2.

TREATMENT OUTCOME OF IMMEDIATE, EARLY AND CONVENTIONAL SINGLE-TOOTH IMPLANTS IN THE AESTHETIC ZONE

A SYSTEMATIC REVIEW TO SURVIVAL, BONE LEVEL, SOFT TISSUE, AESTHETICS AND PATIENT SATISFACTION
**Abstract**

*Aim:* To evaluate, through a systematic review of the literature, the outcome of single-tooth implants in the aesthetic zone with natural adjacent teeth, thereby addressing immediate, early and conventional implant approaches.

*Material and Methods:* MEDLINE (1950-2008), EMBASE (1966-2008), and CENTRAL (1800-2008) were searched to identify eligible studies. Two reviewers independently assessed the methodological quality using specific study-design related assessment forms.

*Results:* Out of 86 primarily selected articles, 19 studies fulfilled the inclusion criteria. A meta-analysis showed an overall survival rate of 95.5% (95% CI: [93.0 – 97.1]) after one year. A stratified meta-analysis revealed no differences in survival between immediate, early and conventional implant strategies. Minor marginal peri-implant bone resorption was found together with low incidence of biological and technical complications. No significant differences in outcome measures were reported in clinical trials comparing immediate, early or conventional implant strategies.

*Conclusion:* The included literature suggest that promising short-term results can be achieved for immediate, early and conventional single-tooth implants in the aesthetic zone. However, important parameters as aesthetic outcome, soft tissue aspects and patient satisfaction were clearly underexposed. The question whether immediate and early single implant therapies will result in better treatment outcomes remains inconclusive due to lack of well-designed controlled clinical studies.
**Introduction**

The application of dental implants for single-tooth replacements has evolved into a viable prosthodontic alternative to conventional fixed bridgework, resin-bonded restorations or removable partial dentures. Long-term studies have reported excellent implant survival rates when applied for single-tooth replacements (Schellner et al. 1998, Romeo et al. 2002). Psychological benefits and tooth structure conservation adjacent to the tooth to be replaced, are among the advantages of implant supported restorations.

In the anterior zone, the success of single-tooth implant therapy is not only determined by high survival rates, but even more by the (long-term) quality of survival, dictated by a mixture of several factors. Preferably, the appearance of the peri-implant soft tissue should be in harmony with the mucosa around the adjacent teeth and the implant crown should be in balance with the neighbouring dentition (Meijer et al. 2005). Various implant treatment strategies have been proposed for the accomplishment of optimal aesthetics. These include approaches to rehabilitate the underlying bone structures by augmentation procedures with autologous bone and/or bone substitutes (Weber et al. 1997, Jensen et al. 2006, Pelo et al. 2007), techniques to manipulate and enhance the architecture of the peri-implant soft tissue (Zetu & Wang 2005, Esposito et al. 2007) and methods for alveolar ridge preservation following tooth extraction (Lekovic et al. 1997, Irinakis & Tabesh 2007). Furthermore, implants and abutments with specific configurations have been introduced to sustain the hard and soft tissue (Wohrle 2003, Morton et al. 2004, Lazzara & Porter 2006, Maeda et al. 2007, Noelken et al. 2007) together with provisionalization techniques to restore the soft tissue contour (Jemt 1999, Al-Harbi & Edgin 2007), and the introduction of ceramic customized abutments and ceramic implant crowns (Canullo 2007, Schneider 2008).

Traditionally, dental implants were placed in healed extraction sites according to a two-stage surgical procedure and an undisturbed load-free period of three to six months. In contemporary implantology, however, installation of implants in fresh extraction sockets and reducing the load-free period by immediate restoring implants after insertion have gained attention. Besides shortening of total treatment time, fewer surgical interventions and eliminating the need for a temporary prosthesis, these immediate approaches might lead to a reduction of peri-implant crestal bone loss and a better soft tissue healing thus possibly improving the aesthetics (Esposito et al. 2006, Glauser et al. 2006, Harvey 2007). On the other hand, there are potential risk factors involved with these techniques such as enhanced possibility of infection, mismatch between socket wall and implant leading to gap creation and induction of fibrous tissue formation around the bone-implant interface caused by implant micromovement during eventful wound healing (Gapski et al. 2003, Esposito et al. 2006). These risk factors may
worsen the treatment outcome. This discrepancy needs further study.

The outcome of a single-tooth implant with natural neighbouring teeth may be dissimilar to cases in which multiple adjacent teeth are replaced by dental implants, because dimensions of the hard and soft tissue between adjacent implants differ significantly from dimensions found in single implant cases. Single implant cases take benefit of tissue support of the adjacent dentition (Grunder 2000, Kan et al. 2003b, Belser et al. 2004). When considering the heights of inter-implant papillae for instance, studies indicated that these papillae might show inadequacy for complete enclosure of the inter-implant area with soft tissue, thereby failing to duplicate the interproximal soft tissue appearance of the adjacent teeth (Tarnow et al. 1992, Tarnow et al. 2003, Lee et al. 2005). This deficiency may affect the aesthetic outcome unfavorably. The soft tissue height proximal to single-tooth implants is on average higher and is suggested to be related to the interproximal bone level of the adjacent teeth (Grunder 2000, Kan et al. 2003b). Hence, single-tooth implant therapy may lead to more favorable treatment outcomes compared to a therapy in which adjacent implants are involved.

To date, several reviews have been published regarding the clinical outcome of immediate and conventional implant supported single-tooth restorations in partially edentulous patients (Creugers et al. 2000, Berglundh et al. 2002, Belser et al. 2004, Glauser et al. 2006, Jung et al. 2008). Most of these reviews have mainly converged on implant survival and addressed to a lesser degree other outcome measures that determine the quality of survival. Furthermore, none of these reviews systematically analyzed the literature concerning the efficacy of single-tooth implants in the aesthetic zone neither did these reviews concentrate explicitly on the outcome of single implants with natural neighbouring teeth, applied to replace one missing tooth. However, it is worthwhile for patients and clinicians to know whether an immediate or conventional single-tooth implant represents a predictive, reliable and effectual therapy to re-establish function and aesthetics subsequent to the loss of a single anterior tooth. Therefore, the objective of this study was to evaluate, through a systematic review of the literature, the outcome of single-tooth replacements by dental implants in the aesthetic zone in cases in which the adjacent teeth are natural, thereby focussing on immediate, early and conventional implant treatment strategies.

**Material and Methods**

*Types of studies*

Longitudinal studies (Randomized controlled trials (RCTs), clinical trials, cohort-studies and case series) were considered for evaluation. Retrospective studies were excluded. Only case series that investigated at least five patients were contemplated.
for inclusion. No time restrictions were implemented. Language was restricted to papers published in English, German, French, Spanish, Italian and Dutch.

**Type of participants**
Patients who were treated with an implant-retained single-tooth replacement in the aesthetic zone neighbored with natural teeth, could be included. The aesthetic zone was defined as the region in the maxilla or mandible, ranging from second premolar to second premolar (teeth 15-25 and teeth 35-45).

**Types of intervention**
- immediate implant placement: defined as implant placement immediately following extraction of a tooth;
- early implant placement: defined as installation of the implant 4 to 8 weeks after extraction;
- conventional implant placement: implant placement ≥ 8 weeks post-extraction;
- immediate loading: application of a load by means of a restoration within 48 hours of implant placement;
- early loading: application of a load by means of a restoration after 48 hours but less than 3 months after implant placement;
- conventional loading: application of a load by means of a restoration ≥ 3 months after implant placement (Laney 2007).

For studies to be eligible in this review, they had to evaluate endosseous root-form dental implants with a follow-up of at least 1 year after placement of the implant crown.

**Types of outcome measures**
- implant survival, defined as presence of the implant at time of follow-up examinations;
- changes in marginal peri-implant bone level assessed on radiographs;
- aesthetics evaluated by dental professionals;
- aspects of the peri-implant structures, i.e. level of marginal gingiva, papilla index (Jemt 1997), probing pocket depth, presence of plaque, bleeding on probing;
- patient satisfaction including aesthetics;
- biological and technical complications.

**Search Strategy**
For this review, a thorough search of the literature was conducted in databases of MEDLINE (1950-2008 (via PUBMED) and EMBASE (1966 – 2008). The search
was supplemented with a systematic search in the ‘Cochrane Central Register of Controlled Trials’ (CENTRAL) (1800–2008). The search strategy used, was a combination of MeSH terms and free text words and is summarized in Table 1. The search was complemented by checking references of relevant review articles and eligible studies for additional useful publications. Titles and abstracts of the searches were scanned independently by two examiners. Full-text documents were obtained for all possibly relevant articles. Full text analysis was performed for second selection by two reviewers independently against the stated inclusion criteria. In case of disagreement, consensus was reached by discussion, if necessary in consultation with a third reviewer.

Table 1. Search strategy.

| #1 Search “Dental Implants”[MeSH] OR “Dental Implantation”[MeSH] OR implant* |
| #2 Search “single implant*” OR “single tooth” OR “single teeth” OR “single crown*” OR “single restoration*” |
| #3 Search “aesthetic*” OR “esthetic*” OR “anterior*” OR “front*” OR “incisor*” |
| #4 Search #1 AND #2 AND #3 |

Run data search: June 2008.

Quality assessment

Methodological quality was assessed using specific study-design related forms designed by the Dutch Cochrane Collaboration. As there was no checklist available for the assessment of the quality of case series, a quality-assessment tool was specifically developed for this review, adapted from the quality form used for clinical trials (Table 2). Two observers independently generated a score for the included articles, expressed in the number of plusses given. It was decided that studies scoring 5 or more plusses were considered to be methodological ‘acceptable’.

Data extraction and synthesis

For each trial the following data were extracted by two review authors independently and recorded in a data sheet:

- number of patients, implants placed, drop-outs and follow-up time. For all included longitudinal studies of more than one year, follow-up time was calculated as person-years;
- details of type of intervention;
- details of the outcomes stated, including method of assessment.

Agreement was reached by a consensus discussion and if necessary a third reviewer was consulted. If feasible, a meta-analysis was carried out if the outcome measures could be meaningfully combined.
Table 2. Quality assessment of case series.

<table>
<thead>
<tr>
<th>Item</th>
<th>+</th>
<th>-</th>
<th>?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Are the characteristics of the study group clearly described?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Is there a high risk of selection bias? Are the inclusion and exclusion criteria clearly described?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Is the intervention clearly described? Are all patients treated according to the same intervention?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Are the outcomes clearly described? Are adequate methods used to assess the outcome?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Is blinding used to assess the outcome?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Is there a sufficient follow-up?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Can selective loss-to follow-up sufficiently be excluded?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Are the most important confounders or prognostic factors identified and are these taken into consideration with respect to the study design and analysis?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Five or more plusses = methodologically acceptable.

**Statistical analysis**
With respect to the quality assessment, agreement between both reviewers was calculated using Cohen’s kappa ($\kappa$) statistics.

For the meta-analysis the statistical software package “Meta-analysis” was used (Comprehensive Meta-analysis Version 2.2, Biostat, Englewood NJ (2005), www.meta-analysis.com). For the calculation of the overall effects for the included studies, weighted rates together with random effects models were used. Stratification procedures were applied for follow-up time and type of intervention. Within each stratum, heterogeneity between included studies was checked by human eyeball criteria.

**Results**

**Description of studies**
The MEDLINE search provided 610 hits, the EMBASE search 23 hits and the CENTRAL search 27 hits. After scanning of titles and abstracts, 86 articles were selected and screened as full text articles. Reference-checking of relevant reviews and included studies revealed one additional article (Hall et al. 2006). However, this report showed to be a shortened version of a later publication (Hall et al. 2007) and did not contain any new information. A number of 41 studies did not satisfy
the inclusion criteria because data of single-tooth implants in anterior and posterior zones was not presented separately or adjacent implants were also included, making it not possible to extract proper data. Furthermore, 14 studies were excluded due to improper study design (not longitudinal or not prospective) and 5 studies because of a follow-up < 1 year. A total of 26 articles fulfilled the inclusion and exclusion criteria and were assessed methodologically. Of these 26 studies, 7 studies were excluded. Reasons for exclusion are depicted in Table 3.

Table 3: Studies excluded after quality assessment and reasons for exclusion.

<table>
<thead>
<tr>
<th>Study</th>
<th>Study design</th>
<th>Reasons for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Henriksson 2004</td>
<td>Clinical trial</td>
<td>Heterogeneity in clinical procedure (different implants, different load-free periods), in/exclusion criteria unclear, no blinding used, prognostic factors/confounders not considered.</td>
</tr>
<tr>
<td>Lorenzoni 2003</td>
<td>Case series</td>
<td>Patients not treated according to same intervention (immediate and conventional placement included), in/exclusion criteria unclear, no blinding used, prognostic factors/confounders not considered.</td>
</tr>
<tr>
<td>Ferrara 2006</td>
<td>Case series</td>
<td>High risk of selection bias (implants with insufficient primary stability were excluded; method to assess stability not clear), outcomes not clearly described, methods used to assess the outcome unclear, no blinding used, prognostic factors/confounders not considered.</td>
</tr>
<tr>
<td>Grunder 2000</td>
<td>Case series</td>
<td>Patients characteristics unclear, in/exclusion criteria unclear, no blinding used, prognostic factors/confounders not considered.</td>
</tr>
<tr>
<td>Locante 2004</td>
<td>Case series</td>
<td>Patients not treated according to same intervention (immediate and conventional placement included), high risk of selection bias (implants with insufficient primary stability were excluded; method to assess stability not clear), in/exclusion criteria unclear, no adequate methods used to assess the outcome, no blinding used, follow-up routine unclear, prognostic factors/confounders not considered.</td>
</tr>
<tr>
<td>Groisman 2003</td>
<td>Case series</td>
<td>Patient characteristics unclear, high risk of selection bias (only favorable cases selected), method of assessment not clear, no blinding used, prognostic factors/confounders not considered, follow-up routine unclear.</td>
</tr>
<tr>
<td>Barone 2006</td>
<td>Case series</td>
<td>Patient characteristics not clear, high risk of selection bias (only favorable cases selected), no blinding used, prognostic factors/confounders not considered.</td>
</tr>
</tbody>
</table>
The κ-value for inter-assessor agreement on the methodological quality was 0.89. Disagreements were generally caused by slight differences in interpretation and were easily resolved in a consensus meeting. Finally, 19 publications remained for data extraction. Figure 1 outlines the algorithm of the study selection procedure. Of the included studies, 5 were RCTs, 2 were clinical trials and 12 were case series. Six publications presented outcomes of the same patient population, but differed in follow-up (Palmer et al. 1997, 2000, Cooper et al. 2001, 2007, Jemt & Lekholm 2003, 2005) and results of one study group were reported in two different publications addressing different topics (Schropp et al. 2005a, 2005b).

**Figure 1. Algorithm of study selection procedure.**

Identified articles
- MEDLINE search: n = 610
- EMASE search: n = 23
- CENTRAL search: n = 27

Included for full text analysis n = 86

Included for methodological appraisal n = 26

Included for data analysis n = 19

Excluded articles
- Improper study design
- Non-topic related
- No abstract available
- Follow-up < 1 year

Excluded articles
- Required data not presented
- Improper study design
- Follow-up < 1 year

Excluded articles
- Grunder 2000; Groisman et al., 2003; Lorenzoni et al., 2003; Locante et al., 2004; Henriksson et al., 2004; Ferrara et al., 2006; Barone et al., 2006

Most of the studies only evaluated maxillary implants, but three studies did also include implants placed in the mandible (38 implants in total) (Schropp et al. 2005a, Schropp et al. 2005b, Romeo et al. 2008). Furthermore, implants were installed mostly in completely healed extraction sockets or early after extraction (10 days to 4 weeks) and subsequently were restored according to immediate, early (1 to 3 weeks after implant placement) or conventional loading protocols. Restorations that were seated immediate or early after implant placement, were
<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention</th>
<th>Design</th>
<th>No. of patients/implants</th>
<th>Implant system</th>
<th>Reason(s) for tooth loss (no.)</th>
<th>Follow-up period (yrs)</th>
<th>No. of implant drop-outs</th>
<th>Survival rate (%)</th>
<th>Change in marginal bone level ± SD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kan 2003</td>
<td>Immediate placement and immediate loading</td>
<td>CS</td>
<td>35/35</td>
<td>Replace Select</td>
<td>Fracture (15), endodontic failure (12), root resorption (8)</td>
<td>1</td>
<td>0</td>
<td>100</td>
<td>- 0.24 ± 0.35* **</td>
</tr>
<tr>
<td>De Rouck 2008</td>
<td>Immediate placement and immediate loading</td>
<td>CS</td>
<td>30/30</td>
<td>Replace Select</td>
<td>Fracture (10), caries/endodontic (9), periodontal (7), root resorption (4)</td>
<td>1</td>
<td>1</td>
<td>97</td>
<td>- 0.88 ± 0.52* **</td>
</tr>
<tr>
<td>Lindeboom 2006</td>
<td>Immediate placement vs conventional placement</td>
<td>RCT</td>
<td>25/25</td>
<td>Frialit-2</td>
<td>NR</td>
<td>1</td>
<td>2</td>
<td>92</td>
<td>- 0.51 ± 0.12* **</td>
</tr>
<tr>
<td>Schropp 2005 (a)</td>
<td>Early placement vs conventional placement</td>
<td>RCT</td>
<td>23/23</td>
<td>3i</td>
<td>Root fracture (NR), endodontic failure (NR), periodontitis (NR), advanced caries lesions (NR)</td>
<td>2</td>
<td>NR</td>
<td>NR</td>
<td>- 0.8 ± NR ‡</td>
</tr>
<tr>
<td>Schropp 2005 (b)</td>
<td>Early placement vs conventional placement</td>
<td>RCT</td>
<td>23/23</td>
<td>3i</td>
<td>Root fracture (NR), endodontic failure (NR), periodontitis (NR), advanced caries lesions (NR)</td>
<td>2</td>
<td>3</td>
<td>91</td>
<td>- 0.7 ± NR ‡</td>
</tr>
<tr>
<td>Gotfredsen 2004</td>
<td>Early placement vs conventional placement</td>
<td>CT</td>
<td>10/10</td>
<td>Astra Tech</td>
<td>Root fracture (15), agenesis (3), trauma (2)</td>
<td>5</td>
<td>0</td>
<td>100</td>
<td>- 0.34 ± 0.57* **</td>
</tr>
<tr>
<td>Romeo 2008</td>
<td>Immediate placement</td>
<td>CS</td>
<td>48/48</td>
<td>ITI</td>
<td>Caries/endodontic with root or crown fracture (NR)</td>
<td>1</td>
<td>0</td>
<td>100</td>
<td>NR</td>
</tr>
<tr>
<td>Study</td>
<td>Intervention</td>
<td>Design</td>
<td>No. of patients/implants</td>
<td>Implant system</td>
<td>Reason(s) for tooth loss (no.)</td>
<td>Follow-up period (yrs)</td>
<td>No. of implant dropouts*</td>
<td>Survival rate (%)</td>
<td>Change in marginal bone level ± SD (mm)</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------------------------</td>
<td>--------</td>
<td>--------------------------</td>
<td>----------------</td>
<td>--------------------------------</td>
<td>------------------------</td>
<td>------------------------</td>
<td>------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>Hall 2007</td>
<td>Immediate loading vs conventional loading</td>
<td>RCT T C</td>
<td>14/14 14/14</td>
<td>Southern Implants</td>
<td>NR</td>
<td>1</td>
<td>1 2</td>
<td>93 100</td>
<td>-0.63 ± 1.00†  -0.78 ± 1.01‡</td>
</tr>
<tr>
<td>Ericsson 2000</td>
<td>Immediate loading vs conventional loading</td>
<td>CT T C</td>
<td>14/14 8/8</td>
<td>Brånemark</td>
<td>NR</td>
<td>1.5</td>
<td>2 0</td>
<td>85.7 100</td>
<td>-0.14 ± 0.36 † -0.07 ± 0.79§</td>
</tr>
<tr>
<td>Cooper 2001</td>
<td>Early loading</td>
<td>CS</td>
<td>48/54</td>
<td>Astra Tech</td>
<td>NR</td>
<td>1</td>
<td>3</td>
<td>94.4 ±</td>
<td>-0.4 ± NR§</td>
</tr>
<tr>
<td>Cooper 2007</td>
<td>Early loading</td>
<td>CS</td>
<td>48/54</td>
<td>Astra Tech</td>
<td>NR</td>
<td>3</td>
<td>11</td>
<td>94.4</td>
<td>-0.42 ± 0.59§</td>
</tr>
<tr>
<td>Andersen 2002</td>
<td>Early loading</td>
<td>CS</td>
<td>8/8</td>
<td>ITI</td>
<td>NR</td>
<td>5</td>
<td>0</td>
<td>100</td>
<td>+0.53 ± NR§</td>
</tr>
<tr>
<td>Meijndert 2007</td>
<td>Conventional</td>
<td>RCT</td>
<td>93/93</td>
<td>ITI</td>
<td>NR</td>
<td>1</td>
<td>2</td>
<td>97.8 NR</td>
<td></td>
</tr>
<tr>
<td>Jemt 2003</td>
<td>Conventional</td>
<td>CS</td>
<td>10/10</td>
<td>Brånemark</td>
<td>Trauma (10)</td>
<td>3</td>
<td>1</td>
<td>100</td>
<td>-0.3 ± 0.36†</td>
</tr>
<tr>
<td>Jemt 2005</td>
<td>Conventional</td>
<td>CS</td>
<td>10/10</td>
<td>Brånemark</td>
<td>Trauma (10)</td>
<td>6</td>
<td>2</td>
<td>100</td>
<td>-0.3 ± 0.24 †</td>
</tr>
<tr>
<td>Zarone 2006</td>
<td>Conventional</td>
<td>CS</td>
<td>30/34</td>
<td>ITI</td>
<td>Agenesis (30)</td>
<td>2 - 3.2</td>
<td>1</td>
<td>100</td>
<td>-1.2 ± 0.61§</td>
</tr>
<tr>
<td>Palmer 1997</td>
<td>Conventional</td>
<td>CS</td>
<td>15/15</td>
<td>Astra Tech</td>
<td>NR</td>
<td>2</td>
<td>1</td>
<td>100</td>
<td>+0.01 ± 0.50 †</td>
</tr>
<tr>
<td>Palmer 2000</td>
<td>Conventional</td>
<td>CS</td>
<td>15/15</td>
<td>Astra Tech</td>
<td>NR</td>
<td>5</td>
<td>1</td>
<td>100</td>
<td>+0.12 ± 0.49 §</td>
</tr>
<tr>
<td>Cardaropoli 2006</td>
<td>Conventional</td>
<td>CS</td>
<td>16/16</td>
<td>Brånemark</td>
<td>NR</td>
<td>1</td>
<td>5</td>
<td>100</td>
<td>-1.6 ± 0.57 §**</td>
</tr>
</tbody>
</table>

*Standard deviation calculated. **Defined as implants that did not survive and implants lost to follow-up. †From implant placement. ‡From healing abutment placement. §From temporary crown placement. ¶From definitive crown placement. Abbreviations: NR= not reported, RCT=randomized clinical trial, CT= clinical trial, CS = case series, T = test group, C = control group.
### Table 5. Outcomes of included studies, arranged according to type of intervention and study design.

<table>
<thead>
<tr>
<th>Study</th>
<th>Aesthetics (range)</th>
<th>Patient satisfaction (range)</th>
<th>Papilla index</th>
<th>Level of marginal gingiva ± SD (mm)</th>
<th>Probing depth ± SD (mm)</th>
<th>Presence of plaque</th>
<th>Bleeding on probing</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kan 2003</td>
<td>NR</td>
<td>9.9 (9 - 10)</td>
<td>NR</td>
<td>-0.55 ± 0.53 ‡</td>
<td>NR</td>
<td>26%</td>
<td>NR</td>
<td>4 fistula, 2 temporary abutments loosened</td>
</tr>
<tr>
<td>De Rouck 2008</td>
<td>NR</td>
<td>9.3 (8.2-10)</td>
<td>NR</td>
<td>-0.53 ± 0.76 ‡</td>
<td>3.46 ± 0.69</td>
<td>17%</td>
<td>41%</td>
<td>1 crown loosened</td>
</tr>
<tr>
<td>Lindeboom 2006</td>
<td>T, C</td>
<td>NR</td>
<td>NR</td>
<td>22% score 2, 78% score 3</td>
<td>61% proper level</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Schropp 2005 (a)</td>
<td>T, C</td>
<td>NR</td>
<td>NR</td>
<td>resp. 8%,35%,57% score 0,1,2 *</td>
<td>83% proper level</td>
<td>NR</td>
<td>NR</td>
<td>1 fistula, exposure of metal margins in 4 cases</td>
</tr>
<tr>
<td>Schropp 2005 (b)</td>
<td>T, C</td>
<td>NR</td>
<td>NR</td>
<td>resp. 3%,34%,63% score 0,1,2 *</td>
<td>50% proper level</td>
<td>NR</td>
<td>NR</td>
<td>1 fistula, exposure of metal margins in 4 cases</td>
</tr>
<tr>
<td>Gotfredsen 2004</td>
<td>T, C</td>
<td>5.9 (2.9 - 9.5)</td>
<td>9.6 (7.1 - 10)</td>
<td>-0.3 ± 0.5 † + 0.3 ± 0.6 †</td>
<td>NR</td>
<td>21% (pooled data)</td>
<td>38% (pooled data)</td>
<td>2 soft tissue dehiscences, 1 fistula, 2 abutments loosened</td>
</tr>
<tr>
<td>Romeo 2008</td>
<td>NR</td>
<td>NR</td>
<td>67% score 3 *</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>No complications</td>
</tr>
<tr>
<td>Hall 2007</td>
<td>T, C</td>
<td>NR</td>
<td>resp. 18%,51%,31% score 1,2,3 (pooled data)</td>
<td>-0.67 ± 0.49 † -0.33 ± 0.78 †</td>
<td>No sign. diffs.</td>
<td>No sign. diffs.</td>
<td>No sign. diffs.</td>
<td>1 temporary crown fractured</td>
</tr>
<tr>
<td>Ericsson 2000</td>
<td>T, C</td>
<td>All patients satisfied</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>25%</td>
<td>17%</td>
<td>1 temporary crown loosened twice</td>
</tr>
<tr>
<td>Study</td>
<td>T</td>
<td>C</td>
<td>NR</td>
<td>NR</td>
<td>NR + 0.34 ± 0.94</td>
<td>NR</td>
<td>0.5% of sites examined</td>
<td>NR</td>
</tr>
<tr>
<td>---------------</td>
<td>---</td>
<td>---</td>
<td>----</td>
<td>----</td>
<td>-----------------</td>
<td>----</td>
<td>---------------------</td>
<td>----</td>
</tr>
<tr>
<td>Cooper 2001</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>+ 0.51 ± 1.42</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Andersen 2002</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Meijndert 2007</td>
<td>66% acceptable</td>
<td>8.5 (6-10)</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Jemt 2003</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Jemt 2005</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>- 0.1 ± NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Zarone 2006</td>
<td>3% not satisfactory</td>
<td>NR</td>
<td>resp. 6%, 12%, 82% score 1, 2, 3</td>
<td>-0.6 ± NR</td>
<td>2.6 ± 0.2 #</td>
<td>18%</td>
<td>No bleeding</td>
<td>No implant-related complications.</td>
</tr>
<tr>
<td>Palmer 1997</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>No recession</td>
<td>NR</td>
<td>NR</td>
<td>No bleeding</td>
</tr>
<tr>
<td>Palmer 2000</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>No recession</td>
<td>NR</td>
<td>NR</td>
<td>Rare</td>
</tr>
<tr>
<td>Cardaropoli 2006</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>resp. 14%, 68%, 18% score 1, 2, 3</td>
<td>-0.6 ± 0.7</td>
<td>2.4 ± 0.8</td>
<td>9%</td>
</tr>
</tbody>
</table>

*Modification of Papilla Index. † Mean VAS-scores for aesthetic appearance and general function. #Standard deviation calculated. ‡ From implant placement. § From temporary crown placement. ¶ From definitive crown placement. Abbreviations: T = test group, C = control group, NR = not reported.
all kept out of direct occlusal contact. Two studies reported on immediately restored implants placed directly after tooth extraction. All clinical trials except one compared the outcome of immediate or early implant placement and immediate or early implant loading with conventional approaches. This RCT focused on different bone augmentation procedures and all implants were placed and restored conventionally according to the same protocol (Meijndert et al. 2007). Characteristics of the included studies are presented in Table 4 and are arranged according to type of intervention and study design.

Due to methodological diversity of the ‘acceptable’ studies, only data on implant survival and to a limited degree marginal bone resorption could be meaningfully combined in a meta-analysis. Therefore, the outcomes are mainly presented as a descriptive review in the subsequent sections and are depicted in Table 4 and 5.

**Implant survival**

The implant survival rate was defined as the percentage of implants that was still present at follow-up. All implants that were lost, failed within the first six months after placement. In some studies implant mobility was detected at second stage surgery (seven implants) (Schropp et al. 2005b, Lindeboom et al. 2006, Meijndert et al. 2007) or occurred following placement of the provisional restoration (one implant) (Cooper et al. 2001), whereas other implants were already in function when they appeared not to be osseointegrated (six implants) (Ericsson et al. 2000, Cooper et al. 2001, Hall et al. 2006, De Rouck et al. 2008). Altogether, a total number of 509 single-tooth implants was originally installed in 499 patients of which 13 patients and 13 implants were lost to follow-up and no information on survival was available regarding these implants. A total of 14 implants did not survive.

Since it is generally known that implant loss is most often observed early after implant installation and/or implant restoration, event rates and survival rates were calculated in a stratified manner. To that end, results are presented for implants that were followed up to one year after implant restoration (including implants that were lost before restoration and consequently were not yet in function) and implants with an observation period of more than one year after restoration (with a correction for implants that were lost within the first year after restoration). Results of the weighted meta-analysis (for study size) of implant loss within one year, expressed as event rates, are shown in Figure 2. The overall event rate was calculated as 0.045 (95% confidence interval (CI): 0.029 – 0.070) and can be expressed as a survival rate of 95.5% (95% CI: 93.0 – 97.1). The weighted meta-analysis (for person-years and study-size) regarding loss of implants that are more than one year in function, showed an event rate of 0.007 (95% CI: 0.003 – 0.019).
Globally four different treatment strategies could be identified. In this matter, survival outcomes of immediate and early placed implants that were restored conventionally were combined as well as implants that were installed conventionally but were restored immediately or early. Results of the weighted (for study-size) stratified meta-analysis are presented in Table 6, revealing no differences in survival rate after one-year follow-up. Focussing on the studies individually, no statistically significant differences in implant survival were found in clinical trials comparing immediate or early implant procedures with conventional ones.
Marginal bone level changes

All articles except three reported on changes in marginal peri-implant bone levels determined radiographically. Most of the studies used intra-oral radiographs obtained according to a standardized paralleling technique, although it was questionable whether Cooper et al. (2001), Jemt and Lekholm (2003, 2005), Palmer et al. (1997, 2000) and Gotfredsen (2004) used standardized radiography for their measurements. There was variety in the peri-implant bone level evaluation over time since studies used different starting points for their analysis. In the various studies, the first radiographic examinations had been performed just after implant placement, after healing abutment connection, at provisional crown placement or at definitive crown placement. Because of this heterogeneity, it was not possible to perform an analysis from which conclusions could be drawn concerning differences in marginal bone changes between the several treatment strategies. However, some insight could be gained into crestal bone changes occurring from definitive crown placement to one year thereafter in patients treated conventionally. The five studies included for this weighted (for study-size) meta-analysis (viz. Palmer et al. 1997, Ericsson et al. 2000, Gotfredsen 2004, Jemt & Lekholm

<table>
<thead>
<tr>
<th>Intervention</th>
<th>No. of patients/implants</th>
<th>No. of studies included</th>
<th>No. of implants lost to follow-up</th>
<th>No. of implants that not survived</th>
<th>Calculated survival rate (%) [95% CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate placement and immediate loading</td>
<td>65/65</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>97.5 [88.3 - 99.5]</td>
</tr>
<tr>
<td>Immediate/early placement, conventional loading</td>
<td>106/106</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>93.6 [85.4 - 97.3]</td>
</tr>
<tr>
<td>Conventional placement, immediate/early loading</td>
<td>84/90</td>
<td>4</td>
<td>0</td>
<td>6</td>
<td>92.4 [84.4 - 96.4]</td>
</tr>
<tr>
<td>Conventional placement, conventional loading</td>
<td>244/248</td>
<td>11</td>
<td>11</td>
<td>3</td>
<td>96.8 [85.7 - 97.2]</td>
</tr>
</tbody>
</table>

* These implants were not included in the analysis.

Abbreviations: CI=confidence interval.

Table 6. Stratified meta-analysis of implant survival after one-year.
2005, Cardaropoli et al. 2006) (in total 52 implants) revealed a mean marginal bone loss of 0.20 mm (95% CI: 0.034 – 0.36) during the first year after installation of the definitive crown (see Figure 3). Data from radiographic examinations were mostly presented as mean values and consequently no frequency distributions were given. Cooper et al. (2001) considered the incidence of marginal bone loss of 48 implants one year after insertion. The latter authors found that after one year eight implants showed a cortical bone loss of 1.0 to 2.0 mm and three implants more than 2.0 mm. Finally, the bone level changes detected in the experimental and conventional study groups of the included clinical trials were not significantly different.

**Figure 3. Meta-analysis of marginal bone level changes 1 year after installation of the definitive crown.**

![Graph showing marginal bone level changes](image)

Aesthetics
Albeit all implants reviewed were inserted in the aesthetic zone, only three studies included the aesthetic outcome in their analysis. Zarone et al. (2006) considered one implant not being satisfactory because of exposure of the titanium neck. It was, however, unclear how the aesthetics were measured. At the three-year control visit Gotfredsen (2004) asked an independent dentist to evaluate the aesthetic appearance of the implant crowns using a visual analog scale (VAS) ranging from ‘very unsatisfied’ (score 0) to ‘very satisfied’ (score 10). In the study by Meijndert et al. (2007), a prosthodontist rated the aesthetics on colour photographs using an objective rating index. It appeared that 34% of the cases were judged as poor aesthetics.
**Peri-implant structures**

To evaluate the quantity of the interproximal gingival papillae, some studies made use of the papilla index according to Jemt (1997) or a slight modification of this classification (Schropp et al. 2005a, Romeo et al. 2008). It revealed that in these studies an increase of tissue volume in the embrasures could be observed during follow-up. For instance, Jemt and Lekholm (2003) found a mean papilla index of 1.1 at crown placement (score 1 and 2 denote, respectively, less than half of the height and at least half of the height of the proximal area filled by soft tissue) while at two-year follow-up a mean score of 2.4 was found (score 3: complete closure of proximal space with soft tissue). The majority of the papillae analyzed were associated with papilla index scores of 2 or 3 after follow-up, but no significant differences were observed between the different test and control groups.

With respect to the marginal peri-implant mucosal level, Schropp et al. (2005a) reported that the clinical crown height was acceptable in significantly more cases in the early placement group than in the conventional group at follow-up; of the latter almost two-thirds of the crowns were assessed to be too short. The same difference was found by Gotfredsen (2004), although not reported as significant. Lindeboom et al. (2006) observed that gingival recession was more prominent in the immediately-placed implant group, but the sample size was too small to demonstrate a significant difference. Hall et al. (2006) found no statistical significant differences between immediately or conventionally restored implants. Jemt and Lekholm (2005) reported that implant crowns were on average 0.7 mm longer than the contralateral natural crowns after five-year follow-up. The same value was recorded by Gotfredsen (2004) after five-year and he found that 17 of the 20 implant crowns were too long. The studies by De Rouck et al. (2008) and Kan et al. (2003) measured the levels of the midfacial gingival level before tooth removal and after immediate implant placement and restoration. After one-year follow-up, both studies reported a significant soft tissue loss of respectively 0.53 mm and 0.55 mm at the midfacial aspect.

Only a few studies recorded peri-implant probing pocket depths. Schropp et al. (2005b) observed a mean reduction in probing depth of 0.5 mm during the two-year observation period to a mean probing depth of 4.2 mm. The mean probing depths presented by other studies were clearly lower. Studies that assessed the presence of plaque on the surfaces of the implant restoration showed high variance in outcome from 0.5 % to 61% of sites examined. According to bleeding on probing, the same phenomenon could be observed.

**Patient satisfaction**

Four studies assessed patient satisfaction regarding the final aesthetics and one study (Gotfredsen, 2004) also evaluated the general functioning of the implant
restoration. High satisfaction scores were reported. Three studies (Gotfredsen 2004, Meijndert et al. 2007, De Rouck et al. 2008) made use of a VAS (range 0-10), one study (Kan et al. 2003a) of a scale ranging from very unsatisfied (score 0) to very satisfied (score 10), and in one study (Ericsson et al. 2000) patients were asked about their satisfaction with the aesthetic outcome.

**Complications**
The complications described in the various articles were subdivided in biological and technical ones. With respect to biological complications, the authors reported on fistula formations, peri-implant mucositis and soft tissue dehiscences. All fistula subsided after placement of the definitive restoration (Andersen et al. 2002, Kan et al. 2003a) or after non-invasive therapy (Gotfredsen 2004, Schropp et al. 2005b). In the study by Schropp et al. (2005b) exposure of metal margins was found in four patients. In three cases, the margin became exposed during the observation period because of soft tissue recession. In one case, the metal margin of the crown was present just after crown placement, but became covered with peri-implant mucosa during function.

Technical complications that were notified were loosening of (temporary) abutments and loosening or fractures of (temporary) crowns. In most of the cases, abutments could be retightened and crowns could be recemented easily. In the study by Andersen et al. (2002) three out of eight definitive crowns loosened after approximately one year. In two of these cases, this was a direct result of a new trauma.

It could be noticed that not all studies provided data regarding complications other than implant loss and crestal bone resorption. Concerning the comparative studies, only Gotfredsen (2004) found more complications in the experimental ‘early placement’ study group. However, these implants were restored with standard abutments, while preparable abutments were used for the conventional implants and the author believed that the technical complications were probably more related to this difference.

**Discussion**
This systematic review assessed the outcome of single-tooth implants in terms of implant survival, marginal bone level changes, aesthetics, soft tissue aspects, patient satisfaction and complications. Aside from the traditional approaches of implant installation and restoration, more progressive treatment strategies of immediate or early implant placement and immediate or early loading were considered for evaluation. Unfortunately, we could not draw firm conclusions regarding the most preferable treatment strategy, owing to the lack of controlled clinical trials.
Notwithstanding these limitations, promising results were reported for immediate, early and conventional single-tooth implant procedures in the aesthetic zone.

The implant survival meta-analysis on implants in the aesthetic zone up to one year after implant restoration, revealed an overall survival rate of 95.5% (95% CI: [93.0 – 97.1]) irrespective of the type of intervention. It should be stated that, with respect to the loss of implants that are more than one year in function, a very low event rate was calculated (0.007 (95% CI: [0.003 – 0.019]). In general, late implant losses are attributed to fracture of the implant, overload and peri-implantitis in particular (Quirynen et al. 2007). In reference to the last, the strict in- and exclusion criteria implemented in most of the included trials such as good oral hygiene, uncontrolled periodontal disease or smoking concomitant with close follow-up routines, could limit the development of peri-implantitis and thereupon late implant failure. Of course, in this view, the relative short follow-up periods of the included studies have to be taken into account.

The high implant survival rate (95.5% after one year) reported in the present review, are in line with other reviews reporting on survival rates of single-tooth implants (Creugers et al. 2000, Berglundh et al. 2002, Jung et al. 2008). However, the last two reviews only included studies with follow-up periods of at least five year, justifying that a comparison with our calculated survival rate should only be made with caution. Furthermore, these reviews aggregated implant survival of diverging indications, including anterior and posterior, and maxillary and mandibular single-tooth replacements. Particularly the posterior maxilla constitutes an area of challenge due to the presence of the maxillary sinus and the low bone density frequently found here. Long-term implant survival studies have even indicated that the posterior maxilla presents the lowest survival rate (Graziani et al. 2004). Apparently, this does not count for the survival of maxillary anterior single-tooth implants.

The more progressive protocols, where implants are immediately installed in fresh extraction sockets or immediately loaded, scored comparable survival percentages as the conventional protocol of installation and restoration. Although no differences were noted neither in the stratified meta-analysis nor in the included clinical trials, these results should only be conceived as a tendency, since these were based on only a few (randomized) controlled trials and a low number of patients.

Two studies were included investigating the most escalating approach, viz. immediately loading of immediately placed implants. All implants integrated successfully. In these case series only patients were enrolled satisfying strict inclusion and exclusion criteria like presence of adequate bone volume without the necessity of bone grafting, an intact labial bony plate after tooth extraction, complementary soft tissue dimensions and ability to achieve good implant stability. It implies that
this modality should be implemented with caution and should be preceded by careful patient selection and treatment planning. The same hold true for immediate or early implant loading of implants placed in healed sites. Studies investigating these approaches, pointed out the importance of good initial implant stability before loading and all provisional crowns were cleared from occlusion.

It was only possible to combine the outcome measures of implant survival and to a limited degree crestal bone changes in a stratified meta-analysis. Reasons were that different outcomes or time points were used or some variables were not taken into consideration. With reference to the clinical trials, for only one outcome measure a significant difference was observed. Schropp et al. (2005a) reported that the level of the marginal peri-implant mucosa was acceptable in significantly more cases where implants were installed in early healed extraction sites compared to conventionally healed sites; of the latter almost two-thirds of the crowns were assessed to be too short. All other clinical trials failed to show any significant differences.

Remarkably, only three studies assessed the aesthetic outcome of which only one study made use of an objective aesthetic index. The lack of documentation of well-defined aesthetic parameters in anterior implant research was demonstrated earlier by Belser et al. (2004). Nowadays, two instruments are available that aim to objectify the aesthetic outcome of single-tooth implant crowns, namely the Implant Crown Aesthetic Index to measure the aesthetics of crown and mucosa (Meijer et al. 2005) and the Pink Esthetic Score (Furhauser et al. 2005) which focuses on soft tissue solely. It was concluded that both indexes showed reproducibility, based on calculations of intra- and interobserver agreement. However, the validity of these indexes was not investigated and although they show good face validity, the construct validity in particular needs further research. Because these indexes were developed fairly recently, this could be a prominent reason that only Meijndert et al. (2007) used the Implant Crown Aesthetic Index, apart from the fact that the latter authors introduced this index (Meijer et al., 2005). Meijndert et al. (2007) reported that in 34% of the cases, the aesthetics were not acceptable, which is a rather high percentage. It must be noted, however, that in all cases a local bone augmentation procedure was needed prior to implantation because of severe bone deficiencies. This implies again the significance of the aesthetic appearance before implant treatment and that the final aesthetics might be strongly related to that appearance. To illustrate, when the starting point is favorable, favorable aesthetics could be expected from an implant based single-tooth replacement, both from the patient’s and professional’s perspectives, while an unfavorable starting point might lead to satisfactory results from the patient’s perspective while the professionals objective judgement might be unfavorable. This incongruity might lead easily to bias in aesthetic implant research.
It is widely accepted that randomized controlled trials (RCTs) provide ‘gold standard’ evidence of the effectiveness of therapies. However, there is scarcity of existing RCTs in implant research, probably caused by medical-ethical reasons, costs or workload involved in this type of research. Nevertheless, relevant information is not exclusively provided by RCTs for matters of longevity. Cohort-studies, case series and clinical trials could also provide valuable longitudinal information. Therefore, these types of studies were considered for evaluation too. It appeared that seven eligible comparative trials could be included, of which four studies examined immediate or early implant placement, two studies immediate implant loading and one study focussed on different bone augmentation procedures prior to implantation. Sample sizes were relatively small and presumably underpowered to demonstrate significant differences between experimental and conventional single-tooth implant approaches. Furthermore, not all clinical trials randomly allocated patients to the study groups and for three trials it was unclear if the outcome assessors were blinded. Probably, some trials were confounded by the type of prosthetic restoration as Schropp et al. (2005b) and Gotfredsen (2004) made use of different types of abutments and Ericsson et al. (2000) reported that ceramic or metal-ceramic crowns were utilized. Probably, these variances could have their influence on parameters like the aesthetic outcome and patient satisfaction.

The remaining studies included for this review, could be classified as case series and as a consequence were of a lower level of evidence. Although these studies were well documented and methodological acceptable within their framework, results of these studies should be interpreted with caution. Selection and measurement bias will always be present in case series, together with a potential risk of incorporation bias, favoring the final outcome of the intervention. Moreover, for most of the case series it was not reported or unclear whether consecutive recruitment was used. Non-consecutive enrolment may lead to selection of patients with more favorable pre-operative conditions.

Besides the low number of RCTs and small study groups, one of the major drawbacks of the reviewed literature was the lack of sufficient follow-up. Eight of the included studies followed their patients for only one year. It is noteworthy that, on the other hand, only a small number of patients were lost to follow-up. In our opinion, the follow-up periods were too short to lead to definitive conclusions as to whether a single-tooth implant in the aesthetic zone is a reliable therapy over the long term. However, since there is sufficient evidence in present implantology that implant losses predominately occur within the first months after placement, the favorable short term survival rates of single implant replacements in the anterior zone might justify the expectations of a successful long-term survival. For other parameters including aspects of the peri-implant mucosa, aes-
thetic outcome and patient satisfaction, more long-term research is needed, such as cohort-studies.

In conclusion, evidence from the included literature suggest that single-tooth implants in the aesthetic zone with natural adjacent teeth will lead to (short-term) successful treatment outcomes regarding implant survival, marginal bone level changes and incidence of biological and technical complications. However, with reference to quality of study design, number of patients included and follow-up duration, the included studies showed inadequacies. Moreover, other parameters of utmost importance as the aesthetic outcome, soft tissue aspects, and patient satisfaction were clearly underexposed. The question whether immediate and early implant placement or immediate and early implant loading will result in comparable – or even better – treatment outcomes than conventional implant protocols of installation and restoration, remains inconclusive. Thus, more well-designed (randomized) comparative trials are needed investigating objective aesthetic and satisfaction parameters in particular, to verify these treatment strategies.
References


