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ORIGINAL ARTICLE

Peri-implant bone changes following tooth extraction, immediate placement and loading of implants in the edentulous maxilla

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Abstract The aim of this study was to clinically and radiographically evaluate peri-implant bone level changes after rehabilitation of a fully edentulous maxilla by placement of six implants in either fresh extraction sites or healed edentulous ridges up till 18 months after implant placement. Twenty patients with a terminal dentition in the maxillae (11 men, 9 women) received a total of 120 OsseoSpeed® implants; 118 implants could be loaded immediately of which 59 were placed in extraction sockets and 59 were placed in healed sites. Within 24 h after surgery, all patients received a chairside-assembled, fibre-reinforced temporary fixed prosthetic reconstruction in occlusion. Six months post-surgery, final screw-retained CoCr (15) or Ti (5) computer numerical control-milled and acrylic-veneered frameworks were placed directly at implant level without interposing abutments. Intraoral radiographs were taken 6 and 18 months after implant placement. Implant survival rate was 100%. Mean marginal bone level was located on average −0.35 mm below the reference point (standard deviation 0.29, range −1.20 to +0.02 mm) 18 months after loading. Whether implants were placed in healed bone sites or fresh extraction sockets did not significantly affect the bone level changes. Furthermore, the use of either CoCr or Ti at the implant level did not significantly affect marginal bone loss. Within the limits of this prospective clinical trial, results seem to indicate that immediate placement and occlusal loading of five to six implants in the edentulous maxilla can be carried out successfully. Whether or not those implants are placed in fresh extraction sockets does not seem to alter the outcome. The present data show a successful 1-year outcome of a treatment protocol involving tooth extraction immediately combined with implant placement and loading.

Keywords Dental implant · Marginal bone level · Maxilla · Fibre-reinforced provisional fixed prosthesis · CoCr-fixed prosthesis · Immediate placement · Immediate loading

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Introduction

It is quite easy to hypothesize that dentate patients, suffering a terminal periodontal disease and thus facing total tooth loss, would favour a treatment strategy that instantly converts their current situation into a novel functional fixed restoration on implants. Different causes for future edentulism can be discerned. The most obvious cause is untreatable periodontal disease, but also advanced caries, failing root canal therapy, inadequate numbers of teeth to support a fixed prosthesis (non-strategic teeth) or a history of numerous failed rehabilitations can be a reason to not rely any further on the patients' own teeth. Tooth loss and edentulism often bring about negative psychological, social and professional repercussions [1]. Immediate implant placement and loading has obvious social and economical

advantages. The overall treatment time is reduced; the surgical and prosthetic interventions are more concentrated which leads to an increased patient satisfaction [2]. Less evident advantages comprise improved implant survival rates, better aesthetics, enhanced hard and soft tissue maintenance and better cost/effectiveness as compared to delayed or conventionally placed implants.

There is abundant evidence that supports immediate loading of implants in healed regions with high success rates (for review, see [3, 4]). Also, similar implant success rates are obtained for immediately placed implants in fresh extraction sockets as for early or delayed placed implants [4]. However, fewer studies have been published on clinical outcomes of immediately loaded implants placed in fresh extraction sites, and seldom reports were focussed on the maxilla. Quirynen et al. [4] report in their systematic literature review a higher incidence of implant loss for immediately placed and loaded implants, mainly for those with a minimally rough surface. In a more recent systematic review and meta-analysis, high survival rates (up to 99%) are reported for immediately placed molar implants, with no evidence for a significant difference between immediately and delayed loading/restoration [3]. Crespi et al. [5] present a survival rate of 98.9% at 48 months follow-up for 198 implants, immediately placed and loaded in extraction sockets of periodontally infected sites. This group could not find any significant outcome differences as compared to implants placed in uninfected sites.

Primary implant stability and lack of micromovements are the main factors to obtain predictably high success rates for osseointegrated implants [6]. High levels of primary implant stability are not always achievable in freshly extracted maxillary sockets. A more palatinal-placed implant, undersizing osteotomies and selecting implants with adequate lengths and diameters may help overcoming these anatomical limitations and may increase the primary stability [7–9]. Yet, these factors cannot ensure an insertion torque of at least 40 Ncm, which has been suggested as the minimum value for immediate functional implant loading [8]. However, controversy exists whether high insertion torques also apply to immediately loaded multiple, splinted implants versus single, unsplinted implants [10, 11]. In both cases, as underlined by Brunski [12], implant micromotions exceeding 100 μm should be avoided to prevent fibrous repair instead of osseous regeneration.

The present clinical trial aims to describe and validate a novel simplified surgical–prosthetic protocol to minimise micromovements of the implants in order to achieve predictable osseointegration of six immediately placed and immediately loaded implants after maxillary tooth extraction. In a preliminary, prospective study design, cumulative survival rates and marginal bone level changes are reported 6 months of occlusal loading with a provisional fixed prosthesis and 12 months with the final prosthetic restoration.

Materials and methods

Patients

From March 2007 till December 2008, 20 patients with a terminal maxillary dentition (11 men, 9 women; mean age 61 years, range 46–87 years) were consecutively treated with 120 OsseoSpeed® implants (Astra Tech AB, Mölndal, Sweden), following an immediate placement and loading protocol approved by the local ethical committee. The inclusion and exclusion criteria are listed in Table 1. An essential inclusion criterion was the presence of all or almost all teeth requiring extraction in combination with the presence of adequate remaining bone for the placement of four implants with a predominant length of 13 to 15 mm in the anterior maxilla (incisor to first premolar) and two implants of minimally 9 to 11 mm long in the posterior region (second premolar to molar), all of these having a minimal buccopalatal width of 3.5 mm. In total, 179 teeth were extracted in 20 patients with an average of nine teeth per patient (ranging from 4 to 15). The reasons for extraction (Table 2) were terminal periodontal disease (n=123), the presence of untreatable recurrent periapical granulomas (n=25) or a combination of both (n=7). The 24 remaining teeth could be considered as healthy, but were extracted because of their non-strategic position or obliteration to an adequate prosthetic solution. It should be pointed out that as far as possible patient recruitment

Table 1 Inclusion and exclusion criteria for immediate placement and loading of implants in the maxilla

Inclusion criteria	Exclusion criteria
No systemic disease	Advanced surgery, for example, sinus lift operations
All or almost all teeth lost due to terminal periodontal disease and/or untreatable endodontic problems	Bone augmentation procedures
Adequate bone volume to predominantly receive anteriorly an implant ≥13×3.5 mm and posteriorly an implant ≥9×3.5 mm	
Grafting limited to circumferential socket defects	

Table 2 Reasons for tooth extraction

Number	Total	Periodontal reasons	Endodontic reasons	Periodontal–endodontic reasons	Non-strategic
Total	179	123	25	7	24
Max/pat	15	15	12	5	5
Min/pat	4	0	0	1	0

Reasons for extraction were terminal periodontal disease, presence of untreatable recurrent periapical granulomas or a combination of both. The few non-strategic teeth refer to teeth that could be considered as healthy but were extracted because of their non-strategic position or obliteration to an adequate prosthetic solution

Max maximum, *min* minimum, *pat* patient

focussed on jaw bones with maximally one or two remaining healthy teeth. When exceeding this number, another prosthetic therapy planning was followed preserving healthy teeth next to fixed partial implant rehabilitations.

No minimum insertion torque value, measured on the drill units, was set. Smoking habits, diabetes, clenching or poor oral hygiene were not considered exclusion criteria although smokers (four patients) were advised to quit smoking prior to the surgical intervention but they did not succeed. One patient had been subjected to radiotherapy in the area of the nose base 10 years prior to implant therapy. Three patients could be categorised as bruxists. Seventeen patients had a skeletal relation class I, while three patients demonstrated a class II relation. Pre-extraction periodontal treatment was not performed. Antagonistic jaws included a full arch with natural teeth or fixed prostheses on teeth (15 patients), a fixed full implant prosthesis (one patient) or removable prostheses in the dorsal region in addition of a natural front (four patients). The study was conducted in accordance with the Declaration of Helsinki from 1975, and informed consent was obtained from all patients prior to this study.

Surgery

Panoramic radiographs (Cranex Tome, Soredex, Tuusula, Finland) were used for evaluation of the bone volume. Additional cone beam CTs (i-CAT®, Imaging Sciences International, Hatfield, PA, USA) were taken whenever considered necessary by the treating surgeon based on clinical inspection and evaluation of the panoramic radiograph. The evaluation of the pre-extraction data, if necessary added by specific patient wishes (e.g. more ideal position), determined the design of the surgical guide plate to be used during surgery for implant positioning and subsequently for converting into a temporary fixed prosthesis in occlusion (Fig. 1). Antibiotics (amoxicillin 875 and clavulanic acid 125) were administered 30 min prior to surgery with a continued postoperative intake for 7 days (three times a day). All patients were operated under local anaesthesia, added in some patients with a sedative drug (Temesta Expidet, Wyeth, Naarden, the Netherlands) 30 min prior to the intervention. After careful removal of the teeth, incisions were made for mucoperiosteal flaps at or slightly palatal to the ridge crest, with buccal relieving incisions in the second molar areas. The alveolar sockets were carefully and thoroughly debrided.

The drilling protocol was adapted to the bone quality subjectively assessed by the surgeon in order to obtain maximum primary stability although no minimum value was set and values could be as low as 5 Ncm. Maximal implant length and optimised bone preservation around the implant were aspired. The regions of the second incisor, first premolar and first molar were considered as preferred sites for implant placement. A total of 120 implants were installed. Two different diameters (3.5 mm, 108 implants; 4 mm, 12 implants) and four different lengths (15 mm, 53 implants; 13 mm, 48 implants; 11 mm, 12 implants; 9 mm, 7 implants) were used. Sixty implants were placed in extraction sockets and engaged the palatinal and lateral walls of the site. The implants were placed on average

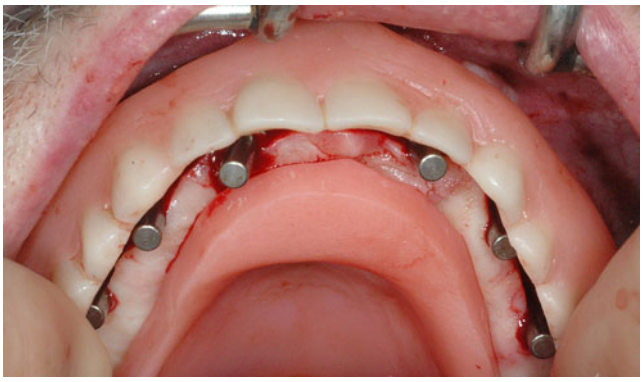

Fig. 1 A surgical guide plate based upon the original dentition was used during surgery for implant positioning and was subsequently converted into a temporary fixed prosthesis in occlusion. Ideally, implant positions used were at the region of the second incisor, second premolar and first molar

2 mm below the palatal wall of the extraction socket to compensate for the expected remodelling of the thin upper ends of the alveoli. Sharp osseous remnants of the sockets were flattened as needed. Small autogenous bone chips were placed in the gaps of more than 2 mm between implant surfaces and socket walls, or to treat large dehiscences or fenestrations. Only if the residual extraction socket was too large, the ideal implant position was slightly adapted by selecting a suitable neighbouring site. The remaining 60 implants were placed in healed edentulous sites. Healing abutments were placed before suturing (Vicryl 4/0, Ethicon, New York, NY, USA). Paracetamol and/or non-steroidal anti-inflammatory drugs were advised to be taken at the patient's own discretion for pain relief. A physiologic saline solution was advised for 2 weeks.

Provisional fixed prosthesis

Immediately after the surgical procedure or the next day, all patients received fixed temporary prosthetic restorations on six implants (n=18) or on five implants (n=2), resulting in 118 implants that were immediately loaded. In two patients, one implant was not incorporated in the patient's provisional fixed prosthesis because it was not possible to place the temporary abutment without vertically or horizontally displacing the implant. If the two not used implants for immediate loading were deducted, also equal amounts of implants in both sites were counted. The surgical guide, made by adapting a prefabricated acrylic denture based upon the original or idealised tooth setup, has a 5-mm-wide palatal slot located 4 mm behind the incisal edge from the first molar to the first molar and leaves the palatal support intact for correct positioning during surgery. A single prosthodontist performed the subsequent prosthetic procedure. Temporary (non-indexed) abutments were screwed on the fixtures and intraorally connected with each other with a glass fibre reinforcement (Everstick®, Stick Tech Ltd Oy, Turku, Finland) using a flowable composite (Tetric® Evoflow, Ivoclar Vivadent, Liechtenstein; Fig. 2). In three patients, two-angled abutments each were needed in the lateral incisor region to compensate for a too vestibular inclination of the implants. Titanium cylinders were mounted on the abutments.

After correct positioning of the surgical guide, the guide was now polymerised in occlusion with autopolymerising resin (Unifast Trad®, GC Europe, Haasrode, Belgium) to the abutments and the glass fibre. Overheating of the tissues was avoided by abundant rinsing with physiological saline solution. Once the abutments were connected in the surgical guide, the denture-like shape was converted into a fixed prosthesis design in the dental laboratory. The fixed prosthesis was designed with bullet-shaped pontics, and the cantilever was limited to half a tooth in order to minimise the risk of fractures. Three hours later, the provisional screw-retained fixed prosthesis was inserted and tightened with a torque of 20 Ncm (Fig. 3). Minor occlusal corrections were usually needed to distribute the occlusal contacts equally on as many teeth as possible to spread the load on all fixtures. Occlusal surfaces were flattened to reduce horizontal relations. Patients were asked to avoid tooth contact during the day (parafunctional activity) and to avoid tough types of food. Oral hygiene with a soft toothbrush is instructed and after 2 weeks small interdental brushes (<2.5 mm) are added for approximal cleaning.

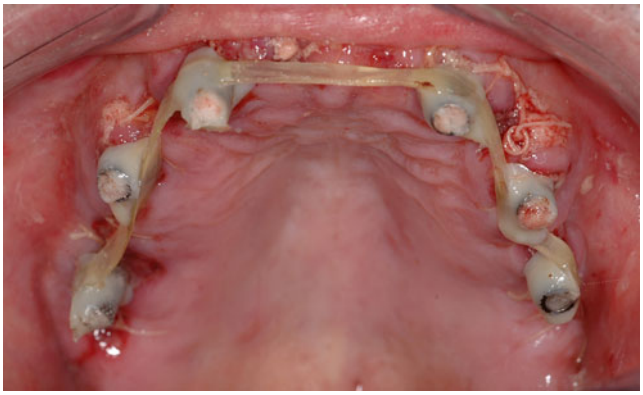

Fig. 2 Temporary abutments were screwed on the fixtures and intraorally connected with each other with a glass fibre reinforcement (Everstick®) using a flowable composite

Final prosthesis

After 6 months, the provisional reconstruction was removed, and all fixtures were checked for stability by a

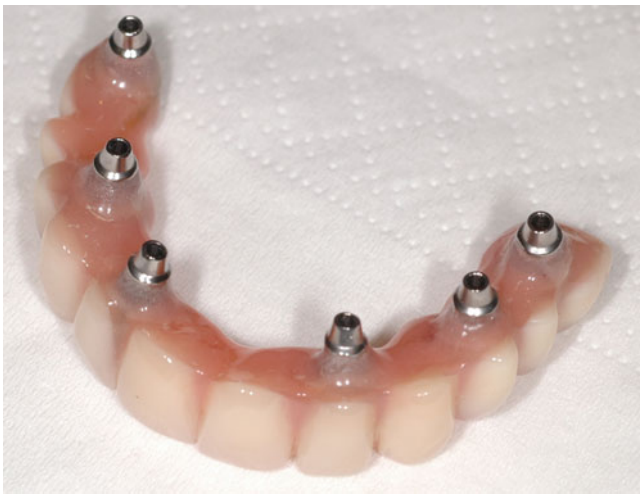

Fig. 3 The surgical guide was polymerised in occlusion with autopolymerising resin to the abutments and the glass fibre and converted in the dental laboratory to a fixed screw-retained fixed prosthesis design with *bullet-shaped* pontics and limited cantilever length

manual torque of 20 Ncm. The same prosthodontist who manufactured the temporary fixed prosthesis created the final prosthetic reconstruction too. All patients received a screw-retained metal–resin construction with 12 teeth adapted to the patients' need and demands. The metal base was milled out of titanium (five patients) or chrome cobalt (15 patients) using CAD/CAM technology (ISUS, E.S. Healthcare, Hasselt, Belgium) and engages with high precision directly in the fixtures without interposing abutments, except for three patients where two implants each needed an angled abutment to allow a screw-retained fixed prosthesis. Anchoring directly on the implant level of the prosthetic suprastructure is against the manufacturer's guidelines of using uni-abutments in all patients which should guarantee the perfect seal at the implant level and is one of the points of interest of this study.

Radiographic follow-up

Intraoral radiographs were made following the paralleling technique (Rinn XCP® holders, Dentsply, York, PA, USA) using conventional radiographs and digital (VistaScan Perio®, Dürr Dental, Bietigheim-Bissingen, Germany and Digora®, Soredex, Tuusula, Finland) photostimulable phosphor plates. All conventional radiographs were digitized with a transparency scanner (Snapscan 1236®, AGFA, Mortsel, Belgium) at 800 dpi as such that these could be used for marginal bone level and density measurement. The radiographic examination was performed at the 6-month recall visit and was considered as the baseline registration (corresponding to 6 months of functional loading period with the provisional fixed prosthesis). A follow-up radiograph was taken after 1 year of function with the final prosthetic reconstruction (1 year final fixed prosthesis registration). No radiographs were taken at the time of implant placement as this could not contribute to the study as half of the implants were placed in fresh extraction sockets.

Marginal bone level changes between both time points were assessed at the mesial and distal implant surface of each implant by two independent observers, being dento-maxillofacial radiologists. First, the reference level that started from the abutment connection point of the assessed implant was indicated. Then the bone level was measured from the reference level to the first bone-to-implant contact level using Adobe® Photoshop software (Adobe System Incorporated, San Jose, CA, USA). The measurements were initially made in pixel format. Linear measurements (in millimetres) could be performed after calibration of the images according to the respective implant lengths [13].

Statistical analysis

All data were gathered and statistically analysed by using the software of Medcalc® version 11.3.2 (Company Medcalc Software, Mariakerke, Belgium) with the p level set at 0.01. Success criteria for implant survival were implant stability when individually tested at the 6 months evaluation with manual torque testing at 20 Ncm. Furthermore, a successful implant caused no pain with the absence of mucosal suppuration and radiolucency around the implant. Additionally, bone loss with reference to the baseline should not exceed 1 mm during the first year (according to the criteria of Albrektsson and Zarb [14]).

Descriptive statistics was performed by determining mean values, standard deviations (SD) and cumulative frequencies. Bland and Altman plots were used to test inter-observer agreement. These plots indicated that measurements of both observers showed mean differences between 0 and 0.001 ± 0.04 and 0.07 mm, being 1.96 times the standard deviation of the differences. Those differences were considered to be of no clinical importance, allowing all further measures to be performed with the measured data set of one observer only. Using a Wilcoxon-matched pairs test, the difference in bone level between baseline and 1 year after the final prosthesis installation was tested. The Kruskal–Wallis test (H test) was then performed to analyse the influence of different variables on the outcome and bone loss.

Results

All patients were evaluated during the recall visits at baseline (6 months after implant placement) and 1 year after final fixed prosthesis installation.

Implant and fixed prosthesis outcome

None of the 120 inserted implants (of which 118 were immediately loaded) was lost during follow-up. The two not immediately loaded implants were considered as dropouts for implant level analysis and were not used in the study for further analysis. Yet on a patient level, it was opted to report on the whole group ($n=20$) to make the sample more representative. During the 20-Ncm torque testing after 6 months, implants were neither perceived mobile nor showed signs of pain or infection, resulting in a survival rate of 100%. Five glass fibre-reinforced provisional fixed prostheses showed veneer chipping off, yet no fracture of the fixed prosthesis core was reported. Two patients suffered from speech problems due to the bulkiness of the palatal aspect of the fixed prosthesis. This discomfort was eliminated with the final fixed prosthesis where a more concave palatal contour is easier feasible. No fractures were recorded for any of the final prostheses.

Radiographic findings

Following the D'Agostino–Pearson test for normal distribution, the normality was rejected, as such that non-parametric testing was opted for further analysis. Using a Wilcoxon-matched pairs test, the difference in bone level between baseline and 1 year after the final fixed prosthesis installation was tested. An overall Wilcoxon-matched pairs test revealed a significant difference between the bone level at baseline and at 1 year after loading (mean −0.21 mm, SD 0.27, range −1.16 to +0.05 mm, $p<0.01$). At baseline, the bone level was on average −0.14 mm below the reference point (SD 0.17, range −0.76 to +0.04 mm). Twelve months after loading the final fixed prosthesis, a bone level average of −0.35 mm below the reference point was measured (SD 0.29, range −1.20 to +0.02 mm).

Table 3 shows the mean mesial and distal marginal bone levels for each implant region. To observe from which sites the observed differences were originating, Wilcoxon-matched pairs tests were carried out in the individual regions. With correction for multiple comparisons, it became obvious that significant difference in bone loss could only be determined for left premolar region and right incisor region ($p<0.01$), while no significant bone loss was observed for any of the other regions.

The mean bone loss in individual patients falls within the success criteria as described by Albrektsson and Zarb [14]. Only one patient reported bone loss larger than 1 mm; another patient had a mean bone loss of 0.51 mm. All other patients had less than 0.4 mm bone loss. The success rate of the immediately loaded implants is consequently 99.1%. Figure 4 shows the radiographs of one patient illustrating the marginal bone level after 6 and 18 months. Figure 5 displays the cumulative frequency distribution of the bone level changes around all individual implants. The bone level changes on the *x*-axis show besides bone loss also a few implants with bone gain, probably due to bone remodelling during the healing of the extraction sockets. Most of the data points are located around the zero bone loss level.

The Kruskal–Wallis test (*H* test) was used to analyse the influence of different variables on the outcome and bone loss. It was found that smoking (four patients) was not affecting the bone loss at 1 year after final fixed prosthesis loading in the present sample (Table 4). The test also showed that the type of metal base of the prosthetic suprastructure (CoCr versus Ti) is not affecting the bone loss at 1 year after final fixed prosthesis loading (Table 4).

For the incisor implants with angulated abutments, reported bone loss was not remarkably deviating from the overall reported bone loss. Individual implant data showed values within the 5–95 percentile range and within the range of the mean ±2 SD for marginal bone loss, in agreement with the lack of significance as found in the Kruskal–Wallis statistics for the incisor implants with and without angulated abutments.

Analysis of the effect of extraction socket healing on the bone loss reveals that there is no significant difference in the approach placing implants immediately in extraction sockets or after healing of extraction sockets ($p>0.3$; Fig. 6 and Table 4).

Discussion

Immediate implant placement at the time of tooth extraction followed by immediate function on six Astra Tech OsseoSpeed implants with a chairside-made screw-retained provisional fixed prosthesis appears to be a predictable treatment option in the maxilla. The survival rate was 100% and the individual fixture success rate, based on radiographic bone level, was 99.1% after 18 months. Within the limits of the present report, a control group could not be added. The most important reason was that the present concept is revolutionary and thus in various aspects deviating from a more conventional approach. Should one aim for testing the potential added value of each of these aspects, up to four to five different control groups would be required, each differing from the test group by one of these aspects. In terms of ethics, recruitment and follow-up, the latter is hardly feasible.

The very high survival and success rates obtained in this study after in total 18 months of loading illustrate the conflicting results that are reported in reviews on the

Table 3 The mean of mesial and distal marginal bone levels for each implant region at 6 months and at 1 year after loading

	Mean bone level at 6 months Mean of mesial and distal in mm (SD, range)	Mean bone level at 1 year after loading Mean of mesial and distal in mm (SD, range)
Right molar region	−0.19 (0.43, −1.78 to +0.00)	−0.39 (0.71, −2.81 to +0.22)
Right premolar region	−0.19 (0.45, −1.89 to +0.18)	−0.32 (0.48, −1.99 to +0.00)
Right incisor region	−0.10 (0.26, −0.72 to +0.45)	−0.48 (0.83, −3.75 to +0.19)
Left incisor region	−0.14 (0.20, −0.66 to +0.00)	−0.25 (0.46, −1.53 to +0.62)
Left premolar region	−0.17 (0.32, −1.25 to +0.25)	−0.44 (0.45, −1.35 to −0.45)
Left molar region	−0.10 (0.33, −1.13 to +0.77)	−0.28 (0.40, −1.05 to +0.47)

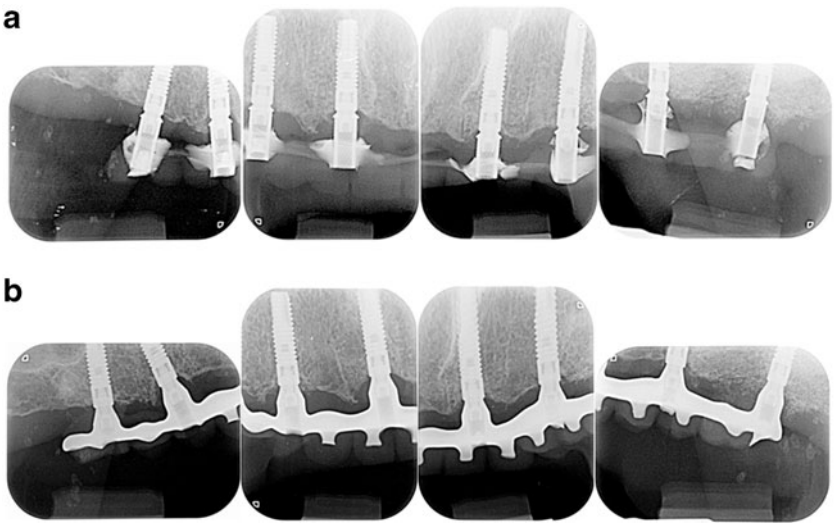

Fig. 4 **a**, **b** Radiographic images of one patient illustrating the marginal bone level changes after 6 months (**a** radiographs of a subject showing a mean marginal bone loss of −0.06 mm after 6 months) and after 18 months (**b** radiographs of a subject showing a mean marginal bone loss of −0.18 mm after 18 months)

combination of immediate restoration/loading. Quirynen et al. [4] conclude that the incidence of implant loss is higher when combining immediate placement and immediate loading. Schropp and Isidor [9] further indicate that evidence for success in the maxilla as well as in the posterior mandible of immediate loaded implants placed in fresh extraction sockets or in healed bone is limited, but all reviews agreed in that achievement of primary stability is a prerequisite for treatment success. In this study, it was not possible to obtain a high primary stability or even stability for each implant. This was particularly true for the maxillary posterior region where extraction of a (pre)molar would normally result in a rather large socket, impeding primary stability and increasing the risk of peri-implant bony defects after surgery. Additionally, the posterior maxilla also is characterised by a poor bone quality while being further compromised by the proximity and/or interference of the maxillary sinuses. Low primary stability was effectively encountered in this study by splinting all six implants together with a reinforced temporary fixed prosthesis. The idea was to create as rigid as possible a chairside-made implant prosthesis unit. To realise this, a special type of a parallel-walled threaded titanium implant with a microtextured surface was selected as it allowed a strong and stable connection between implant and abutment by its conical seal design. Temporary abutments were mounted on the implants and directly polymerised in the provisional fixed prosthesis without placing uni-abutments and temporary cylinders as recommended by the manufacturer. This implied that the provisional fixed prosthesis was fixed on the implants, using larger abutment screws instead of smaller prosthetic screws. The latter is a unique concept as it creates a direct contact between implant and fixed prosthesis, without the need for an abutment interface. This allowed torque forces of 20 Ncm which firmly secure even the less stable implants in the temporary restoration. The internal glass fibre further added to the rigidity of the provisional fixed prosthesis. Since the provisional fixed prosthesis was polymerised to the temporary abutments in situ, the passive fit was subsequently optimal while cost-effective at the same time.

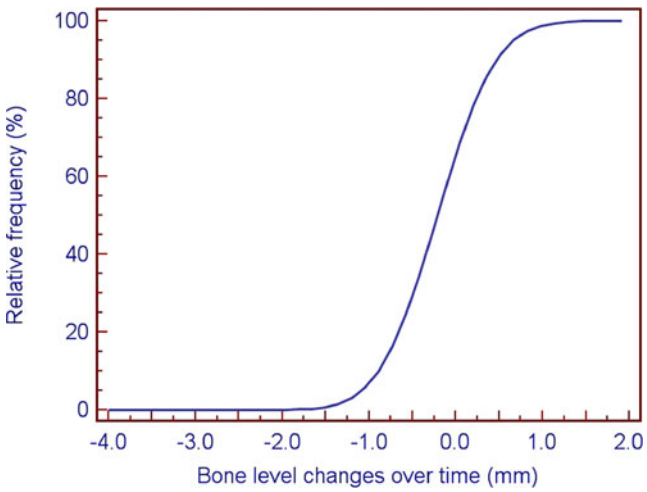

Fig. 5 Cumulative frequency distribution graph showing the relative frequency of the bone level changes over time around all individual implants

As radiographs at implant placement in fresh extraction sockets could not be used as a reliable baseline, any changes between this moment and the 6-month recall could not be monitored. One year after final fixed prosthesis placement, the marginal bone level was located on average 0.35 (SD 0.29) mm below the reference point. Several authors have reported limited marginal bone loss during the first year of loading and beyond for the Astra Tech implant system. Collaert and De Bruyn [15] indicate a mean marginal bone loss during the first year of loading of 0.6 mm in the immediately loaded edentulous maxilla for TiOblast

Table 4 Results of the Kruskal–Wallis test (*H* test) analysing the influence of different variables on the outcome of bone loss at 1 year after final fixed prosthesis loading

Variables	Number	Number	*p* value
Smoking habit	16 non-smoking patients	4 smoking patients	0.48
Prosthetic suprastructure	15 CoCr metal-based final fixed prosthesis	5 Ti-based final fixed prosthesis	0.69
Healed versus non-healed extraction sites	59 healing extraction sites	59 healed extraction sites	0.58

fixtures. In a meta-analysis by Laurell and Lundgren [16], a pooled marginal bone level change of −0.24 mm (95 confidence interval −0.345, −0.135) is found for Astra Tech implants over 5 years in function, yet the study does not report on immediately placed and/or loaded implants. Norton [17] reports a survival rate of 96.4% and a mean marginal bone loss of 0.40 mm (range 0 to 1.53 mm) for 28 immediately loaded solitary Astra Tech ST dental implants, 1 year after placement. Sixteen of the 28 implants are placed at the time of tooth extraction. In total 10 of the 28 implants show no marginal bone loss at all; moreover, eight of these ten were placed at the time of tooth extraction. Östman et al. [18] measures an average marginal bone resorption of 0.37 (SD 0.39) mm during the first year in function of 101 immediately loaded NanoTite Prevail implants in healed sites of which 88 implants were placed in the maxilla. Crespi et al. [19] report a mean marginal bone loss of 0.65 (SD 0.58) mm to the mesial side and 0.84 (SD 0.69) mm to the distal side in the maxilla 18 months after placement of immediately loaded Out-Link implants placed in fresh sockets after tooth extraction. Although bone loss around various implant systems cannot easily be compared due to differences in implant design and surgical protocol, the 0.34 (0.29) mm of marginal bone loss found in this study is very acceptable and well below previous postulations that bone loss should not exceed 1 mm during the first year of function and an annual bone loss thereafter not exceeding 0.2 mm [14, 20].

One of the most remarkable results in this study was that placing implants in fresh extraction sockets had no negative effect on the marginal bone loss, even more; it was similar as for implants placed in healed extraction sockets. Surely, the modified surgical procedure for placing implants in fresh extraction sockets largely counteracted the physiological and inherent marginal bone loss that took place after extracting a tooth as demonstrated in animal experiments of one working group [21, 22] and in clinical studies [23, 24]. One of the reasons to use the Astra Tech implant was its fully parallel-walled body which allows the surgeon to regulate the depth location of the implant in the extraction socket in function of the estimated post-extraction alveolar bone remodelling. In most patients, the implants were placed about 2 mm under the palatal marginal edge of the extraction socket. The positioning of the implant shoulder was depending on the size of the extraction socket and difficult to exactly quantify. On average, an implant was positioned deeper in a canine socket (about 3 mm) than in a lateral incisor socket (about

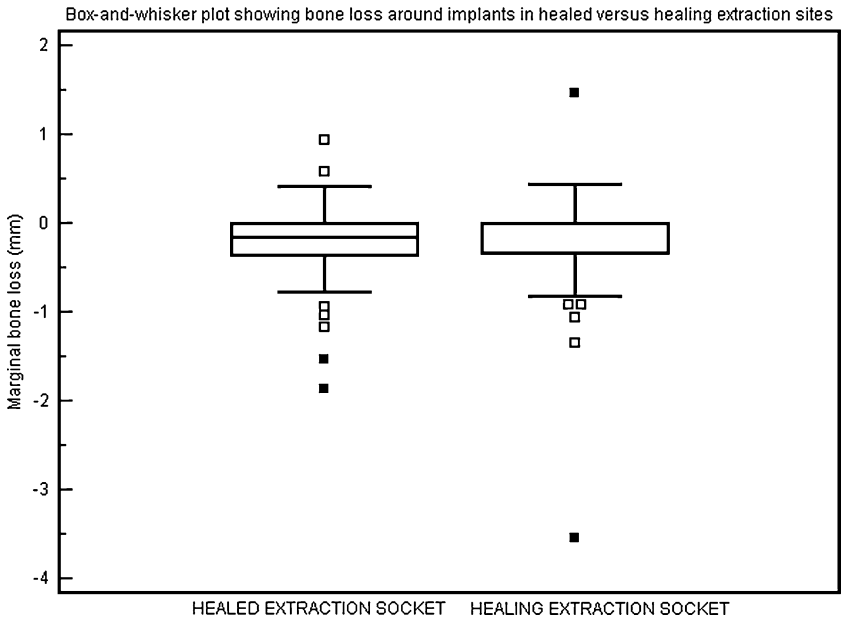

Fig. 6 Box-and-whisker plot showing bone loss around implants in healed sites versus immediate implant sites

1.5 mm). The palatal wall of the extraction socket appeared to be the most reliable to refer to since in many sites, deep defects were noticed at the vestibular and/or mesial and distal side. Also, implants were placed in the palatal aspect of the extraction socket, leaving a distance of at least 4 mm to the original buccal bone wall. By placing implants palatal and rather deep in the alveolus, the 'empty' area around the implant was substantially reduced and could thus be more easily filled by a blood clot, enhancing the possibilities for new bone formation. This could thus results in similar marginal bone levels as in healed bone and may explain why radiographic observations tend to show a so-called bone gain around particular implants (see Fig. 5).

The presently introduced treatment concept allows a simplified and cost-effective prosthetic procedure, where the fixed prosthesis inserts at implant level and implants are interconnected with an in situ applied glass fibre. Results seem to indicate that this concept did not impede the outcome of the less stable implants in the extraction sockets. The elimination of interposing abutments in the temporary and final structure allowed having a rigid two-component (implant-fixed prosthesis) assembly which profits maximally of the morse-tapered connection between implant and suprastructure. The chairside-assembled temporary fixed prosthesis was sufficient resistant to fracture. Although five glass fibre-reinforced provisional fixed prostheses showed veneer chipping off, the latter could be used to signal possible overload to the patient, thus acting as a feedback to control masticatory function and grinding habits.

Eliasson et al. [25] indicate that computer numerical control (CNC)-milled frameworks present levels of precision of fit within clinically acceptable limits, corresponding to the previously reported precision levels for frameworks fitting on abutments. In a 10-year follow-up study, Ortorp and Jemt [26] compare CNC-milled titanium frameworks to gold alloy castings for rehabilitation of the edentulous jaws and conclude that CNC Ti frameworks are a viable alternative. Hjalmarsson [27] investigated in vitro CoCr and commercially pure (CP) titanium frameworks regarding precision of fit, estimated material degradation and possible adverse cellular responses. He also evaluated and compared the clinical and radiological 5-year outcome of abutment-free porcelain-veneered CoCr prostheses compared to acrylic-veneered CP titanium prostheses, with or without abutments. None of the frameworks presented a perfect, completely 'passive fit', whether they were casted, sectioned and laser-welded or CNC-milled. There were indications of active corrosive processes for both implants and framework materials. He also saw that epithelial cells and fibroblasts preferred titanium to CoCr surfaces. The clinical outcomes after 5 years of implant level prostheses made of porcelain-veneered CoCr or acrylic-veneered titanium seem comparable to acrylic-veneered titanium prostheses made at abutment level. In our protocol, 5 Ti and 15 CoCr CNC-milled frameworks were made directly engaging in the morse-tapered connection of the implant. The use of CNC-milled frameworks at implant level was not described before for the Astra Tech implant system. Passive access of the fixed prosthesis to the implants is only possible if the total axis deviation of all implants together does not exceed 20°. The six angulated abutments that were used in three patients in the anterior region were not placed to allow fixed prosthesis insertion but were necessary to avoid screw access holes in the vestibular aspect of the fixed prosthesis. The present results indicate that neither direct fixed prosthesis anchorage at the implant level nor using CoCr has affected implant outcome, as measured by survival rates or marginal bone levels.

Conclusion

The present report presented a new treatment concept for rehabilitation of the edentulous maxilla by immediate loading of six implants, placed in either immediate extraction sites or healed edentulous ridges. A clinical trial evaluated the first group of 20 consecutive patients, needing full maxillary rehabilitation. The new treatment concept eliminates the need for a temporary full denture. The chairside-assembled temporary fixed prosthesis with glass fibre reinforcement and the elimination of abutments in the final fixed prosthesis, using CNC-milled frameworks, simplified and accelerated the procedure and reduced the cost of the treatment.

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Conflict of interest None.

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