methods: An electronic MEDLINE search supplemented by manual searching was conducted to identify prospective and retrospective cohort studies on FPDs with a mean follow-up time of at least 5 years. Patients had to have been examined clinically at the follow-up visit. Assessment of the identified studies and data abstraction was performed independently by two reviewers. Failure and complication rates were analyzed using random-effects Poisson regression models to obtain summary estimates of 5- and 10-year survival proportions.

Results: From a total of 3844 titles and 560 abstracts, 176 articles were selected for full-text analysis, and 13 studies met the inclusion criteria. Meta-analysis of these studies indicated an estimated survival of implants in combined tooth–implant-supported FPDs of 90.1% (95 percent confidence interval (95% CI): 82.4–94.5%) after 5 and 82.1% (95% CI: 55.8–93.6%) after 10 years. The survival rate of FPDs was 94.1% (95% CI: 90.2–96.5%) after 5 and 77.8% (95% CI: 66.4–85.7%) after 10 years of function. There was no significant difference in survival of tooth and implant abutments in combined tooth–implant FPDs. After an observation period of 5 years, 3.2% (95% CI: 1.5–7.2%) of the abutment teeth and 3.4% (95% CI: 2.2–5.3%) of the functionally loaded implants were lost. After 10 years, the corresponding proportions were 10.6% (95% CI: 3.5–23.1%) for the abutment teeth and 15.6% (95% CI: 6.5–29.5%) for the implants. After a 5 year observation period, intrusion was detected in 5.2% (95% CI: 2–13.3%) of the abutment teeth. Intrusion of abutment teeth were almost exclusively detected among non-rigid connections.

Conclusion: Survival rates of both implants and reconstructions in combined tooth–implant-supported FPDs were lower than those reported for solely implant-supported FPDs (Pjetursson et al. 2004). Hence, planning of prosthetic rehabilitation may preferentially include solely implant-supported FPDs. However, anatomical aspects, patient centered issues and risk assessments of the residual dentition may still justify combined tooth–implant-supported reconstructions.

It was evident from the present search that tooth–implant-supported FPDs have not been studied to any great extent and hence, there is a definitive need for more longitudinal studies examining these reconstructions.
In the last decade, the use of oral implants in partially edentulous patients has become a widely accepted therapy to restore form and function in previously diseased and/or mutilated dentitions. A systematic review covering an observation period of at least 5 years and a report utilizing meta-analysis documented that survival rates of implants in completely edentulous patients are similar to those of partially edentulous patients [Lindh et al. 1998; Berglundh et al. 2002]. Furthermore, a systematic review [Pjetursson et al. 2004] recently addressed survival and complication rates of fixed partial dentures (FPDs) supported by oral implants alone. After 5-years of service, the survival of implants was 95.4% and that of FPDs was 95%, and after 10 years of service, 92.8% for implants and 86.7% for FPDs, respectively.

Originally, Brånemark implants were recommended to be free-standing from the natural teeth due to the anatomical difference and biomechanical aspects of those two elements. Therefore, approaches using solely osseointegrated implants as prosthetic abutments were predominantly examined in longitudinal studies. Teeth with healthy periodontal ligaments show mobility upon displacement of the crown with a force of 0.1 N of 50–200 μm [Mühlemann 1951a, 1951b], while osseointegrated oral implants demonstrate values of less than 10 μm [Cohen & Orenstein 1994]. On the other hand, tactile perception of natural tooth abutments was shown to be significantly higher than that demonstrated for implant abutments (Hämmerle et al. 1995). These increased thresholds for tactile perception in implants were established already after one week of healing and remained unchanged during the entire healing period of tissue integration (3 months) of the implants [Keller et al. 1996]. Hence, for reasons of chewing comfort the incorporation of natural teeth as abutments in otherwise implant-supported reconstructions may also be practiced. However, there is a paucity of studies evaluating the longevity of FPDs supported by a combination of both teeth and implants.

Therefore, the main objective of this systematic review was to obtain robust estimates of the long-term survival rates of combined tooth–implant-supported FPDs and of the incidence of biological and technical complications over an observation period of at least 5 years. Results for combined tooth–implant-supported and implant-supported FPDs have been reviewed elsewhere [Pjetursson et al. 2004].

### Material and methods

#### Search strategy

The search strategy was similar to the one used in a systematic review of implant-supported FPDs [Pjetursson et al. 2004]. Briefly, a MEDLINE (PubMed) search up to and including April 2004 was conducted for English-language articles published in the Dental Literature text searching for ‘fixed partial dentures OR bridges’, ‘partial edentulism’, ‘implants AND fixed partial dentures OR bridges’, ‘implants’ AND ‘complications’, ‘implants’ AND ‘failure’, ‘implants’ AND ‘longitudinal’.


#### Study selection

No randomized controlled clinical trials (RCTs) comparing implant therapy with conventional reconstructive therapy could be found. Hence, only controlled clinical trials comparing tooth–implant reconstructions with solely implant-supported reconstructions were included. Furthermore, prospective or retrospective cohort studies with a mean follow-up time of at least 5 years were included in this systematic review.

Exclusively publications in English were included.

Patients had to have been examined clinically at the follow-up visit. Publications based on patient records only, questionnaires or interviews were excluded. To be eligible for inclusion, the studies had to report details on the characteristics of the suprastructures. Publications that combined findings of both FPDs and single crowns were included, if at least two out of three of the reconstructions were FPDs.

#### Data extraction

Information on survival proportions of both implant and combined tooth–implant reconstructions and on biological and technical complications were retrieved. Data were extracted independently by two reviewers using a data extraction form. Disagreement was resolved by consensus.

Biological complications included disturbances in the function of the implant characterized by a biological process affecting the supporting tissues. 'Peri-implantitis', 'intrusion of abutment teeth' and 'soft tissue complications' were included in this category.

Technical complications represent a collective term for mechanical damage of the teeth and/or implants, implant components and/or suprastructures. Among
those, ‘fractures of the implant, screw or abutment’, ‘fractures of the luting cement’ (loss of retention), ‘fracture or deformation of the framework or veneers’ and ‘screw or abutment loosening’ were assessed.

Statistical analysis

By definition, failure and complication rates are calculated by dividing the number of events (failures or complications) in the numerator by the total exposure time (FPD time and/or implant time) in the denominator. The numerator could usually be extracted directly from the publication. However, the total exposure time of the implant or FPDs needed to be calculated by taking the sum of:

1. Exposure time of FPDs/implants that could be followed for the whole observation time.
2. Exposure time up to a failure of the FPDs/implants that were lost due to failure during the observation time.
3. Exposure time up to the dropout of the patients who did not complete the observation period due to reasons such as death, change of address, refusal to participate, non-response, chronic illnesses, missed appointments and work commitments.

For each study, event rates for FPDs and/or implants were calculated by dividing the total number of events by the total FPDs or implant exposure time in years. For further analysis, the total number of events was considered to be Poisson distributed for a given sum of implant exposure years and Poisson regression models with a logarithmic link-function and total exposure time per study as an offset variable were used (Kirkwood & Sterne 2003a, 2003b). Robust standard errors were calculated to obtain 95% confidence interval (CI) of the summary estimates of the event rates. For the analysis of loss of tooth or implant abutments, the total number of teeth and loaded implants were used as denominator. All analyses were performed using Stata® (Stata Corporation, College Station, TX, USA), version 8.2.

Results

Included studies

A total of 13 studies of combined tooth–implant-supported FPDs were included in the analysis. The characteristics of the selected studies are shown in Table 1. With the exception of Koth et al. [1988] and Jemt et al. [1989] all studies were published within the past 7 years. These studies reported on ten different patient cohorts, and three of the cohorts were examined after an observation period of both 5 and 10 years (Table 2).

Nine studies were prospective and the four remaining were retrospective cohort studies (Table 1). A total of 555 patients in the age range of 17–83 years were included in these studies. The proportion of patients with implants who could not be followed for the complete study period was available for 10 of 13 studies and ranged from 0% to 25%.

The studies reported on five commercially available implant systems: The Bioceram® sapphire implants (Kyocera America, Inc., San Diego, CA, USA), The Branemark® System (Nobel Biocare AB, Göteborg, Sweden), IMZ® (Friedrichfeld, Mannheim, Germany), ITI® Dental Implant system (Straumann AG, Waldenburg, Switzerland) and Omniloc® Implant (formerly CalciTek, now Sulzer Dental, Carlsbad, CA, USA).

The studies were mainly conducted in an institutional environment, such as a university or specialized implant clinic. One of the studies was a multicenter study.

In three of the studies the patients were randomized into test and control groups to compare implant-supported FPDs with combined tooth–implant-supported FPDs
To compare hydroxyapatite (HA) and titanium plasma-flame (TPF) implant surfaces (Mau et al. 2002) and to compare rigid and non-rigid connection between teeth and implants in the reconstruction (Block et al. 2002). In this review, all the data from the included studies on combined tooth–implant-supported FPDs were used irrespective of treatment modalities.

Eight of the studies reported on patient cohorts in which all the patients were
followed for the same observation period, with a follow-up time of 5 years (Koth et al. 1988; Olsson et al. 1995; Brägger et al. 2001; Block et al. 2002; Mau et al. 2002) or 10 years (Steflik et al. 1995; Fartash & Arvidson 1997; Gunne et al. 1999). The remaining four studies represented studies with variable individual observation periods ranging from 1.3 to 15 years (Table 2).

The 13 studies reported on a total of 538 FPDs (Table 2) that were supported by 1002 oral implants, and 56 of the FPDs were examined both after 5 and 10 years.

For seven out of 10 cohorts, information on FPD design was presented: 63% of the FPDs were screw retained and only 9% were cemented (Table 2).

### Survival

#### Implant survival

All of the 13 studies reported on the survival of the implants (Table 3) and the studies were separated in two group. The first group consisted of eight studies with a mean follow-up time of 5.6 years (range 5–6.5 years) (Table 2). Of the originally 932 implants placed, 90 implants were known to be lost, and 25 of the implants were lost before functional loading and 65 during function. The estimated study-specific 5-year survival proportion varied between 75.7% and 98.6% (Table 3). The estimate annual failure rate per 100 years for implants in combined tooth–implant-supported FPDs ranged from 0.28 to 5.56, and, derived from random-effects Poisson regression, the summary estimate was 2.09 (95% CI: 1.13–3.86%) (Fig. 2, Table 3).

Implant loss prior to functional loading was detected in 2.7% of all implants placed. For failures after loading, the estimated annual failure rate was 1.33 (95% CI: 0.66–2.66%) for studies with 5 years of follow-up.

The second group consisted of six studies with a mean follow-up time of 10 years. Of the 143 implants originally placed, 24 implants were known to be lost. The study-specific estimated 10-year survival proportion varied between 64.7% and 100%, and the summary estimate of the survival proportion after 10 years for implants in combined tooth–implant-supporting FPDs was 82.1% (95% CI: 55.8–93.6%) (Table 3).

#### FPD survival

FPD survival was defined as the FPD remaining in situ with or without modification for the observation period. Nine studies provided data on survival of the FPDs (Table 4). The reports were divided into two groups. The first group with a total of 115 FPDs and a mean follow-up time of 5.2 years, and the second group with a total of 72 FPDs and a mean follow-up time of 10 years.

In the former group, 7 out of 115 FPDs were lost, and the study-specific estimated 5-year survival varied between: 90.5% and 100% (Table 4). The estimated failure rate per 100 years for combined tooth–implant-supported FPDs of the five included studies

### Table 3. Annual failure rate and survival of implants

<table>
<thead>
<tr>
<th>Study (year of publication)</th>
<th>Total no. of implantations</th>
<th>Mean follow-up time</th>
<th>No. of failures</th>
<th>Total implantation exposure time</th>
<th>Estimated failure rate (per 100 implant years)</th>
<th>Estimated survival after 5 years (%)</th>
<th>Estimated survival after 10 years (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-year follow-up&lt;br/&gt;Block et al. (2002)</td>
<td>80</td>
<td>5</td>
<td>1</td>
<td>357</td>
<td>0.28</td>
<td>98.6</td>
<td></td>
</tr>
<tr>
<td>Mau et al. (2002)*</td>
<td>297</td>
<td>5</td>
<td>51</td>
<td>1112</td>
<td>4.59</td>
<td>79.5</td>
<td></td>
</tr>
<tr>
<td>Naert et al. (2001)</td>
<td>339</td>
<td>6.5</td>
<td>19</td>
<td>2040</td>
<td>0.93</td>
<td>95.4</td>
<td></td>
</tr>
<tr>
<td>Brägger et al. (2001)</td>
<td>19</td>
<td>5</td>
<td>1</td>
<td>93</td>
<td>1.08</td>
<td>94.8</td>
<td></td>
</tr>
<tr>
<td>Kindberg et al. (2001)</td>
<td>115</td>
<td>6.5</td>
<td>9</td>
<td>431</td>
<td>2.09</td>
<td>90.1</td>
<td></td>
</tr>
<tr>
<td>Hosny et al. (2000)</td>
<td>31</td>
<td>6.5</td>
<td>1</td>
<td>195</td>
<td>0.51</td>
<td>97.5</td>
<td></td>
</tr>
<tr>
<td>Olsson et al. (1995)</td>
<td>23</td>
<td>5</td>
<td>2</td>
<td>100</td>
<td>2</td>
<td>90.5</td>
<td></td>
</tr>
<tr>
<td>Koth et al. (1988)</td>
<td>28</td>
<td>5</td>
<td>6</td>
<td>108</td>
<td>5.56</td>
<td>75.7</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>932</td>
<td>90</td>
<td>4436</td>
<td></td>
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<tr>
<td>Summary estimate (95% CI)†</td>
<td>2.09 (1.13–3.86)</td>
<td>90.1 (82.4–94.5)</td>
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<tr>
<td>10-year follow-up&lt;br/&gt;Brägger et al. (2004)</td>
<td>22</td>
<td>10</td>
<td>5</td>
<td>198</td>
<td>2.53</td>
<td>77.7</td>
<td></td>
</tr>
<tr>
<td>Gunne et al. (1999)</td>
<td>23</td>
<td>10</td>
<td>2</td>
<td>186</td>
<td>1.08</td>
<td>89.8</td>
<td></td>
</tr>
<tr>
<td>Fartash &amp; Arvidson (1997)</td>
<td>27</td>
<td>10</td>
<td>1</td>
<td>270</td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Steflik et al. (1995)</td>
<td>28</td>
<td>10</td>
<td>9</td>
<td>207</td>
<td>4.35</td>
<td>64.7</td>
<td></td>
</tr>
<tr>
<td>Jemt et al. (1989)*</td>
<td>43</td>
<td>n.a.</td>
<td>8</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
<td>24</td>
<td>861</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summary estimate (95% CI)‡</td>
<td>1.97 (0.66–5.84)</td>
<td>82.1 (55.8–93.6)</td>
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</tr>
</tbody>
</table>

*The authors defined ‘functional deficiency’ as implant loss, bone loss since insertion more than half of the implant length either mesial or distal or both and manual implant mobility of implant >1.
†The proportion of implants lost prior to functional loading was based on information in another study on the same patient cohort (Naert et al. 2002).
‡Based on random-effects Poisson regression, test for heterogeneity P<0.0001.
§Total exposure time could not be estimated within the 1% range.
*Based on random-effects Poisson regression, test for heterogeneity P=0.0046.
CI, confidence interval; n.a., not available.
ranged from 0 to 2 and, derived from a standard Poisson regression analysis, the summary estimate was 1.2% (95% CI: 0.7–2.1%) (Fig. 3, Table 4). The summary estimate for the survival proportion after 5 years (Table 4) for combined tooth–implant-supported FPDs was 94.1% (95% CI: 90.2–96.5%).

In the second group 14 out of 72 FPDs were lost. The study-specific survival after 10 years varied between 70.2% and 85.1% (Table 4), and the summary estimate of the survival proportion after 10 years for combined tooth–implant-supported FPDs was 77.8% (95% CI: 66.4–85.7%).

Abutment survival

Eight studies (Table 5) reported on survival of tooth and implant abutments in combined tooth–implant FPDs. After an observation period of 5 years, 3.2% of the abutment teeth and 3.4% of the functionally loaded implants were lost. At 10 years, information was available only from two studies (Gunne et al. 1999; Brägger et al. 2004). The corresponding proportions were 10.6% for the abutment teeth compared to 15.6% for the implants, respectively. The reasons reported for loss of abutment teeth were tooth fractures, caries, endodontic complications and periodontitis. Loss of retention was frequently associated with tooth fractures or caries.

Complications

Biological complication

Only three out of 13 studies provided information on soft tissue complications and ‘periimplantitis’. One study (Koth et al. 1988) of bioceram sapphire implants reported that three out of 21 implants had radiographic evidence of infrabony pocket formation after an observation period of 5 years. Brägger et al. (2001) defined ‘peri-implantitis’ as sites with probing pocket depth (PPD) ≥ 5 mm and bleeding on probing (BOP) with 10% of the patients or 9.6% of the implants being affected after an observation period of 5 years. Reporting on the same patient cohort after an observation period of 5 years, 3.2% of the abutment teeth and 3.4% of the functionally loaded implants were lost. At 10 years, this information was available only from two studies (Gunne et al. 1999; Brägger et al. 2004). The corresponding proportions were 10.6% for the abutment teeth compared to 15.6% for the implants, respectively. The reasons reported for loss of abutment teeth were tooth fractures, caries, endodontic complications and periodontitis. Loss of retention was frequently associated with tooth fractures or caries.

### Table 4. Annual failure rate and survival of combined tooth–implant-supported FPDs

<table>
<thead>
<tr>
<th>Study (year of publication)</th>
<th>Total no. of FPDs</th>
<th>Mean follow-up time</th>
<th>No. of failures</th>
<th>Total FPDs exposure time</th>
<th>Estimated failure rate (per 100 FPD years)</th>
<th>Estimated survival after 5 years (%)</th>
<th>Estimated survival after 10 years (%)</th>
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</thead>
<tbody>
<tr>
<td><strong>5-year follow-up</strong></td>
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<tr>
<td>Brägger et al. (2001)</td>
<td>18</td>
<td>5</td>
<td>1</td>
<td>88</td>
<td>1.14</td>
<td>94.5</td>
<td></td>
</tr>
<tr>
<td>Kindberg et al. (2001)</td>
<td>41</td>
<td>5</td>
<td>3</td>
<td>201</td>
<td>1.49</td>
<td>92.8</td>
<td></td>
</tr>
<tr>
<td>Hosny et al. (2000)</td>
<td>18</td>
<td>6.5</td>
<td>0</td>
<td>117</td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Olsson et al. (1995)</td>
<td>23</td>
<td>5</td>
<td>2</td>
<td>100</td>
<td>2</td>
<td>90.5</td>
<td></td>
</tr>
<tr>
<td>Koth et al. (1988)</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>73</td>
<td>1.37</td>
<td>93.4</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>115</td>
<td>7</td>
<td>7</td>
<td>579</td>
<td>1.21</td>
<td>94.1</td>
<td>70.2</td>
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<tr>
<td><strong>Summary estimate (95% CI)</strong></td>
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<td></td>
<td><strong>2.1 (95% CI: 1.1–3.9)</strong></td>
<td><strong>44.1</strong></td>
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<tr>
<td><strong>10-year follow-up</strong></td>
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<tr>
<td>Brägger et al. (2004)</td>
<td>22</td>
<td>10</td>
<td>7</td>
<td>198</td>
<td>3.54</td>
<td>70.2</td>
<td></td>
</tr>
<tr>
<td>Gunne et al. (1999)</td>
<td>23</td>
<td>10</td>
<td>3</td>
<td>186</td>
<td>1.61</td>
<td>85.1</td>
<td></td>
</tr>
<tr>
<td>Stefflik et al. (1995)</td>
<td>15</td>
<td>10</td>
<td>3</td>
<td>133</td>
<td>2.26</td>
<td>79.8</td>
<td></td>
</tr>
<tr>
<td>Jemt et al. (1989)</td>
<td>12</td>
<td>n.a.</td>
<td>1</td>
<td>n.a.†</td>
<td>n.a.†</td>
<td>n.a.†</td>
<td>n.a.†</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>72</td>
<td>14</td>
<td>14</td>
<td>517</td>
<td>2.51</td>
<td>77.8</td>
<td>(66.4–85.7)</td>
</tr>
<tr>
<td><strong>Summary estimate (95% CI)</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2.51 (1.54–4.1)</strong></td>
<td><strong>77.8</strong></td>
<td></td>
</tr>
</tbody>
</table>

Based on standard Poisson regression, test for heterogeneity $P = 0.72$.

Based on standard Poisson regression, test for heterogeneity $P = 0.48$.

Total exposure time could not be estimated.

FPDs, fixed partial dentures; CI, confidence interval; n.a., not available.
period of 10 years (Brägger et al. 2004), three out of 22 or 13.6% of the implants had been treated for 'peri-implantitis'.

In a random-effects Poisson model analysis, the estimated cumulative rate of biological complications reported in the two studies after 5 years for implants in combined tooth–implant-supported FPDs was 11.7% (95% CI: 9.7–14.7%).

Technical complication
In general, the 13 studies did not report on technical complications in details. However, some information could be retrieved from various studies.

The most common technical complication as veneer fracture (acryl, ceramic and composite). This was only reported in one study (Kindberg et al. 2001), in which four out of 41 FPDs or 9.8% had fractures of veneers. Another study (Brägger et al. 2004) reported on fractures of veneers after 10 years in 2 out of 22 FPDs or 9.1%.

Another common technical complication was loss of retention. This was reported in two studies with a 5-year observation period (Hosny et al. 2000; Naert et al. 2001). After a 5-year follow-up period, 6.2% (95% CI: 3.7–10.4%) of the FPDs had loss of retention. Two studies (Fartash & Arvidson 1997, Brägger et al. 2004) reported on loss of retention after a 10-year observation period with an estimated 24.9% (95% CI: 7.9–63.1%) of the FPD that lost retention.

Connection-related complications (abutment or occlusal screw loosening) were reported in only one study after a follow-up time of 5 years and found in 3.6% of abutments. After an observation period of 10 years, there were two studies (Gunne et al. 1999; Brägger et al. 2004) reporting 26.4% (95% CI: 20.3–33.9%) of abutments with screw loosening.

Abutment fracture or abutment screw fracture was reported in two studies (Hosny et al. 2000; Naert et al. 2001). After a 5-year follow-up period, 0.7% (95% CI: 0.5–0.9%) of the FPDs had abutment or abutment screw fractures.

Another rarely encountered complication was implant fractures. After a 5-years follow-up time, 0.9% (95% CI: 0.8–1.2%) of the implants were fractured.

Five studies reported on intrusion of abutment teeth. After a 5-year observation period, intrusion was detected in 5.2% (95% CI: 2.0–13.3%) of the abutment teeth (Table 6).

**Discussion**
This systematic review is part of a series of reviews addressing the survival and complication rates of FPDs of different designs.

This systematic review was performed to evaluate the evidence available for combining teeth and oral implants into the same FPDs and to compare this treatment option with solely implant-supported FPDs.

One research group (Åstrand et al. 1991; Gunne et al. 1992; Olsson et al. 1995; Gunne et al. 1999) has addressed this question on the highest level of evidence in an RCT.
The authors selected 23 patients with a residual dentition in the mandible and complete maxillary dentures. The two edentulous sites in the mandible of each patient were randomly selected for a FPD incorporation supported by either two implants [control] or by one abutment tooth and one implant [test]. Over a 10-year observation period, 2 out of 23 test implants and 5 out of 46 control implants were lost during function. There was no significant difference between test and control sites and hence, the authors concluded that the combination of teeth and implants in FPDs may be recommended as a predictable and reliable treatment alternative in the reconstruction of the posterior mandible.

However, this study had clearly not the necessary power to detect smaller but clinically relevant differences of the proportion of lost implants. With the two groups of 23 and 46 implants, this study had a power of 43% to detect a 10% vs. 30% difference in the proportion of implants lost. Another drawback of this study is the fact that all the FPDs were constructed in the mandible and that all the patients had complete dentures in the opposing maxilla. Moreover, it was evident that the results of the control sites were substantially below what can be expected for solely implant-supported FPDs. Survival rates of implants for this patient cohort was 86.5% at 5 years compared with an average survival rate of 95.4% as reported in a recent systematic review [Pjetursson et al. 2004], and 85.5% compared with an average of 92.8% after an observation time of 10 years.

A further three studies [Hosny et al. 2000; Brägger et al. 2001, 2004; Naert et al. 2001] assessed within the same patient cohort both solely implant-supported FPDs and combined tooth–implant-supported FPDs. Two of these studies reported a higher proportion of implants lost for the combined tooth–implant-supported FPDs. Ten out of 339 or 2.9% of the implants in the combined tooth–implant-supported FPDs were lost in function after a mean observation period of 6.5 years [Naert et al. 2001]. In the second study, one out of 19 or 5.3% of the implants in the combined tooth–implant-supported FPDs were lost in function after an observation period of 5 years [Brägger et al. 2001]. After 10 years, the corresponding figures were one out of 69 or 1.4% and five out of 22 or 22.7% for the combined and the solely implant-supported FPDs [Brägger et al. 2004]. In the third study [Hosny et al. 2000], no implants were lost in function, for both groups over a mean observation period of 6.5 years.

In this systematic review, a large number of longitudinal cohort studies with a mean follow-up time of at least 5 years were reviewed, regarding survival of combined tooth–implant-supported FPDs and their biological and technical complications. Survival was defined as the FPD remaining in situ with or without modification for the whole observation period.

The present search aimed to identify longitudinal cohort studies that reported on combined tooth–implant-supported FPDs. When titles and abstracts did not provide sufficient information on study duration and whether or not information on the suprastructures was provided, a full-text analysis of the articles was carried out. The majority of longitudinal implant studies did not address the reconstructions at all. Nor did they distinguish between different types of reconstructions. Therefore, a substantial proportion of the published literature could not be included in this systematic review. It was impossible to judge whether or not the patients excluded from the present review might have differed in survival and event rates.

For three out of five studies with a mean follow-up time of ten years, a 5-year report was also available. Instead of excluding the 5-year data, it was decided to divide the studies into two groups: A group with approximately 5-year follow-up and a second group with a 10-year follow-up time.

It may be argued that 5 years may be too short to obtain reliable information on survival and complication rates of FPDs. However, after reviewing the literature it was evident that there was little information available on combined tooth–implant FPDs after an observation period of, e.g., 10 years. Only five studies with total of 94 FPDs were reported.

Of the 13 studies included in the systematic review, ten reported on titanium oral implants and three on single-crystal aluminum oxide implants. All thirteen studies were performed in institutional environments such as university or specialized implant clinics. Therefore, the long-term outcomes observed here cannot be generalized to dental service provided in private practice.

The cumulative failure rate of implants was 8.9% after 5 years, and 17.9% after 10 years. Approximately 2.7% of the implants were lost prior to functional loading. This result is in agreement with the results from two previous systematic reviews [Berglundh et al. 2002; Pjetursson et al. 2004].

However, while comparing the annual failure rates of 1.33 [95% CI: 0.66–2.66%] during the first 5 years after loading of implants in combined tooth–implant-supported FPDs with that of implants in solely implant-supported FPDs of 0.51% [95% CI: 0.39–0.67%], a significantly higher failure rate has to be recognized for implants in combined tooth–implant-supported FPDs. The cumulative failure rate of the combined tooth–implant-supported FPDs was

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**Table 6. Intrusion of tooth abutments**

<table>
<thead>
<tr>
<th>Study (year of publication)</th>
<th>Total no. of tooth abutments</th>
<th>Mean follow-up time</th>
<th>No. of intrusions</th>
<th>Total abutment exposure time</th>
<th>Estimated intrusion rate (per 100 abutment years)</th>
<th>Estimated complication rate after 5 years (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-year follow-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block et al. (2002)</td>
<td>80</td>
<td>5</td>
<td>12</td>
<td>357</td>
<td>3.36</td>
<td>15.5</td>
</tr>
<tr>
<td>Naert et al. (2001)</td>
<td>313</td>
<td>6.5</td>
<td>11</td>
<td>1884</td>
<td>0.58</td>
<td>2.9</td>
</tr>
<tr>
<td>Kindberg et al. (2001)</td>
<td>85</td>
<td>5</td>
<td>3</td>
<td>327</td>
<td>0.92</td>
<td>4.5</td>
</tr>
<tr>
<td>Brägger et al. (2001)</td>
<td>18</td>
<td>5</td>
<td>0</td>
<td>88</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hosny et al. (2000)</td>
<td>30</td>
<td>6.5</td>
<td>0</td>
<td>195</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>526</td>
<td>26</td>
<td>2851</td>
<td></td>
<td>1.07</td>
<td>5.2</td>
</tr>
<tr>
<td>Summary estimate (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.4–2.87)</td>
<td>(2–13.3)</td>
</tr>
</tbody>
</table>

CI, confidence interval.
5.9% after 5 years and 22.2% after 10 years. Compared with the results of a systematic review on solely implant-supported FPDs [Pjetursson et al. 2004], there is no difference in the FPD failure rate (5.9% vs. 5.9%) after 5 years, but at 10 years, the failure rate for the combined tooth–implant-supported FPDs was substantially higher with 22.2% compared to 13.3% in the review mentioned. The 10-year results for combined tooth–implant-supported FPDs must be interpreted with caution because it is based on only 60 FPDs. Hence, no definite generally applicable recommendations can be made for the clinician before further studies of similar nature are available.

Eight of the publications reported both on loss of abutment teeth as well as less of implant abutments after functional loading. After an observation period of 5 years, 3.2% of abutment teeth were lost compared with 3.4% of the implant abutments. After a 10-year follow-up time, five out of 47 or 10.6% of abutment teeth and seven out of 45 or 15.6% of the implant abutments were lost [Gunne et al. 1999; Brägger et al. 2004]. There was no statistically significant difference between loss of abutment teeth and loss of implants. The reason for lower survival rates of combined tooth–implant-supported FPDs does not seem to be higher failure rates of the abutment teeth.

Two studies reported on biological complications. The estimated cumulative rate of biological complications after 5 years for implants in combined tooth–implant-supported FPDs was 11.7%.

The incidence of technical complications ranged from 0.7% to 9.8% after a follow-up time of 5 years. The most common technical complications were fractures of veneer material [9.8%], followed by loss of retention [6.2%] and abutment/screw loosening [3.6%]. Rarely encountered technical complications were abutment and screw fractures [0.7%] and implant fractures [0.9%]. However, after an observation period of 10 years, loss of retention was detected in 24.9% of the FPDs and abutments/screw loosening was encountered up to 26.4%. Again, it must be kept in mind that these rates are based on reports with few FPDs (n = 60).

Five studies reported on intrusion of abutment teeth in conjunction with combined tooth–implant-supported FPDs. After a 5-year observation period, intrusion was detected in 5.2% of the abutment teeth. In a randomized cross-arc model, one group of authors [Block et al. 2002] examined the effect on teeth and implants when rigidly or non-rigidly connected in a combined tooth–implant-supported FPD. The percentages of patients who had measurable intrusion were 66% for non-rigid connections, and 44% for rigid connections. In that study [Block et al. 2002], 25% of the non-rigid connections had greater than 0.5 mm intrusion of abutments compared to 12.5% of the FPDs with rigid connections. Kindberg et al. [2001] reported intrusion in three out of 36 patients. All these patients had non-rigid connections. Fugazzotto et al. [1999] examined 3096 sites with implant–tooth connections after an observation period ranging between 3 and 14 years. Intrusion of abutment teeth was detected in only nine cases. Again, all incidences were in connection with fractures or loosening of the rigid connection. It may, therefore, be concluded that intrusion of abutment teeth in combined tooth–implant-supported FPDs are almost exclusively detected for non-rigid connections.

In conclusion, combined tooth–implant-fixed partial dentures yield a survival of 94.1% after a 5-year observation period. However, based on the results of 60 FPDs, the survival of FPDs in such situations was only 77.8% after 10 years. Nevertheless, the failure rates of abutment teeth and implant abutments were not significantly different indicating that neither the tooth nor the implant may be held responsible for this relatively low survival.

Comparing the results of the present systematic review to those obtained for solely implant-supported FPDs [Pjetursson et al. 2004] planning of prosthetic rehabilitation should preferentially include solely implant-supported FPDs. If, for reasons of anatomical structures or patient-centered preferences, FPDs supported by combination of implants and teeth is to be preferred, a rigid connection should be established by the two abutments. Finally, it was evident from the search of the entire dental literature that tooth–implant-supported FPDs were not studied to any great extent and hence, there is a definitive need for more longitudinal studies addressing such reconstructions.

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Conflicts of interest: None declared.

Résumé

L’objectif de cette revue systématique a été de vérifier la survie à cinq et dix années des prothèses partielles fixées portées sur implants et dents et l’incidence des complications techniques et biologiques. Une recherche Medline ainsi que manuelle ont identifié les études prospectives et rétrospectives avec un suivi d’au moins cinq années. Les patients avaient du subir un examen clinique lors de ce suivi. L’identification des études et l’analyse des données ont été effectuées indépendamment par deux personnes. Les taux d’échecs et de complications ont été analysés en utilisant les modèles de régression Poisson avec effets hasard pour obtenir des estimations à cinq et dix ans. De 3 844 titres et 150 résumés, 176 articles ont été sélectionnés pour l’analyse approfondie et treize études atteignaient les critères d’inclusion. La métanalyse de ces études indiquaient une estimation de survie des implants en combinaison des prothèses fixées sur implants et dents de 90,1% [intervalle de confiance 95% : 85,4 à 94,7%] après cinq années et de 82,1% [53,8 à 93,6%] après dix années. Le taux de survie de ces prothèses étaient de 94,1% [90,2 à 96,5%] après cinq ans et de 77,8% [66,4 à 85,7%] après dix années. Il n’y avait aucune différence significative dans la survie des dents piliers dentaires et implantaires dans ces prothèses sur implants et dents.

Après une observation de cinq années, 3,2% [1,5 à 7,4%] des dents piliers et 14,4% [3,2 à 5,3%] des implants ont été perdus. Après dix années, les proportions correspondantes étaient de 10,6% [3,5 à 23,1%] pour les dents et de 15,6% [6,5 à 29,5%] pour les implants. Après une observation de cinq années, l’intrusion a été détectée dans 5,2% [2,6 à 13,3%] des dents piliers. L’intrusion des dents piliers étaient presque exclusivement détectée le long des connexions non-rigides. Le taux de survie de ces prothèses sur dents et implants étaient inférieur à celui rapporté pour le même type de prothèse seulement placé sur implants [Pjetursson et al. 2004]. Le plan de prothèse pourrait donc avoir une préférence pour la place des prothèses que sur des implants. Ce- pendant les aspects anatomiques, le respect du patient et les risques pour la dentition résiduelle peuvent justifier les reconstructions sur implants et dents. Il était évident que lors de la recherche présente les bridges sur implants et dents n’avaient pas été beaucoup étudiés, il s’avère donc nécessaire de débuter davantage d’études longitudinales.

Zusammenfassung

Ziel: Ziel dieser systematischen Übersicht war eie- nerseits die Bestimmung der Überlebenszeit von
References

Only the references pertinent to this review are presented. The reference list of the studies excluded from the review and the reasons for exclusion are reported in Pjetursson et al. 2004.


Lang et al. Systematic review of FPDs

and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. Journal of Clinical Periodontology 29 Suppl. 3: 197–212.


