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Outcome of implant-supported single-tooth replacements performed by dental students. A 10-year clinical and radiographic retrospective study

Key words  complications, dental implants, dental students, oral implants, retrospective study

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Conflict of interest: None.

Aim: To evaluate the treatment outcome of implant-supported single-tooth replacements performed by dental students as part of their undergraduate dental curriculum after a mean follow-up period of 10 years (range: 7.5 to 12 years).

Materials and methods: A total of 51 patients were consecutively treated by dental students with 55 implants supporting single crowns. The treatment was performed under supervision of dentists and oral and maxillofacial surgeons, all with special knowledge about oral implantology. Survival of implant crown, survival of implant, probing depth, bleeding on probing and peri-implant marginal bone level change were evaluated at the end of the follow-up period. In addition, biological and technical complications during the entire follow-up period were assessed.

Results: A total of 45 patients with 49 implants were available at the end of the study. The survival of the implant crowns as well as the implants was 94%. The mean probing depth at patient level was 4.8 mm. The probing depth varied between 2 and 10 mm at the individual site. The mean bleeding on probing score was 0.57 at patient level and absence of bleeding around all sites of the implants was rarely observed. The mean bone level change was -0.14 mm (range: 1.2 to -1.1 mm) during the first year of loading and 0.16 mm (range: 1.4 to -1.8) after 10 years at patient level. Five episodes of peri-implant inflammation due to excess cement were registered in five patients. Moreover, a fistula was observed at two implants in two patients. Finally, five technical complications occurred in five patients.

Conclusions: Implant-supported single-tooth replacements performed by dental students as part of their undergraduate dental curriculum were characterised by high survival rates as well as few biological and technical complications. It seems acceptable to include implant therapy in the clinical undergraduate dental curriculum, provided a focus remains on straightforward cases with substantial supervision by trained dentists and oral and maxillofacial surgeons.
Introduction

A recently published systematic review focused on the outcome of single-tooth implant treatment. It was concluded that the 5-year survival of implant crowns and implants were 95% and 97%, respectively. The included patients were treated by dentists with special experience in oral implantology.

It has been discussed whether implant therapy should be included in the clinical undergraduate dental curriculum. However, knowledge about the outcome of implant treatment performed by dental students is scarce. Oral implantology has been included in the theoretical as well as in the clinical undergraduate dental curriculum since 1996 at the School of Dentistry, Aarhus University, Denmark. Consequently, the purpose of the present study was to evaluate the treatment outcome of implant-supported single-tooth replacements performed by dental students as part of their undergraduate curriculum.

Materials and methods

The study was performed in accordance with the STROBE Statement (www.strobe-statement.org).

Patients

Consecutively treated patients with need of an implant-supported single crown within the incisor, canine and premolar regions were included in the study. All included patients were treated by dental students at the Department of Oral and Maxillofacial Surgery & Oral Pathology and the Department of Prosthetic Dentistry, School of Dentistry, Aarhus University, Aarhus, Denmark, between 1996 and 1999 as part of the undergraduate curriculum. The exclusion criteria were:

- previous irradiation of the head and neck region
- previous chemotherapy
- HIV-infection
- substance abuse
- autoimmune diseases
- bone metabolic diseases
- uncontrolled diabetes
- poor oral hygiene
- progressive periodontitis
- pregnant women
- breast-feeding women
- immunosuppression.

A total of 51 patients (22 females, 29 males) with a mean age of 43 years (range: 19 to 79 years) were included in the study (Table 1). At the time of implant placement, six (12%) patients were smokers (two smoked < 10 cigarettes per day, two smoked 10 to 20 cigarettes per day and two smoked > 20 cigarettes per day). The reason for tooth loss was registered for each implant region (Table 2). Most teeth were lost due to root fracture or trauma.

Description of procedures

All treatment procedures were performed by 9th- and 10th-term dental students under supervision by dentists and oral and maxillofacial surgeons, all with special knowledge within the field of oral implantology. However, when an augmentation procedure was indicated, this part of the treatment was performed exclusively by an oral and maxillofacial surgeon.

Bone augmentation

Bone augmentation was carried out in 16 patients (31%) at 17 implant sites (31%). Augmentation procedures were performed before implant placement in 11 patients (22%) with 12 implant sites (22%), concomitant with the implant installation in four patients (8%) with four implant sites (7%) or before as well as concomitant with the implant placement in one patient (2%) with one implant site (2%). The augmentation procedure included: 1) autogenous bone harvested from the mandibular symphysis in six patients with seven implant sites, 2) autogenous bone harvested from the lateral aspect of the mandibular ramus in four patients with four implant sites, 3) local bone adjacent to the implant site in six patients with six implant sites and 4) expanded polytetrafluoroethylene membrane (e-PTFE) (Gore-Tex® Regenerative Material, Gore and Associates, Flagstaff, Arizona, USA) in one patient with one implant site. The autogenous bone was used as a block graft in 10 patients with 11 implant sites or as a particulate bone graft in six patients with six implant sites.
Implant installation

In total, 51 patients were treated with a total of 55 Brånemark implants (Brånemark Mk. II, Nobel Biocare, Göteborg, Sweden) with a turned surface inserted according to the manufacturer recommendations by using a 2-stage procedure. A total of 47 patients were treated with one implant, while four patients were treated with two implants. Implant length, platform and site are summarised in Table 1.

Healing abutment and prosthetic treatment

A healing abutment was placed after a mean submerged healing period of 7 months (range: 3 to 17 months). After 3 to 4 weeks, when the peri-implant soft-tissues were healed, healing abutments were substituted by definitive CeraOne® abutments (Nobel Biocare) with an individually determined height. An impression was taken at the abutment level and a CeraOne ceramic crown was fabricated. All crowns were cemented, first temporarily for 1 to 3 weeks.

<table>
<thead>
<tr>
<th>Gender</th>
<th>No.</th>
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<tr>
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<tr>
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<td>&gt; 20 cigarettes per day</td>
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<tr>
<td>No. of inserted implants</td>
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<td>Implant length</td>
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<td>Implant platform</td>
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<tr>
<td>Narrow platform (3.3 mm)</td>
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<td>Regular platform (3.75 mm)</td>
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<tr>
<td>First premolar</td>
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<td>Periodontitis</td>
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<td>9</td>
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<tr>
<td>Caries, including pulp pathology</td>
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<td>5</td>
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<tr>
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<td>2</td>
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<td>2</td>
<td>4</td>
</tr>
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</table>
weeks and then permanently with phosphate cement (DeTrey® Zinc, Dentsply, Konstanz, Germany) (n=29) or TempBond® (Kerr Corporation, Orange, CA, USA) (n = 22). One crown was cemented temporarily with Momax (Svedia Dental-Industri, Enkoping, Sweden) and removal was impossible. Therefore, Momax was not substituted with permanent cement.

**Plaque control, antibiotics and analgesics**

All patients received oral penicillin (1.6 g) or erythromycin (500 mg) 1 hour before bone grafting as well as implant installation. The antibiotic treatment (penicillin 0.8 g, 3 times daily or erythromycin 500 mg, 3 times daily) was continued for 1 week. Ibuprofen (600 mg, 3 times daily) was prescribed as long as required for pain control for all patients after bone grafting as well as implant placement. Finally, the patients were asked to perform mouth rinsing with 0.12% chlorhexidine digluconate 2 times daily until suture removal.

**Follow-up regimen**

Not all patients were included in a systematic maintenance program after treatment at the School of Dentistry, Aarhus University. Some patients were followed by their own dentists, but biological and technical complications were treated at the School of Dentistry, Aarhus University. However, all patients were recalled for a 1-year follow-up. Moreover, all patients were recalled as part of the present study for follow-up examination after a mean follow-up period of 10 years (range: 7.5 to 12 years). Therefore, the maintenance program varied considerably among the included patients.

**Outcome measures**

The outcome measures were:

- **Survival of implant crown.** Failure of implant crown was defined as loss of the implant crown irrespective of the reason for the loss.
- **Survival of implant.** Implant failure was defined as implant mobility and removal of a stable implant due to progressive peri-implant marginal bone loss. Moreover, an unrestorable implant was considered as a failure.
- **Probing depth.**
- **Bleeding on probing.**
- **Radiographic peri-implant marginal bone level changes.**
- **Biological complications during the follow-up period.**
- **Technical complications during the follow-up period.**

Probing depth and bleeding on probing were measured using a light probing force (approximately 25 g) to the nearest mm with a conventional probe at six sites per implant (mesio-buccally, mid-buccally, disto-buccally, mesio-lingually, mid-lingually and disto-lingually).

Intraoral radiographs were taken with the paralleling technique at the time of CeraOne abutment placement as well as after 1 year and a mean follow-up period of 10 years. The radiographs were digitised by a slide scanner (Nikon Super Coolscan, 5000, Nikon, Tokyo, Japan) after selecting constant scanning settings (600 dpi resolution and 256 grey levels). The images were stored in Tagged Image File Format (TIFF) without compression after coding to provide blinding of the recordings.

The distance from the implant-abutment connection to the level where the alveolar bone merged with the implant surface was measured mesially and distally parallel with the vertical implant axis (Por-DiosW, Institute of Orthodontic Computer Science, Middelfart, Denmark)\(^{10}\). Correction of the magnification was based upon the known distance between implant threads (0.6 mm for regular platform implants and 0.5 mm for narrow platform implants). Brightness, contrast and gamma adjustments could be used for image enhancement.

Each patient’s record was thoroughly reviewed and all biological and technical complications were registered during the follow-up period.

Data management and analysis including calculation of descriptive statistics were conducted using Excel (Microsoft, Redmond, WA, USA) and SPSS (Version 13.0 for Windows, Chicago, IL, USA). All assessments were performed by one person (MB).
Results

Three patients with one single implant each passed away after 6, 9.5 and 9.5 years. A representative case after a 10-year follow-up is presented in Fig 1.

Survival of implant crowns

Three of the 52 initially placed implant crowns were lost in three patients. Consequently, 46 out of the 49 implant crowns (94%) survived at the end of the follow-up period. Two crowns were lost due to trauma after 7 and 9 years, respectively. One crown was lost after 8 years due to total crown fracture. All crowns were replaced by new crowns.

Survival of implants

Three of the 55 initially placed implants were lost in three patients. Consequently, 49 out of the 52 implants (94%) survived. All implants were lost before loading. One implant (3.75 × 13 mm) was lost due to mobility at the time of abutment placement. The implant was placed in the maxillary lateral incisor region in combination with a Gore-Tex membrane due to labial atrophy of the alveolar process. The second failure (3.75 × 15 mm) occurred due to mobility at the time of impression. The implant was installed in the maxillary central incisor region. Augmentation with a block of autogenous bone from the lateral aspect of the mandibular ramus was carried out 4 months before implant placement. The third implant (3.75 × 15 mm) placed in the maxillary central incisor region was removed due to malposition. It was concluded that the implant was placed too far labially, making it impossible to make a cosmetically acceptable crown. All implant failures were substituted by new implants after a 3- to 6-month healing period.

Probing depth

Probing depths are presented in Table 3 at patient, implant and site level. Briefly, the mean probing depth was 4.8 mm at patient level. The probing depth varied between 2 and 10 mm at site level. However, only one implant with probing depths of 10 mm was observed. The implant was inserted very deep within the maxillary central incisor region (Fig 2).
Bleeding on probing

Bleeding on probing is presented in Table 3 at patient, implant and site level. The mean bleeding on probing score was 0.57 at patient level. The scores varied between 0 and 1 at site level. Bleeding on probing was observed at 55% of the sites. Absence of bleeding around all sites of the implants was only observed around three implants.

Peri-implant marginal bone level changes

The peri-implant marginal bone level changes after 1 and 10 years are presented in Table 3 at patient, implant and site level. Radiographs of 26 and 20 implants could not be evaluated after 1 and 10 years, respectively, due to lack of radiographic examination at baseline or at the 1-year follow-up or improper technical quality. The mean bone level changes were -0.14 mm (range: 1.2 to -1.1 mm) during the first year of loading and 0.16 mm (range: 1.4 to -1.8 mm) after 10 years at patient level.

Biological complications

The observed biological complications are summarised in Table 3. During the 10-year follow-up period, five episodes of peri-implant inflammation were observed in five patients. Four of the episodes were observed 2 to 4 months after placement of the crown, while one was observed after 3 years. All episodes were caused by excess cement and not related to one specific type of cement (Fig 3). A flap procedure was in all cases necessary to remove the excess cement to establish healthy peri-implant tissues.

A fistula was observed at two implants in two patients at the 10-year examination (Fig 4). Both fistulas were caused by excess cement. The excess cement was removed in one patient, while the other patient was not interested in treatment.

Technical complications

The observed technical complications are summarised in Table 3. During the 10-year follow-up period, two porcelain fractures occurred in two patients (Fig 5). The exact time of fracture was unknown for both patients and no treatment was needed.

Three abutment screws loosened in 3 patients after 3 months, 5.5 years and 6.5 years, respectively. All screws could be tightened while maintaining the original crown.

Discussion

The present study focused on the treatment outcome of implant-supported single-tooth replace-
ments performed by dental students as part of their undergraduate curriculum. The entire treatment was performed under the supervision of dentists or oral and maxillofacial surgeons, all with special knowledge in oral implantology. A total of 45 patients with 49 implants were available at the end of the follow-up period. Implant-supported single-tooth replacements performed by dental students as part of their undergraduate curriculum were characterised by a high rate of implant survival (94%).

It was concluded in a recently published systematic review that the 5-year survival of implant-supported single-tooth crowns was 95% \(^1\). Moreover, the 5-year implant survival was 97%. The review was based on 26 studies involving a total of 1558 implants. It should be emphasised that the patients included in the review were treated by dentists with special experience in oral implantology. In contrast, the patients within the present study were treated by dental students under supervision. In spite of this difference, the treatment outcome as evaluated by survival of implant crowns and implants (94%) seems comparable to previously published studies.

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**Fig 3** A 42-year-old female with agenesis of the left maxillary canine. Initial bone loss due to peri-implant inflammation caused by excess cement was observed 4 months after placement of the crown.

**Fig 4** A fistula was observed at the final examination. Radiograph presented in Fig 2.

**Fig 5** A 54-year-old male with loss of the right maxillary canine. A porcelain fracture involving the mesial part of the incisal edge was observed at the final examination.
The mean bleeding on probing score was 0.57 at patient level. Actually, bleeding on probing was revealed at 55% of the sites, and absence of bleeding around all sites of the implants was observed only around 3 implants. Assessment of probing depth revealed that the mean probing depth was 4.8 mm at patient level, while the probing depth at site level varied between 2 and 10 mm. Although 10-mm probing depths were revealed exclusively in one patient, these figures seem higher than in previously published studies. The background of this difference is unknown, but most implants were placed within regions of high aesthetic demand and expectations of the patients in the present study. To obtain a satisfactory aesthetic outcome, the implants were frequently inserted rather deep within the tissues to obtain a satisfactory emergence profile of the crowns. This is probably the reason for the increased probing depths. Moreover, the patients were not all included in a systematic maintenance program after treatment at the School of Dentistry, Aarhus University. Some patients were followed by their own dentists. The unsystematic maintenance program is probably the main reason for the high proportion of implants with bleeding on probing.

It was demonstrated early on that a peri-implant marginal bone loss of less than 1 mm occurred during the first year of function, while the bone loss after 1 year in most cases was minute. A minute bone loss of 0.14 mm was observed during the first year of loading in the present study, and bone levels remained stable after the first year of loading. The assessed bone loss after 10 years did not exceed 2.17 mm at site level. The bone level changes in the present study seem lower than in previously published studies. The reason for the apparent mean bone gain of 0.16 mm after 10 years may be related to the fact that most implants were inserted deep into bone, thereby influencing the evaluation of the bone level at baseline. Moreover, assessment of the marginal bone level was only possible at approximately half of the implant sites. Many of the radiographs taken at the 1-year follow-up were excluded because a paralleling technique was not used. Increased bone loss may occur in the future due to the high proportion of implants with bleeding on probing. A systematic maintenance program is mandatory to reduce the risk of marginal bone loss, including peri-implantitis, in the future.

In accordance with the previously mentioned systematic review, few biological and technical complications were observed. The most frequent complications were peri-implant inflammation and fistula due to excess cement. It has recently been demonstrated that excess cement in most cases is associated with peri-implant inflammation. Excess cement was revealed mainly around implants inserted deep in the bone in the present study. Therefore, detailed instruction to dental students is mandatory to reduce the risk of introducing excess cement into the peri-implant pocket. Also, meticulous control is important after cementation, especially with implants inserted deep in the tissues. Excess cement can in many cases be observed on introral radiographs taken with the paralleling technique when the cement is located mesially or distally, while cement can not in general be identified on radiographs when located buccally or lingually. Therefore, it may be relevant to take an introral radiograph after cementation when the implant is placed deep in the bone to make sure that excess cement is not present mesially and distally. The excess cement was diagnosed most often shortly after cementation in the present study. Minute peri-implant marginal bone loss was observed, and healthy peri-implant tissues were re-established after removal of the excess cement. Comparable treatment results have recently been reported.

The observed technical complications included 2 porcelain fractures in 2 patients and no treatment was needed. Loosening of three abutment screws was observed in 3 patients. All screws could be tightened while maintaining the original crown. Therefore, few technical complications were observed in the present study. This result is also in accordance with the previously mentioned systematic review.

It has been discussed whether implant therapy should be included in the clinical undergraduate dental curriculum. Implant therapy has for several years been included in the undergraduate curriculum at dental schools, but at different levels. A structured clinical curriculum involving treatment of patients with implants is uncommon. The increasing use of implants indicates that improved theoretical and clinical skills are needed to improve the competencies in implant dentistry at the undergraduate level.
The outcome of implant treatment performed by dental students has been evaluated sparsely\(^5\)-\(^8\). A high survival rate of the superstructures as well as the implants was reported. The treatment included a huge variety of implant treatments, including implant-supported single-tooth replacements, small fixed dental prostheses and overdentures. Implant therapy has been included in the theoretical and clinical undergraduate dental curriculum since 1996 at the School of Dentistry, Aarhus University, Denmark. The clinical curriculum is focusing on implant-supported single-tooth replacements. In accordance with the above-mentioned studies, a high survival rate of the implant crowns and implants was documented in the present study. Also, few complications were observed. Therefore, it seems acceptable and relevant to include implant therapy in the clinical undergraduate curriculum. However, it should be emphasised that the present study was a retrospective study and not all implants could be evaluated due to lack of radiographic examination at baseline or at the 1-year follow-up or improper technical quality of the radiographs.

The intention was to include exclusively straightforward cases in the clinical curriculum. However, recruitment of exclusively straightforward cases was difficult, which is why advanced and complex cases were frequently included. Actually, several implants were inserted in regions with high aesthetic demands and expectations of the patients. Therefore, one implant was removed due to severe malposition that compromised placement of a cosmetically acceptable crown. Moreover, bone augmentation was frequently necessary before or concomitant with the implant placement. Although the results of the present study indicate, in general, a satisfactory treatment outcome, inclusion of advanced and complex cases in the clinical undergraduate curriculum can not be recommended, because the treatment complexity seems to compromise the teaching outcome. Moreover, substantial supervision resources are needed. Assessment of the performed treatment should also involve evaluation of patient satisfaction and the aesthetic outcome before final conclusions about implant treatment performed by dental students can be made. These studies are presently ongoing.

**Conclusions**

A high survival rate of the implant crowns (94\%) and few biological and technical complications were observed in patients treated with implant-supported single crowns by properly supervised undergraduate dental students. Consequently, it seems acceptable to include implant therapy in the clinical undergraduate curriculum provided a focus remains on straightforward cases and substantial supervision by trained dentists. It is also important to provide regular maintenance care to these patients.

**Acknowledgement**

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**References**


