8.

General discussion
The application of a dental implant to replace an anterior tooth is challenging. One should not only strive to rehabilitate function, but also to restore the aesthetics represented by the appearance of the implant crown and the peri-implant mucosa. Besides, as holds for all implant cases, the tissue surrounding the implant should remain healthy and stable over time for good long-term prognosis.

From the broad spectrum of materials and techniques available in aesthetic implant dentistry, this thesis inquired into two aspects, namely the design of the implant neck and the concept of immediate implant loading. Radiographic, clinical and aesthetic outcome measures together with patient satisfaction were assessed reflecting the quality of the final outcome. In this chapter the main research outcomes are discussed. In the last paragraphs, clinical implications and suggestions for future research are given.

Evidence from literature on single-tooth implants in the aesthetic zone
A systematic review of the literature was performed to gain insight into the available evidence on the efficacy of using an implant to replace a missing anterior tooth (Chapter 2). In this review, we focussed on single implants neighboured by natural teeth that had been inserted to replace a missing tooth in the aesthetic zone (defined as the region from teeth 15-25 and teeth 35-45). The included studies suggest that such a therapy will lead to a successful outcome on, at least, the short term with regard to implant survival, marginal peri-implant bone loss and incidence of complications. A meta-analysis revealed an implant survival rate of 95.5 % after one year (based on 19 studies) and only a little amount of marginal bone loss at one year after definitive crown placement (0.20 mm, based on five studies). A low number of complications was reported, most of which were minor and could be solved non-invasively. These favorable results need closer scrutiny, since the available literature showed several shortcomings. First, studies on single-tooth implants in the aesthetic zone underexposed significant variables as soft tissue aspects, aesthetic outcome and patient satisfaction. Variables reflecting the condition of the peri-implant mucosa as probing pocket depth, bleeding on probing and plaque indices were lacking in most of the studies. Furthermore, the few studies that did evaluate soft tissue appearance made use of the papilla index according to Jemt (1997) to express the volume of the interproximal papillae or assessed the level of the facial peri-implant mucosa. Although these outcome measures contribute to the final aesthetic outcome, other aesthetically relevant items as soft tissue colour, texture and contour were not taken into account. To assess the aesthetic outcome, all aesthetically relevant aspects should be considered. For this purpose, objective rating instruments as the Implant Crown Aesthetic Index (Meijer et al. 2005) and the Pink Esthetic Score –White Esthetic Score (Belser et al. 2009) were introduced.
Besides the aesthetics of the mucosa, these indexes also contemplate the aesthetics of the implant crown.

The design of the included studies should be considered as another shortcoming. There was a lack of well-designed clinical trials and most of the studies could be classified as case series. Since case series are prone to selection bias, results of these studies should be interpreted with caution. Furthermore, in most of the studies, sample sizes were small and follow-up periods were too short to draw firm conclusions regarding the treatment outcome of single implant therapy on the long term.

From the perspective of these abovementioned shortcomings, it seems paradoxical that instead of establishing conventional treatment strategies, most of the studies inquired into protocols where implants were inserted in fresh or early healed extraction sites or were subjected to immediate or early loading. Despite promising results for this variety of studies, there was too little evidence to answer the question whether all these treatment strategies will result in a comparable – or even better – outcome than the conventional procedures. Unfortunately, no clinical trials could be retrieved focussing on different implant types or different implant neck designs in particular.

**Single-tooth implants with different neck designs in the aesthetic zone**
The aim of this study, as described in chapters 3 and 4, was to compare the outcome of single-tooth implants in the maxillary aesthetic zone (from teeth 14 - 24) with three different neck designs, namely a smooth ‘machined’ neck (‘smooth group’), a rough neck with grooves (‘rough group’) and a scalloped neck with grooves (‘scalloped group’). Variables were marginal bone level change, clinical and aesthetic outcome measures and patient satisfaction.

**Marginal bone level change**
After implant placement and through time of function, it is commonly accepted that implants will display some extent of bone loss (Albrektsson et al. 1986, Laurell & Lundgren 2009). We considered loss of peri-implant marginal bone measured radiographically as being an important outcome measure expressing the quality of the treatment outcome. First, marginal bone loss may induce pocket formation which could be unfavorable for long-term health of the peri-implant tissues (Rams et al. 1984, Heydenrijk et al. 2002). Second, loss of peri-implant marginal bone might result in recession of the peri-implant mucosal level (Bengazi et al. 1996, Chang et al. 1999b, Hermann et al. 2001a) thereby affecting the aesthetic outcome.

Measurement of marginal bone on peri-apical radiographs is generally accepted
as a reliable and feasible instrument to measure bone loss at least at the proximal side of the implant (Hermann et al. 2001b, Salvi & Lang 2004) and offers fixed reference points from the moment of implant placement to years thereafter, allowing for longitudinal research. Since it is known that peri-implant bone loss occurs circumferentially thus at the facial and palatal aspects as well (Buser et al. 2004, Cardaropoli et al. 2006), radiographic bone loss observed at the proximal implant side might be a measure for bone loss at the facial and palatal sides as well.

In our study, implants with a scalloped implant neck displayed significantly more peri-implant bone loss from implant placement up to the end of follow up (18 months after implant placement; 2.01 ± 0.77 mm) than the implants with a smooth (1.19 mm ± 0.82 mm) and rough neck (0.90 ± 0.57 mm) but with common flat platforms (Chapter 3). Unfortunately, studies on the scalloped implant are scarce and clinical trials are lacking, which limits a comparison of our results with results from the literature. The available publications are in line with our findings since values of 1.5 to 2.1 mm bone loss (standard deviations around 1 mm) between implant placement and 12 months thereafter were reported (Nowzari et al. 2006, Kan et al. 2007, McAllister 2007).

We do not have a clear explanation for the amount of bone loss in the scalloped group as observed in our study. One reason might be that peri-implant bone is mainly formed in a horizontal plane. As a result, the more crestally related facial and palatal part of the implant platform dictates the marginal bone level around the implant. Another reason could be inferred from a biomechanical point of view. Too much stress at the implant neck after loading, might induce initial marginal bone resorption (Oh et al. 2002; Schrottenboer et al. 2008). Possibly, the stress distribution from the scalloped implant to the bone was unfavorable and too high, leading to the amount of marginal bone loss as was observed during the first evaluation period. In this context, the complex connection between implant and abutment could play a role.

Several studies demonstrated that a rough surface topography at the implant neck exhibit less marginal bone resorption than a smooth coronal area (Shin et al. 2006, Bratu et al. 2009, Nickenig et al. 2009) and that (micro)threads at the level of the implant neck have the quality to preserve marginal bone (Palmer et al. 2000, Shin et al. 2006, Lee et al. 2007). In contrast to these observations, we could not detect a significant difference in bone loss between implants with a rough or smooth neck (Chapter 3). However, since the abovementioned studies retrieved data mostly from posterior tooth replacements or from non-clinical research, it is questionable whether these data can be extrapolated to our human study involving maxillary teeth in the aesthetic zone. Unfortunately, clinical trials investigating smooth and rough implant neck architectures for anterior single-tooth replacements are lacking.
Since in our study the implant-abutment interface was closely related to the bone crest (all implant necks were leveled with the bone crest at the time of implant placement), it might be possible that the thought beneficial effect of a rough implant neck, could not be effectuated at a level surpassing the bone resorption around a smooth implant neck. This hypothesis is in line with suggestions from the literature mentioning that the position of the implant-abutment interface relative to the bone crest at the time of implant placement is a significant factor determining marginal bone loss (Hermann et al. 2000, Broggini et al. 2006, Jung et al. 2008). An inflammatory reaction at the implant-abutment interface due to microbial leakage seems to be a major factor for this bone loss. A more apical position of the implant-abutment interface is thought to be a factor increasing the inflammatory reaction (Broggini et al. 2006). Furthermore, a zone of connective tissue will form between the bone crest and the inflammatory cell infiltrate at the implant-abutment interface at the cost of marginal bone (Schwarz et al. 2008).

Other implant features might also be important in preventing bone loss. It has been suggested that besides surface roughness and grooves, a conical internal implant-abutment connection combined with a non-matching implant-abutment diameter favor marginal bone preservation (Wennstrom et al. 2005, Jung et al. 2008, Cochran et al. 2009). It seems that by reducing the diameter of the abutment, the implant-abutment interface and thereby the inflammatory reaction will be displaced further away from the bone, resulting in less marginal bone loss. Furthermore, an internal conical connection has been associated with a more stable connection possibly leading to less bacterial leakage and a better stress distribution (Hansson 2003, Coelho et al. 2008, Cochran et al. 2009). However, the beneficial effects of such connections need further clinical investigation.

**Clinical outcome**

At 18 months post-implant placement, significantly deeper pocket depths were measured in the scalloped group together with higher bleeding scores compared to the other study groups (Chapter 3). This is not a surprising finding when taking into consideration the higher amount of marginal bone loss in the scalloped group and the positive correlation that was found between pocket depth and marginal bone level alterations. From 6 to 18 months, pocket depths and bleeding scores increased significantly in the scalloped group, while in this evaluation period only a small amount of marginal bone loss was observed in this study group. Apparently, the peri-implant tissues in the scalloped group developed more marginal inflammation with time as confirmed by the higher bleeding scores. As described by Schou et al. (2002), even a mild marginal inflammation is associated with a deeper penetration of the probe. This might be a reason that deeper pockets depths were measured at 18 months of follow-up, without
observing a concordant loss of marginal bone loss. Furthermore, inflammation-induced swelling of the peri-implant mucosa might have resulted in increased pockets depth (‘pseudo-pocket’). Although there is no evidence showing a correlation between pocket depth and the presence or absence of active peri-implant disease (Schropp et al. 2005b, Heitz-Mayfield 2008), it has been shown that with increasing pocket depth, an environment is created for periodontal pathogens (Rams et al. 1984, Heydenrijk et al. 2002). We therefore believe that peri-implant pocket depths should be limited and remain stable over time to facilitate healthy peri-implant tissues. The long-term influence of increased pocket depth on marginal bone levels needs further study as applies to the interaction between marginal bone loss and pocket formation.

After placement of the definitive crown (6 months post-implant placement) to 1 year thereafter (18 months post-implant placement) the levels of the mid-facial peri-implant mucosa remained stable (Chapter 3). This corresponded to the small amount of marginal bone loss observed in this period. Despite this small amount of bone loss, the level of the papillae gained some height after definitive crown placement (overall 0.22 mm). The capacity of papillae to exhibit regrowth after crown placement has also been observed in other single-tooth implant studies (Jemt & Lekholm 2003, Schropp et al. 2005a, Den Hartog et al. 2008, Meijndert et al. 2008). The study by Meijndert et al. (2008) in which a comparable restoration procedure and the same evaluation strategy were used, reported a comparable gain in papillary height of 0.25 mm.

To elucidate the effect of marginal bone loss on the level of the mucosa around anterior single-tooth implants, it would have been of interest to compare the total amount of bone loss after 18 months with the total change in peri-implant mucosal level. However, changes of the peri-implant mucosal level can only be measured accurately after placement of the definitive crown (i.e. after six months post-implant placement) since thereafter the actual peri-implant mucosal level is established. After definitive crown placement, only minor marginal bone loss and a concordant change in peri-implant mucosal level was observed. Since the most bone loss already occurred during the first evaluation period, the true effect of bone loss on the peri-implant mucosal level might have been missed.

Scalloped implants were accompanied by more complications of the definitive crown, viz. porcelain fracture (six cases) and mobility (three cases), than the other implants (Chapter 3). The complex connection between the scalloped implant neck and abutment might have been a major factor determining these complications. However, long-term follow-up is needed to unveil the stability of the prosthetic restorations as the problems with the scalloped implant restorations might mainly be an early phenomenon.

In the line of complications, an interesting phenomenon we encountered was a
trauma to an implant crown in one of our patients allocated to the smooth group (Chapter 7). It appeared that only the fixation screw was damaged, while the implant, restoration and peri-implant tissues remained unharmed. Just an easy prosthetic retreatment was necessary and a surgical retreatment was prevented. We realize that the incidence of trauma to implant restorations is not high. However, we favor designing suprastructures as such that these structures are the weakest link in case of trauma, thereby preserving the implant and surrounding tissue.

Aesthetic outcome and patient satisfaction
To assess the aesthetic outcome, objective rating instruments are available, to be used by dental professionals. These instruments are composed of different aesthetically related items based on the anatomic form, colour and surface characteristics of the peri-implant mucosa and implant crown. Such instruments facilitate instant or longitudinal assessment of the aesthetic outcome of different treatment strategies and can be of value for a thorough analysis of the final outcome in order to improve treatment aspects. However, since the patient is the final user of implant therapy, the opinion of the patient is also of importance. Questionnaires to be completed by the patient are commonly employed to assess the subjective appreciation of the aesthetic outcome.

To our best knowledge, only two aesthetic rating instruments are nowadays available to assess the aesthetics of the peri-implant mucosa and implant crown (Meijer et al. 2005, Belser et al. 2009). In our study, both these instruments were used, knowing that these instruments are not yet optimal. A major drawback is that these instruments are not suitable to assess the pre-operative situation as well. When the pre-operative situation can be assessed, this might be of value to better understand the possible role of factors determining the final aesthetic outcome. Furthermore, the instruments are not yet tested for their external validity and with respect to their internal validity, further development is necessary to improve the reproducibility (as discussed in Chapter 4). The same applies to the development of validated questionnaires to assess patient (aesthetic) satisfaction. Nowadays, no such questionnaires are available.

Beforehand, we hypothesized that the design of the implant neck might have an effect on the level of the peri-implant mucosa and with that influences the final aesthetic outcome. However, using both the available aesthetic evaluation instruments (Meijer et al. 2005, Belser et al. 2009), this effect could not be shown in our study (Chapter 4). Although the scalloped implants displayed more radiographic marginal bone loss, there were no differences between study groups regarding the items ‘level of the facial peri-implant mucosa’ and ‘quantity of papillary tissue’ (both these items are part of the aesthetic evaluation instruments).

There are some possible reasons for not observing between-group differences
on these items despite between-group differences in marginal bone loss. First, it might be that the difference in marginal bone resorption between the scalloped group and the other study groups brought about a clinical effect that was too little to be observed with the aesthetic indexes we applied or that the indexes itself were not able to reveal these differences (e.g., because of the shortcomings as discussed earlier). A second reason might be ascribed to the role of the periodontium of the adjacent teeth. Namely, it is assumed that the level of the papilla is related to the bone level next to the adjacent teeth (Choquet et al. 2001, Kan et al. 2003, Romeo et al. 2008). We observed only minor marginal bone loss at the adjacent teeth without differences between study groups. Possibly, the periodontium of the adjacent teeth also acts on the level of the facial peri-implant mucosa. Finally, we believe that the role of the pre-operative situation for the final aesthetic outcome needs discussion. Possibly, the level of the mucosa before implant placement was more relevant to the future level of the peri-implant mucosa than is the amount of bone loss around the implant neck. In our study, all implants were placed in healed extraction sites, up to a third of which were augmented in a separate session before implant placement. It revealed that in 63% of the cases, the level of the facial peri-implant mucosa showed a deviation when compared to the adjacent dentition. It is known that after tooth removal, the walls of the alveolus undergo substantial resorption at the facial aspect, affecting the anatomy of the soft tissue (Schropp et al. 2003a, Araujo & Lindhe 2005). A strategy of immediate or early implant placement or a socket preservation technique might favor the aesthetic outcome. By way of comparison, in other studies (Belser et al. 2009, Buser et al. 2009) in which implants were installed in early healed extraction sites and subjected to simultaneous guided bone regeneration, the level of the facial peri-implant mucosa showed a deficiency in only 22 % and 10% of the cases, respectively. As discussed earlier, it would be helpful to further develop an aesthetic evaluation instrument, by which the pre-operative situation can be assessed as well. This will facilitate a further exploration of predisposing factors.

Although from a professional’s perception the appearance of the peri-implant mucosa and implant crown were not acceptable in, respectively, 40% and 20 % of the overall cases, the subjective aesthetic appreciation of the patient was high. The discrepancy between the aesthetic outcome from a professional’s and patient’s perception has been reported in earlier studies (Chang et al. 1999a, Meijndert et al. 2007, Esposito et al. 2009). As suggested by Chang (Chang et al. 1999a), it might be that factors considered by professionals to be relevant for the aesthetic outcome may not be of decisive importance for patient’s aesthetic satisfaction. Furthermore, we argue that for the final appreciation of the patient, the pre-operative situation plays a role of significance and gives weight to the final judgment. When the pre-operative situation is compromised and patient’s
expectations are realistic, patients might be satisfied even when the aesthetic outcome according to an objective index is poor. The aesthetic indexes do not take the preoperative situation into account as discussed before. The high general patient satisfaction we observed might be deduced from the patient’s appreciation with the aesthetics, since the outcome of all questions was correlated with general patient satisfaction. However, it should be noticed that also other aspects as function and comfort might contribute to general patient satisfaction.

Immediate loading of single-tooth implants in the aesthetic zone

The objective of this study was to compare the outcome of immediate loading with that of conventional loading of implants applied for a missing anterior maxillary tooth for radiographic marginal bone level change and clinical and aesthetic outcome measures together with patient satisfaction (Chapter 5). We hypothesized that immediate loading is not inferior to conventional loading.

Marginal bone level change

It seems rational to argue that immediate loading might induce more marginal peri-implant bone loss than conventional loading, since immediate loading might induce a more uneventful healing of the surrounding peri-implant bone. However, no differences were observed between immediate and conventional loading regarding marginal bone loss at 6 and 18 months post-implant placement. This is in agreement with recent studies on immediate and conventional single-tooth implants in the anterior zone (Hall et al. 2007, Den Hartog et al. 2008, Degidi et al. 2009).

Clinical outcome

Studies on immediate loading have often considered implant survival as the primary outcome measure. This is, however, only one outcome variable reflecting a succeeding therapy. In our study, survival rates were 96.8% for the immediate group (one implant failed) and 100% for the conventional group. These high survival rates were confirmed by other studies on immediately loaded implants, even when inserted in fresh extraction sockets (Den Hartog et al. 2008). It should be realized that the sample size of our study was too small to demonstrate whether immediate loading was non-inferior to conventional loading with respect to implant survival. Additional (long-term) studies would be helpful to draw firm conclusions regarding the potential hazardous effect of immediate loading on implant survival.

It is important to reach sufficient primary implant stability before performing immediate loading. It has been observed that in addition to the anatomy of the bone (Mesa et al. 2008, Roze et al. 2009) and preparation technique (Tabassum
et al. 2010), the geometry (O’Sullivan et al. 2004, Dos Santos et al. 2009) and length of the implant (Mesa et al. 2008) are factors influencing primary stability. In our study, almost all implants were 16 mm in length, the longest available for the type of implant we used. Furthermore, the implants had a rough surface topography and a tapered design, both favoring primary implant stability (O’Sullivan et al. 2004, Dos Santos et al. 2009). It might be attributed to these factors that in our study there were no difficulties to reach primary implant stability. Besides paying attention to sufficient primary stability as being a ‘conditio sine qua non’ for immediate loading, it is also important to carefully instruct the patient and to pay attention to the occlusion of the provisional crown. In our study, all provisional crowns were free from centric and eccentric occlusal contacts with the antagonist teeth.

With respect to the health of the peri-implant tissue expressed in probing depth, bleeding upon probing and amount of plaque, no differences were noticed between the immediate and conventional study group. The implants showed deeper probing pockets depths than the adjacent teeth (as also was observed in the implant neck study Chapter 3). Such deeper pocket depths around single-tooth implants have been reported in another study from our research group (Meijndert et al. 2008). It is argued that this difference in probing depth between implants and natural teeth, might be partly ascribed to the anatomy of the peri-implant mucosa and its attachment to the implant surface, being different compared to the anatomy of the gingiva and its attachment to the root surface (Ber- glundh et al. 1991). It was demonstrated that these differences had an impact on probing depth measurements, since the gingiva was more resistant to probing forces than the mucosal seal around implants (Ericsson & Lindhe, 1993).

Another interesting finding was the high number of implants displaying bleeding upon probing. At 18 months post-implant placement, most of the implants showed bleeding upon probing (around 80% of the implants versus 30% of the adjacent teeth, including the implants from the implant neck study). Unfortunately, data from other relevant studies on this topic are scarce and contradictory values are reported (Den Hartog et al. 2008). Besides, bleeding index scores were presented in percentages as well as in mean values or the unit of analysis differed (per implant or per implant side). Since bleeding on probing indicates presence of inflammation in the peri-implant mucosa (Heitz-Mayfield 2008), the significance of this variable as predictor for the long-term prognosis needs further investigation.

**Aesthetic outcome and patient satisfaction**

There is growing evidence that immediate loading of implants inserted in fresh extraction sockets would lead to more favorable soft tissue levels compared to a
delayed strategy (Block et al. 2009, De Rouck et al. 2009). These studies reported that immediate stabilization of the soft tissue after tooth removal by means of immediate implant placement and immediate placement of the provisional crown, would result in 0.75 to 1 mm more soft tissue preservation mid-facially. In our study, all implants were inserted in healed sites as was common those days. As pointed out earlier, tooth removal induces resorption of the walls of the alveolus affecting the soft tissue anatomy (Schropp et al. 2003b, Araujo & Lindhe 2005). It could be that for healed sites, a potential positive effect of an immediate (provisional) crown on soft tissue preservation subsided. When using the aesthetic evaluation instruments to express soft tissue aesthetics, at least no significant difference between immediate and conventionally loaded implants was observed. The same applied to the volume of the papilla assessed with the papilla index.

General patient satisfaction was high in both study groups and patients were satisfied regarding function, aesthetics and treatment procedure. Other studies on anterior single-tooth implants reported comparable overall satisfaction scores of 8.8 and higher (also using VAS) (Schropp et al. 2004, Den Hartog et al. 2008). As confirmed by other studies (Levi et al. 2003, Schropp et al. 2004), a substantial percentage of conventionally treated patients (30%) experienced the healing time of the implant as long. Although Levi et al. (2003) found that treatment time was not a critical factor for overall satisfaction, the shorter treatment time of immediate loading might serve these patients.

**Principal findings and clinical implications**

The general aims of our study were to compare the outcome of single implants with different neck designs applied to replace a missing anterior tooth in the maxilla and to compare the outcome of immediate loading with conventional loading, again for implants replacing a missing tooth in the anterior maxilla.

First, we assessed the treatment outcome of single-tooth implants in the maxillary aesthetic zone with three different implant neck designs, namely a 1.5 mm smooth implant neck (‘smooth group’), a moderately rough implant neck with grooves (‘rough group’) and a scalloped moderately rough implant neck with grooves (‘scalloped group’). At 18 months post-implant placement, the scalloped group showed significantly more marginal bone loss, deeper probing pocket depths and higher bleeding scores than the smooth group and rough group, while there were no differences in outcome between the smooth group and rough group. Besides, the implants in the smooth and rough groups revealed favorable treatment outcomes in terms of bone loss, implant survival, complications and soft tissue aspects, which are in line with values reported in other studies on single-tooth implants placed in the anterior maxilla (Den Hartog et al. 2008). Although there were no differences in aesthetic outcome between the three dif-
different implants, we suggest the use of implants with a 1.5 mm smooth neck or a rough neck with grooves for single anterior tooth replacements in stead of using implants with a scalloped neck design since the latter implants displayed more bone loss and less clinical performance.

Next, we assessed the treatment outcome of immediately loaded single-tooth implants in the aesthetic zone. It revealed that - on the short term - immediate loading will lead to a treatment outcome that is not less favorable than conventional loading. Since the concept of immediate loading shortens treatment time and offers comfort for the patient, this concept should be considered as a promising alternative to conventional loading. However, it should be realized that the concept of immediate loading has to be performed according to a specified protocol paying attention to adequate primary implant stability, a non-occluding provisional crown and careful patient instruction. Moreover, only short term results are available thus far.

**Future research**

Based on our findings and that of other studies (Hall et al. 2007, Degidi 2009), immediate loading of a single-tooth implant in the aesthetic zone can be considered as an effective treatment strategy on the short term. Additional studies are needed to investigate the efficacy of immediate loading on the long-term, before immediate loading can indeed be considered as an at least equal treatment modality as conventional loading has been shown to be.

Next to immediate loading, the promising concepts of immediate and early implant placement after tooth extraction need further study. In our immediate loading study, all implants were installed in healed extraction sites, at least three months after the tooth had been extracted. However, placement of an implant immediately or early after tooth extraction has been posed to be beneficial for preservation of hard and soft tissue. Furthermore, when immediate or early placed implants are subjected to immediate loading, this could offer even more comfort for the patient than just applying immediate loading. In order to gain more insight into preservation of hard and soft tissue after tooth extraction, studies are needed investigating socket preservation techniques and - whether or not - these techniques should be combined with immediate or early implant placement. Socket preservation techniques could, amongst others, enhance the final outcome since collapse of tissue might be prevented and with that a thorough augmentation procedure.

As applies to our immediate loading study, additional (long-term) studies are needed to validate the conclusions we draw in our study to different implant neck designs. Furthermore, besides focusing on the topography and geometry of the implant neck, additional research on other material aspects is needed.
For instance, the promising concept of internal conical connections between implant and abutment needs further study as holds for the concept of non-matching implant-abutment diameters (‘platform switching’).

An important starting point for future research is that studies should focus on the quality of the outcome, using uniform outcome variables and data presentation. This will ease comparison of studies. In order to compare different types of interventions, clinical trials are needed with sufficiently large study populations and random allocation procedures. Furthermore, we believe that it would be helpful to consider the pre-operative situation and its relation to the final outcome as well. When taking the pre-operative situation into account too, the true effect of an intervention on the final outcome might be determined with more accuracy meanwhile reducing the difference in treatment outcome as rated by the clinician (who now just rates the appearance of the crown and soft tissue) and the patient (who also includes the baseline characteristics in his ratings). With regard to the measurement instruments, efforts should be made to further develop an objective aesthetic rating instrument with good internal and external validity, to be commonly used in implant research. The present aesthetic rating instruments are only tested for their reproducibility and do not take the pre-operative situation into account. The same applies to the development of a validated questionnaire assessing patient satisfaction. Finally, upcoming instruments as three-dimensional imaging techniques could be brought into new research projects. With such measurement instruments, the effect of an intervention on the hard and soft peri-implant tissues can be assessed in all dimensions with more ease and probably with more accuracy.

It is foreseen that, through further research, more insight will be obtained into the efficacy and efficiency of implant treatment strategies to replace a missing anterior tooth. This will favor the ultimate ambition to strive for, viz. efficient creation of a high quality restoration for the long term, satisfying the criteria that reflect function and aesthetics.
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