1. Introduction

Over the past twenty years, dental implants increasingly occupy a preponderant place in dental medicine. Implant dentistry has developed from the principle, which describes the concept of the establishment of a direct structural and functional connection between living bone and the surface of a load-bearing artificial implant, typically made of titanium which is termed “osseointegration” (Branemark, Hansson et al. 1977; Adell, Lekholm et al. 1986). With this, the direct contact between implant surface and bone without a connective tissue interface is described. The implant lacks the physiological movement of a tooth, therefore an osseointegrated implant is immobile (Albrektsson, Zarb et al. 1986; Tetsch P 1990).

After the initial use of osseointegrated implants in edentulous jaws, the indication broadened to partially edentulous dental patients with similar success (Adell, Lekholm et al. 1986; Lekholm, Adell et al. 1986; Quirynen, Naert et al. 1992; Richter EJ 1992; Dietrich u, Lippold R et al. 1993). A single-tooth gap is defined as a gap of one missing tooth bordered by one or more natural teeth on either side. Single tooth implants also show high success rates (Henry, Rosenberg et al. 1995; Henry, Laney et al. 1996).

2. Literature Overview

2.1 Endosseous dental implants

Implantation is defined as the insertion of any object or material, such as an alloplastic substance or other tissue, either partially or completely, into the body for therapeutic, diagnostic, prosthetic, or experimental purposes (Marziani 1954). The dental implant, which is also an implantation material, has developed going through many phases to imitate the shape and form of teeth (Rieger, Fareed et al. 1989; Holmgren, Seckinger et al. 1998; Tada, Stegaroiu et al. 2003; Geng, Xu et al. 2004; Pirker and Kocher 2009). To date two-common implant systems are widely used. Two-piece implants are composed of an anchorage component, which is embedded into the bone resembling a root of the tooth, which is termed the 'endosseous dental implant body'. This component should be osseointegrated in the jawbone and carry a retention component inserted into the implant body to receive a crown (abutment). The abutment is screwed to the implant body and then a crown is fitted to the abutment. The other implant system is the one–piece implant in which the implant body and the abutment are one-piece (Schroeder A 1988; Foitzik C (Hrsg) 1994).

A wide variety of materials have been used for dental and maxillofacial implants. Nowadays, the most popular implant material is commercially pure titanium and its alloys, mainly because of its favourable physical and mechanical properties such as adequate strength, the resistance to corrosion and a modulus of elasticity similar to that of bone and its biocompatibility (Steinemann 1996).

Brånemark proposed that implants integrate in such a way that the bone is in proximity to the implant without any intervening connective tissue. The titanium oxide permanently fuses with the bone, as Brånemark showed in the 1950s (Branemark 1959).

2.2 Features of single tooth implant

The single-tooth implant, between two natural teeth poses a great challenge for the dental implantologist. The quality, quantity of the available bone and the existing location of the anatomical landmarks play a prominent role in the success of the implant. In the aesthetic zone, accurate implant placement is essential (English 1993).

2.2.1 Alveolar bone atrophy

Tooth loss or simple extractions without grafting or implant placement often result in bone-volume deficiency and aesthetic concerns. The osseous alveolar process is reduced through atrophy, this occurs in height and vestibular-palatal or lingual direction. Bone volume resorption varies individually. It is also time and age dependent (Nentwig 1983; Xie, Ainamo et al. 1997; Blahout, Hienz et al. 2007). The greatest resorption occurs in the first 3 months after tooth extraction. It is further reduced after 6 months, and remains fairly stable 1-2 year post-extraction. In the mandible, the rate of resorption is three to four times greater than in the maxilla and more pronounced in the anterior region than in the posterior region (Tallgren 2003).
Maxillary anterior tooth gaps show resorption, while the horizontal reduction is twice as great as the vertical loss (Piesold 1991; Tallgren 2003), whereas the buccal bone lamella is resorbed (Piesold 1991). A clinical study has shown that 23% of the bone volume loss in the anterior area of the upper jaw occurs 6 months after tooth extraction, increasing further in 5 years by 11% (Carlsson, Bergman et al. 1967).
Morphometric measurements of the alveolar process of 258 single tooth gaps showed that 24 months post extraction in 42% the horizontal bone volume, which was measured 5 mm subcrestal, lies between 4.5 mm and 5.5 mm (Piesold 1991). It is noticeable that the bone resorption progresses in an intact dental arch more slowly, when compared to edentulous jaws (Piesold 1991). In a study of Plizzi et al. it was shown that there is a clinical correlation between implant failure and periodontitis as a reason for tooth extraction, even if it is difficult to give it a casual association. It can be hypothesized that periodontitis affected tissues might have a negative local influence because of the presence of infrabony defects that could possibly increase the gap between bone and implant or jeopardize the achievement of primary stability (Polizzi, Grunder et al. 2000). Immediate implants are implants placed into extraction sockets at the same surgery that the tooth is removed, while early implants are implants placed following soft tissue healing. In general, the implant loss remained below 5% for both immediate and early placed implants, with a tendency toward higher losses when implants were also immediately loaded. Because of the lack of long-term data, questions regarding whether peri-implant health, prosthesis stability, degree of bone loss, and esthetic outcome of immediate or implants placed early are comparable with implants placed in healed sites remain unanswered (Quirynen, Van

Assche et al. 2007). In a review study of Chen et al. about clinical and esthetic outcome of implants placed in post-extraction sites it has been shown that there is strong evidence that the placement of implants in post-extraction sites per se does not prevent vertical or horizontal resorption of the ridge (Camargo, Lekovic et al. 2000; Covani, Cornelini et al. 2003; Iasella, Greenwell et al. 2003; Botticelli, Berglundh et al. 2004; Araujo and Lindhe 2005; Araujo, Sukekava et al. 2005; Araujo, Wennstrom et al. 2006; Covani, Cornelini et al. 2007; Chen and Buser 2009).

2.2.2. Esthetic requirements

The predictability of esthetic success depends on the tissue loss present at the initiation of treatment. The greater the amount of bone and soft tissue loss, the more difficult it becomes to produce an ideal aesthetic result. Single tooth implants can provide the morphological substructure that is required to restore natural gingival and papillary architecture. The position and angulation of a dental implant has become increasingly important for the esthetic and functional result of the implant-supported dental prosthesis. The crestal bone level has an influence on the volume of the interproximal dental and peri-implant papilla (Tarnow, Magner et al. 1992; Salama, Salama et al. 1998). Investigations indicate that the position of the soft tissue margin is related to the level of bone support around the implant (Abrahamsson, Berglundh et al. 1996; Berglundh and Lindhe 1996). With time and experience clinicians learned that the placement of an implant into resorbed alveolar ridges resulted in esthetically unsatisfactory restorations and often had compromised implant-to-crown relationships (Mecall and Rosenfeld 1991). However, when dealing with implant-supported restorations in the anterior region, treatment success will also depend on the esthetic outcome (Schropp, Isidor et al. 2005). Particularly with single-tooth replacements, there are high demands upon the clinician, who must ensure that the artificial crown is integrated harmoniously with the existing dentition. Another factor that may be important for obtaining a favorable esthetic result following implant treatment is the preservation or creation of harmonious soft tissue contours of the peri-implant mucosa, especially the papillae (Schropp, Isidor et al. 2005). Several approaches have been suggested for improving the esthetics in relation to implant treatment (de Lange 1995; Shearer 1995), such as development of various implant and abutment designs (Lazzara 1993; Gadhia and Holt 2003; Wohrle 2003).To

achieve an aesthetically satisfactory result, the implant shoulder should be 2 mm to 4 mm apical to the enamel cement junction of the adjacent teeth (Parel S and Sullivan 1989; Strub, M.B. et al. 1993; Saadoun and Le Gall 1998). The gingival zenith can be used as a reference point during aesthetic anterior oral rehabilitation. In addition, the intra-arch gingival level of the lateral incisor gingival zenith relative to the adjacent central and canine teeth can be appropriately established (Chu, Tan et al. 2009). When choosing an abutment for an anterior single-unit case, several factors should be considered: visibility of the region (e.g., high vs. low smile line); biotype of the gingiva, color of the neighboring teeth, and finally, esthetic expectations of the patient (Sailer, Zembic et al. 2007).

2.3 Missing single tooth: Treatment options

In an edentulous space due to the loss of a tooth (extraction, accident or congenitally absent) the dentist has different treatment options to replace a single tooth: such as the conventional bridgework, adhesive bridgework, removable partial denture, orthodontic closure, autotransplantation and implant-stabilized crown

2.3.1 Conventional bridgework:

Conventional bridgework is the most common method to replace a single tooth with a long term result functionally and esthetically (Palmqvist and Swartz 1993; Scurria, Bader et al. 1998; Stipetic, Celebic et al. 2000; Tan, Pjetursson et al. 2004; Marinello C.P. 1990). One of the disadvantages of bridgework is the loss of hard substance of the adjacent teeth because it requires preparation of the teeth and this may damage pulp vitality, and irritate the gingiva around the teeth when doing subgingival marginal preparation to allow for adequate subgingival extension (Behneke N 1988). In addition, compromised esthetic appearance by reason of material blocking and crown edges can limit the esthetic outcome.

2.3.2 Adhesive bridgework

Adhesive bridgework is an accepted alternative to conventional bridgework especially to

minimize tooth substance loss. This type of bridgework requires little preparation of the abutment teeth. Several designs have been described and these can be divided into bridges with perforated or non-perforated retainers. The perforated design was described by Rochette while the non-perforated design was pioneered by Livaditis and Thompson and became popularly known as the "Maryland Bridge". It is now common practice to simply sandblast non-precious alloy retainers which are then bonded with specific chemically active adhesives to the neighboring teeth (Johnston and Hussey 1993).

It can be placed fairly quickly, no, or minimal tooth preparation is required, a predictable appearance may be achieved with the pontic and it is relatively inexpensive compared to other options. The major disadvantage of an adhesive bridge is that occasional debonding may occur. Aesthetics can also be poor, especially where the abutment teeth are thin and the metal retainers may result in apparent tooth discoloration (John A. Hobkirk and Roger M. Watson 2003).

2.3.3 Removable partial denture

The removable partial denture is a prosthesis that is designed and fabricated to be removed by the patient. It contains three major parts: the metal portion, the artificial teeth, and the resin base material (McCracken, Henderson et al. 1973). Treatment with removable partial dentures is a non-invasive and low-cost solution for the prosthetic rehabilitation (Budtz-Jorgensen 1996). Still, the wearing of removable partial dentures may be associated with complaints related to impaired esthetics or oral comfort (Witter, van Elteren et al. 1989). This may be to such a degree that subjects often decide not to wear the denture (Chandler and Brudvik 1984; Germundsson, Hellman et al. 1984; Cowan, Gilbert et al. 1991). The effect of denture wearing in accentuating the accumulation of plaque is well known. And the development of root caries is often a problem (Stipho, Murphy et al. 1978; Budtz-Jorgensen and Isidor 1990; Wright, Hellyer et al. 1992). Major complications of treatment with removable partial dentures are mechanical failures, such as fractures of major or minor connectors, as well as occlusal rests and deformation or fracture of retentive clasps (Wetherell and Smales 1980; Lechner 1985; Budtz-Jorgensen and Isidor 1990). Furthermore, the resorption of the

residual ridge below free-end saddles and wear of the denture teeth may result in a destabilization of the occlusion (Stipho, Murphy et al. 1978; Germundsson, Hellman et al. 1984).

2.3.4 Orthodontic space closure

The orthodontic space closure is another solution especially in young adults with congenital absence of permanent teeth. This option requires no tooth preparation and does not normally involve surgical procedures. The outcome has a projected lifespan similar to that of the remaining dentition, and has a natural appearance (John A. Hobkirk and Roger M. Watson 2003). The treatment, once completed, requires no further maintenance. The technique is not always applicable, when a significant number of teeth are absent. This treatment option takes a long time and the commitment of the patient is therefore very important (John A. Hobkirk and Roger M. Watson 2003). The exposure of the roots of the orthodontically moved teeth, and even their resorption are side effects (Bender, Byers et al. 1997; Vlaskalic, Boyd et al. 1998; Pizzo, Licata et al. 2007; Marinello C.P. 1990).

2.3.5 Autogenous tooth transplantation

Autogenous tooth transplantation is the surgical movement of a tooth or tooth germ in a created tooth bed in another part of the alveolar process or in the alveolus of a previously removed tooth. The science of autotransplantation has progressed, as evidenced by the high success rates reported in studies over the past decade. A lot of these studies demonstrate that autotransplantation is a viable option for tooth replacement for carefully selected patients (Andreasen, Paulsen et al. 1990; Nethander 1994; Cohen, Shen et al. 1995). If the periodontal ligament is traumatized during transplantation, external root resorption and ankylosis is often noted (Pogrel 1987; Cohen, Shen et al. 1995).

2.3.6 Single tooth implant crown

Dental implants represent an alternative to the conventional treatment methods. Osseointegrated implants can provide a successful treatment method for patients,

without damaging adjacent teeth. Especially when the adjacent teeth do not have a caries. In addition, osseointegrated implants can achieve satisfactory esthetic results, and reduce bone atrophy in patients (Adell, Lekholm et al. 1986; Denissen and Kalk 1990; Kalk, Denissen et al. 1993; Carlsson 2004; Barreto, Francischone et al. 2008; Block, Mercante et al. 2009).

2.4 Endosseous dental Prowital® Implant system

The rapid development of the dental market has produced a variety of implant systems, which differ, in size, shape, surface design, and surface coating. Studies with different implant systems show their long-term success (Albrektsson, Jansson et al. 1986; Haas R 1996; Buser D and al. 1997).

2.4.1 Implant macro design

The Prowital® implant system is a two-piece screw implant with the same interior dimensions in all diameters. The body is made of pure titanium Grade 4. The Prowital® implant is a parallel-walled implant-screw with self-tapping threads. The threads in the lower portion are not self-cutting. This proportion is used to facilitate the insertion of the implant into the prepared implant bed. No separate thread-tapping step is required. The macro design or shape of an implant has an important bearing on the bone response, which has a great influence on initial stability and subsequent function (Friberg, Jemt et al. 1991; Jemt, Book et al. 1992; Narhi, Hevinga et al. 2001).

A wide variety of different implant shapes have been developed and clinically tested in the past 20 years. Macroscopically, there are two basic types of implants: Screws and cylinders. In general, a titanium implant of any shape can achieve osseointegration, if primary stability is obtained (Hansson 1999; Ivanoff, Grondahl et al. 1999; Carlsson 2000). Today, screw-type threaded implants are highly preferred in implant dentistry, since threaded implants offer two major advantages (Zitter and Plenk 1987; Albrektsson, Dahl et al. 1988). First, the implant threads improve primary implant stability, which is important to avoid micro movements of the implant until osseointegration is achieved, and the threads seem to play an important role for the load transfer from the implant to the surrounding bone (Quirynen, Naert et al. 1992; Hutton, Heath et al. 1995; Karoussis, Bragger et al. 2004). The implant shoulder is

wider than the implant body and the connection between them makes an angle similar to that of other implant systems such as Osseotite (3i Implant Innovations Deutschland GmbH) and Brånemark (Mk III, Nobel Biocare Deutschland GmbH) (Bertelmann 2008) (Figure 1). The interior geometry of the implant-abutment connection is a high-precision telescopic form (tube-in-tube). The implant-abutment connection is a butt-joint connection with a cam-groove antirotational-geometry which reduces the freedom of rotation (Semper, Kraft et al. 2009).

Prowital® **Osseotite®** **Brånemark Mk III TiUnite®**

Figure 1: shows the shoulder design of the three implants systems

2.4.2. Implant surface (Micro design)

Several attempts have been made to improve implant anchorage in bone by modifying the surface characteristics of titanium (Wennerberg, Ektessabi et al. 1997; De Leonardis, Garg et al. 1999; Carlsson 2000; Barewal, Oates et al. 2003; Juodzbalys, Sapragoniene et al. 2003; Sul, Byon et al. 2008). And because the chemical etching of the titanium implant surface increases significantly the strength of osseointegration (Klokkevold, Nishimura et al. 1997; Klokkevold, Johnson et al. 2001), many attempts were made to create an acid-etched implant surface that results in a surface similar to that gained by using sandblasting combined with acid etching, and many substances were used to etch the implant surface such as HCL, HCL and H_2SO_4, H_2SO_4/HCL and H_3PO_4 and others(Juodzbalys, Sapragoniene et al. 2003). The manufacturer states that the implant surface is acid-etched, but refuses to describe the method and to name the substances used to etch Prowital-implants. The manufacturer describes his implant as follows: „The implant has a

micro-rough acid-etched surface, which reaches up to the implant platform. The surface is called OsseoAttract".

2.5. Loading conditions

Brånemark established a protocol stating that the primary requirement for achieving osseointegration was to leave the implants load-free for 6 months in the maxilla and 3 months in the mandible (Branemark, Hansson et al. 1977). These waiting periods were thought to be necessary to avoid the formation of fibrous tissue around the implant, which would prevent direct bone apposition and, therefore, osseointegration. Recent scientific literature shows that the healing periods before loading implants have changed and evolved (Thomas, Kay et al. 1987; Zubery, Bichacho et al. 1999; Meyer, Joos et al. 2004; Nelson, Semper et al. 2008).

2.6. Success criteria of implants

Success criteria are established to evaluate the success of osseointegration of endosseous implants (Buser, Ingimarsson et al. 2002)

- absence of persistent signs/symptoms such as pain, infection, neuropathies, paraesthesias, or violation of vital structures
- implant immobility
- no continuous peri-implant radiolucency;

2.7. Bone quality

Misch 1990 presented his classification of the different bone qualities. The system of Misch is based on the radiographic appearance of the bone and the tactile assessments of the clinicians. The density of the bone is determined during the initial bone drill, and the evaluation of bone density continues until final implant placement. Misch divided the bone quality into 4 subdivisions (D-1 to D-4) based on the observed bone density. D-1 and D-2 bone generally have dense cortical plates with coarse trabeculae and small bone marrow spaces, D-1 (atrophic anterior mandible)

being denser than D-2 (anterior maxilla, anterior and posterior mandible). D-3 (anterior and posterior maxilla) and D-4 (posterior maxilla) bones range from poorly mineralized or thin trabeculae to complete paucity of mineralized trabeculae (D-3 being denser than D-4) (Table 1) (Misch 1990).

	D1	D2	D3	D4
Description	Dense compact bone.	Dense to thick compact and coarse trabecular bone.	Porous compact and fine trabecular	Fine trabecular bone
Construction	Very dense bone composed of all dense compact.	Combination of dense to porous compact bone on the outside and coarse trabecular bone on the inside.	Composed of the thinner porous compact bone and fine trabecular bone	Very light density and little or no cortical crestal bone. Very Porous.
Tactile sense	Oak or maple-like	Preparation in spruce or white pine wood.	Balsa Wood	Styrofoam
Location	Anterior lower jaw	Ant./post. lower jaw - ant. upper jaw.	Ant./post. upper jaw - post lower jaw	Posterior upper jaw
Rigid initial fixation	Good	Good	Little	Very little

Table1: The classification of bone qualities and densities (Misch 1990). (Ant.: anterior, post.: posterior)

2.8. Peri-implant soft tissue

Some studies show that gingivitis, which is related to plaque in the soft tissue around the implant, may cause more serious problems like marginal swelling around natural teeth that have a periodontal ligament (Carranza 1996). Microbial plaque is the main factor that may threaten the health of tissues around the implant and can cause infections (Carranza 1996). There are 2 stages of peri-implant infection: early mucositis, consisting of inflammation of the peri-implant soft tissues without loss of supporting bone, and a more advanced form involving a loss of osseointegration,

known as peri-implantitis (Lopez-Cerero 2008). Romeo has defined peri-implantitis surrounding oral implants is an inflammatory process affecting the soft and hard tissues resulting in rapid loss of supporting bone associated with bleeding and suppuration (Romeo, Ghisolfi et al. 2004). Many techniques are used to diagnose the diseases around implants such as mucositis and peri-implantitis (Lozada, James et al. 1990). Among these, plaque index, gingival index, bleeding index, probing pocket depth, and probing attachment level are used frequently to evaluate the health of soft tissues around implants. In a clinical study it could be shown that the plaque and gingival-index can be used as an indication of mucositis (Jansen VK and Augthun M 1993). In another study, it was found that there was a correlation between plaque, mucositis and bone loss after 3-year of implant loading (Teixeira, Sato et al. 1997). Statistically significant positive correlations were found between implants with peri-implantitis and periodontal bone loss in the 4 quadrants (Maximo, de Mendonca et al. 2008).

2.9. Clinical studies about acid-etched implants

The surface characteristics of dental implants appear to modulate osteoblasts' growth and differentiation, affecting bone healing and bone integration (Klinger, Tadir et al. ; Buser, Schenk et al. 1991). To increase the strength of osseointegration ablative procedures have been used (e.g. blasting, acid etching) to increase the surface area and to alter its microtopography or texture (Klokkevold, Nishimura et al. 1997; Klokkevold, Johnson et al. 2001). Many studies show that the acid etching of the titanium surface of a dental implant creates a micro textured surface that appears to enhance the early endosseous integration and stability of the implant (Davies 1998; Klokkevold, Johnson et al. 2001). A study of De Lima Fernandes et al. in rabbits compared acid-etched surfaces to machined surfaces of implants inserted into the tibia 9 weeks post implantation. He found that acid-etched implants had higher bone response and implant fixation than turned implants, regardless of the primary stability (Fernandes Ede, Unikowski et al. 2007). Trisi et al. have investigated in their clinical study the bone-implant contact on machined and dual acid-etched surfaces after 2 months of healing in the human maxilla. Based on the histomorphometric results of their study they found that sufficient bone for functional loading of the implant exists on the dual acid-etched surface after 2 months of healing, with the bone-implant

contact being significantly higher than with machined surfaces (Trisi, Lazzara et al. 2003). Juodzbalys et al. in his trial to create a new acid-etched titanium dental implant surface showed that precise acid selection and the sequence of processing played the main role in preparation of the rough titanium surface (Juodzbalys G 2003). Clinical studies on implants with acid-etched surfaces show high success rates, with a high rate of integration and excellent predictability of implants with acid-etched surface (De Leonardis, Garg et al. 1997; Grunder, Gaberthuel et al. 1999; Davarpanah, Martinez et al. 2001; Testori, Del Fabbro et al. 2003; Sullivan, Vincenzi et al. 2005).

2.10. Acid-etched implants and short healing period

Based on the histomorphometric results of a clinical study, sufficient bone for functional loading of the implant exists on a dual acid-etched surface after 2 months of healing in the posterior maxillary arch (Trisi, Lazzara et al. 2003). In a multicenter prospective study the results indicate that Osseotite dual acid-etched endosseous implants can achieve successful osseointegration when loaded after 2 months of healing and remain stable during 5 years of implants function with a post-loading success rate of 99.4% (Sullivan, Vincenzi et al. 2005).

2.11. Clinical studies about single tooth implant

Bone loss around implants can be classified as early or late bone loss (Albrektsson, Zarb et al. 1986; Smith and Zarb 1989; Esposito, Hirsch et al. 1998). Early implant bone loss occurs at the crestal region during healing and up to the first year of loading (Chung, Oh et al. 2007).

In literature, detailed description of the bone loss is missing (Palmer, Smith et al. 1997; Scheller, Urgell et al. 1998; Ericsson, Nilson et al. 2000; Schropp, Kostopoulos et al. 2005; Cooper, Ellner et al. 2007; De Bruyn, Atashkadeh et al. 2009). While in many studies the general crestal bone loss changes were published (Calandriello, Tomatis et al. 2003; Cardaropoli, Lekholm et al. 2006; Zarone, Sorrentino et al. 2006; Cooper, Ellner et al. 2007; Turkyilmaz, Avci et al. 2007), in the present study the mesial and distal crestal bone loss changes over time were evaluated. Also many of the studies measured the crestal bone loss changes from the time of prosthetic

rehabilitation (Palmer, Smith et al. 1997; Scheller, Urgell et al. 1998; Ericsson, Nilson et al. 2000; Schropp, Kostopoulos et al. 2005; Cooper, Ellner et al. 2007; De Bruyn, Atashkadeh et al. 2009), and not directly after the insertion of the implant (Calandriello, Tomatis et al. 2003; Turkyilmaz, Avci et al. 2007). There are few studies that refer to the crestal bone level relative to the implant surface at the time point of implant insertion (Cardaropoli, Lekholm et al. 2006). The crestal bone changes after one year from insertion or rehabilitation varies from one study to the other with regard to many influencing factors. There are many studies about single tooth implants, which evaluate the crestal bone loss around implants with different surfaces and designs. In the literature there is only one study on single-tooth implants with acid-etched surface (Osseotite®) (Schropp, Kostopoulos et al. 2005). In the study mentioned, the baseline to evaluate the crestal bone loss is the time point after healing abutment connection (three months after implant insertion). The study did not refer to the level of bone at the time of implant insertion, neither the crestal bone loss during the healing time. Therefore, the importance of the present study is evident, as it evaluates the crestal bone loss on single-tooth implants with an acid-etched surface from the time point of implant insertion and up to one year post insertion, and without neglecting the substantial crestal bone loss during the healing period. The following table summarizes the information of studies on single-tooth implants with different designs and surfaces (Table 2).

year	Study	Implant System	**Nr.	x-ray at implant insertion	***St. of X-rays	**Crestal bone loss mesial**	**Crestal bone loss Distal**	Time point of evaluation	Type of X-ray	Time/type of healing/loading	Success
1998	Scheller	Brånemark®*	77	no	yes	**0.5**	**0.4**	1 year after loading	intra-oral radiographs	3-6 months	95.9
2000	Ericsson	Brånemark®*	12	no	yes	**0.08**	**0.2**	6-18 months after loading	intra-oral radiographs	immediately	100
			8			**-0.05**	**0.19**			3-6 months	
2005	**Schropp**	**Osseotite®**	**23**	**no**	**no**	**1.3**	**1**	**9 months after insertion**	**intra-oral radiographs**	**Three **** months**	**91**
			23			**1.5**	**1.4**			**Three months**	**96**
1995	Andersson	Brånemark®*	54	no	no	**1.33**		1 year after loading	intra-oral radiographs	3-6 months	98.5
1995	Engquist	Brånemark®*	70	no	no	**0.8**		1 year after loading	intra-oral radiographs	3-6 months	97.6
2003	Calandriello	Brånemark® TiUnite- MK III	24	yes	no	**1.3**		One year	intra-oral radiographs	immediately	100
2006	Cardaropoli	Brånemark®*	11	yes	yes	**1.6**		1 year after loading	intra-oral radiographs	6 months	
2007	Turkyilmaz	Brånemark® TiUnite- MK III	36	yes	yes	**0.7**		One year after insertion	intra-oral radiographs	6 weeks	94.4
			23			**0.81**				6 months	95.7
2009	De Bruyn	Brånemark® TiUnite	53	no	no	**1.5**		1 year after loading	intra-oral radiographs	3-6 months	100

* (Brånemark System, Nobel Biocare AB, Goeteborg, Sweden) **Number Of implant *** Standardization of X-rays **** implants were inserted 10-15 days after tooth extraction

Table 2: clinical studies about single tooth implant

3. **Purpose**

The purpose of this prospective study was to evaluate the radiological crestal bone loss around the ProWital-Implant within one year after surgical placement. The assessment of crestal bone loss was accomplished by means of standardized radiological images to clarify the following items:

- Assessment of the crestal bone loss around Prowital® implant at various time points up to one year after insertion.

- The correlation of crestal bone loss to soft tissue status based on defined clinical parameters.

- The identification of factors influencing (e.g. age, gender, region of insertion) the crestal bone loss.

4. Materials and Methods

Three private dental practices and the Clinic for Oral and Maxillofacial Surgery, Charité Campus Virchow, participated in this prospective study. This study was designed to assess and investigate the peri-implant marginal bone and soft tissue around a single tooth implant Prowital® (Prowital GmbH, Wiernsheim). A regular clinical and radiological check-up was accomplished according to the study-protocol to assess the bone and soft-tissue behaviour around the implants.

4.1. Ethics committee approval.

The study design was prospective and multicenter. The protocol was approved by the Ethical Committee of the Charité Hospital and obtained under license Nr. EA2/044/06.

4.2. Patient selection and implants

During the period from July 2006 to July 2008, a total of 35 patients (male/female 17/18) with a mean age of 55 years (range from 23 to 72 years) were consecutively registered and treated with one or more single tooth implant. A total of 40 implants were placed. Thereof, 22 were placed in the maxilla and 18 in the mandible. The monitoring of all patients after implant placement was based on an established study protocol. Patients were included if they fulfilled the criteria shown (Figure 2).

4.2.1. Inclusion criteria:

- Existence of a single missing tooth with disease-free adjacent teeth.
- The cervical gap width was at least 6.5 mm.
- The minimum age at the time of implantation was 18 years.
- Patient does not require augmentation.
- Patients were also included if they received daily medication with coumarin derivates.

4.2.2. Exclusion criteria:

- Lack of patient compliance
- Poor oral hygiene
- Untreated periodontitis
- Alcoholism or drug abuse
- Inadequate bone volume around implant
- Compromised general health which would inhibit osseointegration (bone diseases and metabolic bone diseases) or patients who generally demonstrate a health risk regarding the local operation.
- Liver disease
- History of renal failure
- Uncontrolled diabetes
- Haematopoiesis disease
- Immune suppression
- History of leukocyte dysfunction or deficiency
- Radiation/ chemotherapy
- Acute infection in implantation area

Figure 2: Inclusion and exclusion criteria

4.3. Details about the Prowital® implant

The Prowital® implant is available in different diameters (ø 3.5 / 4.3 / 5.0 mm) and lengths (9, 11, 13, 15 mm). The manufacturer states that the implant surface is acid-etched.

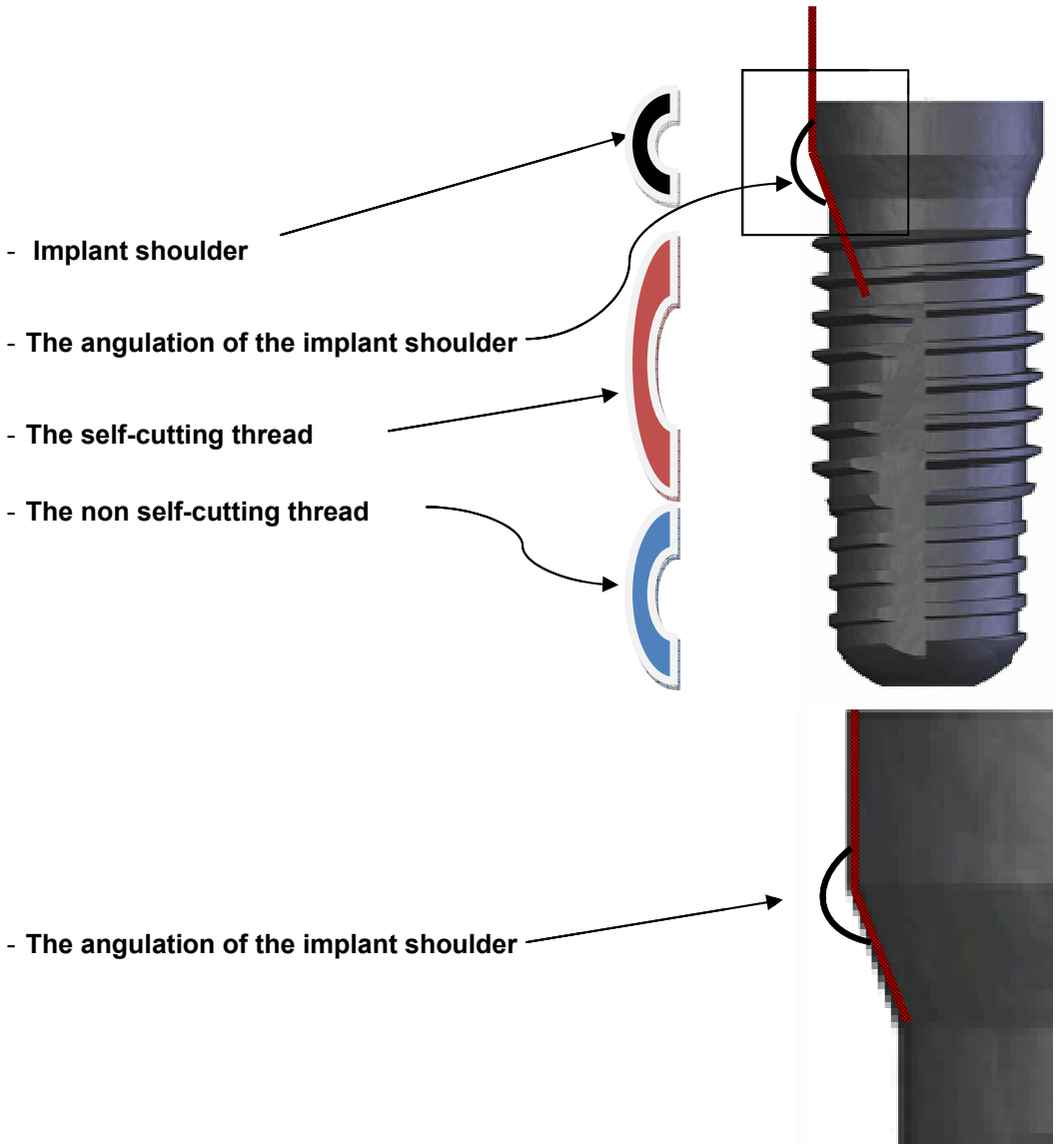

Figure 3: Prowital® implant macrodesign

4.4. Surgical procedure

All implants were placed according to the manufacturers' instructions using low-speed drilling for preparation of the implant sites. No prophylactic systemic antibiotics were used. Two-stage surgery was performed. All implants were placed under local

anaesthesia (Ultracain® D-S forte) and after raising a full-thickness muco-periosteal flap. Stabilization of the wound margins was performed with a recurrent suture technique (5-0 Monocryl®). The sutures were removed after 7-10 days. The details of the implants placed were registered in the study protocol and comprised: diameter and length. The implant exposure was performed using minimal invasive semilunar incisions above the implant to achieve beneficial soft tissue conditions around the implant, then the gingival formers were placed. After implant placement and during the healing period, the patients were monitored with clinical and/or radiographic evaluation.

4.5. Success criteria

In this work the Buser-creteria of success were applied (Figure 4):

- absence of persistent subjective complains such as pain, foreign body sensation, and/or dysesthesia
- absence of peri-implant infection with suppuration
- absence of mobility
- absence of continuous radiolucency around the implant

Figure 4: Buser success criteria

4.6. Prosthetic procedure

Prosthetic procedure was initiated when the implants were successfully integrated and the torque value of the individual implant at second stage surgery was > 35 Ncm. According to the study protocol, loading was initiated as early loading in a period of 12 weeks in the maxilla and 6 weeks in the mandible post-surgery. A closed-tray impression of the implants for the fabrication of the master model was made in all cases using a polyether impression material (Impregum, ESPE). Conventional prosthetic steps were followed including a bite-registration. The implant-retained superstructures were cemented with (IMprov, Dentegris). All abutment screws were tightened with a torque specified by the implant manufacturer.

4.7. Clinical evaluation

4.7.1. Inspection criteria

The patients were routinely seen for clinical examination at 4 weeks after prosthetic restoration, and every 3 months thereafter during the first year. The follow-up examination with the investigation of clinical parameters was at 6 months and 12 months after implant insertion. At these recall appointments, implant success was examined according to the criteria of Buser (Buser, Ingimarsson et al. 2002).The amount of plaque was scored using the modified plaque index (mPI) and the degree of inflammation of the peri-implant mucosa was recorded using the modified bleeding index (mBI) (Mombelli, van Oosten et al. 1987) (Figure 5). Moreover, the mesial and distal pocket depth was measured at each implant with the periodontal Williams's probe which has circumferential lines at 1 mm, 2 mm, 3 mm, 5 mm, 7 mm, 8 mm, 9 mm, and 10 mm. All patients were enrolled in an oral hygiene program.

mPI (modified plaque index)

- Score 0: no detection of plaque.
- Score 1: Plaque only recognized by running a probe across the smooth marginal surface of the implant. Implants covered by titanium spray in this area always score 1.
- Score 2: Plaque can be seen with the naked eye.
- Score 3: abundance of soft matter.

mBI (modified bleeding index)

- Score 0: no bleeding when a periodontal probe is passed along the gingival margin adjacent to the implant.
- Score 1: Isolated bleeding spots visible.
- Score 2: Blood forms a confluent red line on margin.
- Score 3: Heavy or profuse bleeding.

Figure 5: modified Plaque index and modified Bleeding index

4.7.2. Bone quality

The bone quality was evaluated subjectively by the surgeon by tactile control during pilot drilling depending on the classification proposed by Misch in 1990 (Misch 1990).

4.8. Radiological examination

4.8.1. X-ray method

To display the peri-implant bone behavior, either a standardized Orthopantomogram (OPG)(Kodak 8000, Marne la Vallée Cedex 2 France and OrthophosXG 5/Ceph, Germany) was utilized as described by Gomez (Gomez-Roman 1995) or intraoral periapical images with standardized bite registration with the right-angle technique. To reproduce the same image of the X-rays at different time points, individualized film holders were used. The bite registrations were fabricated using silicon impression material (Provil® Novo Putty regular, Heraeus Kulzer GmbH), and were placed on the individual bite blocks. The mounted film-holder was brought into the correct position, and the patient closed the mouth carefully until reaching the contact with the bite-block. In the impression material the impressions of the superior and inferior teeth or anatomy were clearly noticeable, which permits the finding of the registered position. The excessive silicon was removed with the scalpel. After disinfection with (Descosept® Dr. Schumacher GmbH), the individualized bite blocks were kept in individual boxes. In a similar approach OPGs were also standardized by modification of the bite-blocks using silicon impression material to make an individual silicon bite.

4.8.2. Evaluation of the radiological image

- **Measuring method**

To evaluate the vertical changes of the crestal bone level, a quantitative evaluation of peri-implant bone resorption was performed: Routinely taken orthopantomographies and intraoral periapical images were analyzed as described by Gomez-Roman et al.

(Gomez-Roman 1995) at the mesial and distal site of each implant. A luminescent screen and magnifying glasses (Surgical telescopes 3.5x, Designs for Vision Inc., Ronkonkoma, NY, USA) were used. A reference point at the level of the implant-shoulder for Prowital implants was determined (Fig. 6). The vertical change of the marginal bone level was measured with the digital gauge (Holex, Hoffmann, Nürnberg, Germany) three times each at the mesial (m) and distal (d) aspects of each implant parallel to its axis from the reference point up to the deepest point of the peri-implant translucency, which is where the bone shows the first radiologic implant contact. If the bone contact is apical to the reference point, the data has a positive value, if it is coronal the value is negative (Figure 6).

Values measured on the radiographic picture were adjusted by using the following equation, where the original implant length was inserted to eliminate distortions of the radiograph:

The individual magnification factor (IMF) was calculated for every radiologic image separately according to the following equation:

$$IMF = \frac{\text{real implant length}}{\text{radiologic implant length}}$$

The real crestal bone alterations were calculated using the following equation.

Real crestal bone alteration = measured bone alteration X IMF

This procedure was performed on x-rays taken at all time points described (t0-t2). Mesial and distal values were interpreted separately. Mean values for all mesial and distal measurements were specified as m0/d0= data of mesial/distal bone contact/level relative to the implant reference point at time point of implant insertion (t0), m1/d1= data of mesial/distal bone contact/level to the implant reference point at six months after insertion (t1), m2/d2= data of mesial/distal bone contact/level relative to the implant reference point one year following insertion (t2). To evaluate the rate

and process of marginal bone resorption, consecutive mean values of the following time point were related to measurements of the previous value: Bone level changes in the interval were analyzed by subtraction the values of bone loss from the previous value. Results were specified as m1-0, m2-1, m2-0 and d1-0, d2-1, d2-0 and show the amount of bone loss between the relevant time points.

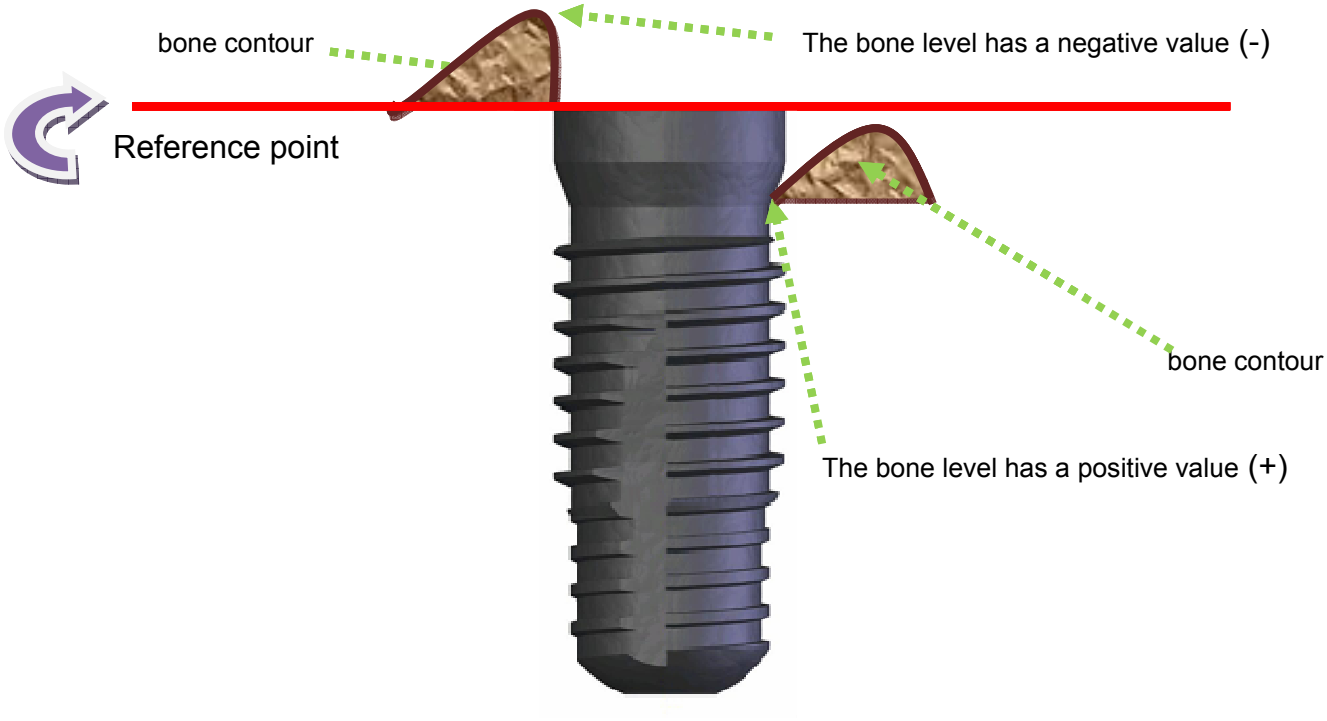

Figure 6: Measurement points.

4.9. Statistical analysis

Descriptive analysis was performed with all data available. Statistical analysis was accomplished using SPSS 17 for Windows. The non-parametric Mann–Whitney *U* test or Kruskal-Wallis Test was used to evaluate the relationship of crestal bone loss to each of the following:

Implant length, diameter, location, gender, age, clinical parameters like pocket depth, mBI, and mPI. To assess the relationship between patients' age and crestal bone loss, the non-parametric Spearman's rank correlation coefficient test was used.

Numerical values are given as means ± SD, the criterion for statistical significance was set at $P<0.05$.

5. Results

5.1 Patients

Between 2006 and 2008, a total of 35 patients (17 males, 18 females) were treated with 40 endosseous dental implants restored by single crowns.
The age of the patients at time of implant insertion was 23 to 72 years old, the mean age was 54 (Table 3).

	mean	Minimum	Maximum
Male	57	33	69
Female	51	23	72
All Patients	*54*	*23*	*72*

Table 3: Age distribution of the patients

5.2. Drop-out and implant success

Throughout the observation period no implant loss was recorded. No implants showed any clinical signs of infection or mobility and were considered successful according to the Buser success criteria (Buser, Ingimarsson et al. 2002). Only the radiological data of one implant at the time of the one-year follow-up was missing. All data for the other implants were available for analysis.

5.3 Implant localization and gender

From a total of 40 implants, 22 (55%) were located in the maxilla and 18 (45 %) in the mandible (Table 4). With regard to gender, 21 implants (52.5 %) were inserted in males and 19 implants (47.5%) were inserted in females (Table 4).

	Male	Female	Total	Total (%)
Maxilla	10	12	22	**52.5**
Mandible	9	9	18	**47.5**
Total	**19**	**21**	**40**	**100**

Table 4: Distribution of implants by gender

The detailed localization of the 40 implants is shown in Table 3. As to location of implants inserted, 7 (17.5 %) and 33 (82.5 %) implants were inserted into the anterior and posterior regions of the jawbone, respectively (Table 5).

			1	**7**		**1**		**5**	**1**		**5**		**2**			**22**
18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28	**Total**
48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38	**Total**
		4	**2**	**1**							**1**	**1**	**8**	**1**		**18**

Table 5: The localization of 40 implants (FDI)

5.4 The implant dimensions

Distribution of implant length and diameter is shown in Table 6.

Diameter / Length

		Length			Total Implant
		9 mm	11 mm	13 mm	
Diameter	3,5 mm	0	2	2	4
	4,3 mm	2	6	12	20
	5 mm	0	4	12	16
Total Implant		2	12	26	40

Table 6: Implant dimensions

5.5. Hard tissue parameters

5.5.1. Bone quality

At the time of implantation, the bone quality was recorded according to Misch (Misch 1990). In the present study, 18 implants were inserted in the mandible with D2 bone density. In the maxilla and mandible, 15 implants were inserted in bone with D3 bone density. The other implants were inserted in the maxilla in D4 bone density and no implant was inserted in bone with D1 bone density. The distribution of bone quality according to the location in the jaws is shown in Table 7.

Bone quality / Location

		Area			Total
		Front maxilla	Posterior maxilla	Posterior mandibule	
Bone quality	D2	0	0	18	18
	D3	7	8	0	15
	D4	0	7	0	7
Total		7	15	18	40

Table 7: Distribution of bone density with reference to the region in the jaw.

After applying known torques using a manual torque wrench, a good tightening torque (torque > 35 Ncm) was recorded in a total of 33 implants in maxilla (19) and mandible (14), while 4 implants recorded a medium tightening torque (torque 10–35 Ncm) and 3 implants a low tightening torque (torque < 10 Ncm) (Table 8).

Tightening torque	Maxilla	Mandible	Total of implant
good (torque > 35 Ncm)	19	14	33
medium (torque 10–35 Ncm)	1	3	4
low (torque < 10 Ncm)	2	1	3
Total	22	18	40

Table 8: Distribution of tightening torque at implantation

5.5.2. Radiological parameters

The descriptive analysis for all X-ray images in reference to the vertical bone level around implants at the time point of implantation placement (t0), at 6 months (t1) and one year after implantation (t2) has shown the following results.

5.5.2.1. Bone level at implant placement

The measured vertical bone level for all 40 implants shows an absolute mean value of 0.1 mm mesially (SD ± 0.3 mm) and of 0.1 mm distally (SD ± 0.7 mm).

5.5.2.2. Bone level at six months

The measured vertical bone level difference for all 35 implants shows an absolute mean value of 0.6 mm mesially (SD ± 0.6 mm) and of 0.7 mm distally (SD ±0.8 mm)

5.5.2.3. Bone level after one year

The measured vertical bone level difference for all 39 implants shows an absolute mean value of 1.4 mm (SD ±0.8 mm) mesially, and of 1.6 mm (SD ±0.8 mm) distally (Table 9).

	Implantation (t0)	At six months (t1)	After one year (t1)
Mesial	0.1 mm	0.6 mm	**1.4 mm**
Distal	0.1 mm	0.7 mm	**1.6 mm**

Table 9: crestal bone level at scheduled time of examination

The median value of crestal bone level relative to implant surface at insertion time was mesial 0 mm (max: 1.4 mm, min: -1.6 mm) and distal 0 mm (max: 1.6 mm, min: -0.8 mm). One year after insertion of the implants the median value of mesial and distal crestal bone level relative to implant surface was 1.7 mm (max: 2.9 mm, min: 0.7 mm) and 1.8 mm (max: 3.1 mm, min: 1.0 mm), respectively (Fig 7).

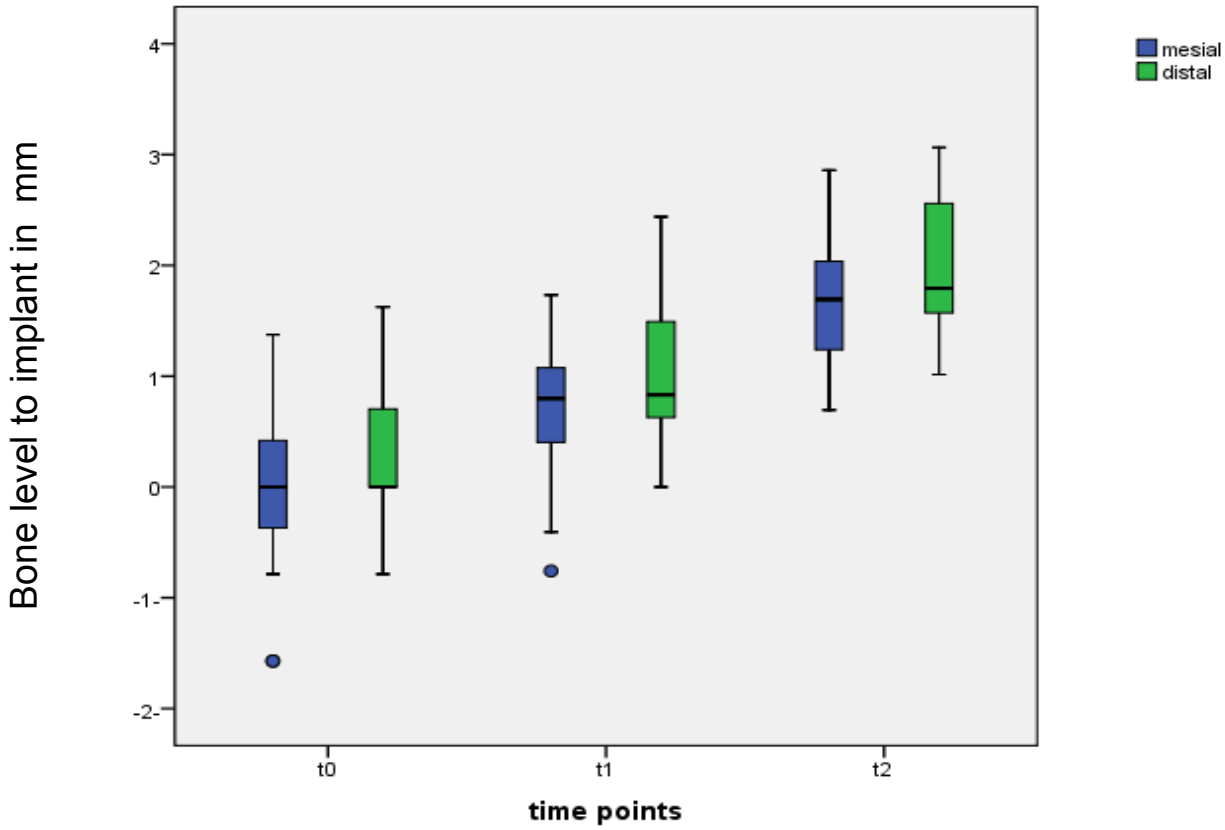

Figure 7: Boxplot expressing bone level relative to implant surface in mm, measured with respect to the reference point for implants at time point from t0-t2.

5.5.2.4. Mesial and distal crestal bone loss

At 6 months the mean value of mesial crestal bone loss was 0.6 mm, and it was lower than the distal crestal bone loss, whose mean value was 0.7 mm. After one year the mean value of mesial crestal bone loss was 1.4 mm, and it was lower than the distal crestal bone loss, whose mean value was 1.6 mm. But the difference was not statically significant.

5.5.3 The vertical bone level above the implant shoulder

Fifteen out of 80 measured sides of the 40 implants (nine unilateral and three bilateral) were radiologically located below the bone level (subcrestal) at the time of insertion. This positive value should be taken into consideration when evaluating of the bone loss (Table 10).

Unilateral	Bilateral	Aspects	Minimum value	Maximum value	Mean
9	3	15	0.1 mm	1.6 mm	0.8 mm

Table 10: Values of implant sites that were located below the bone level.

One year following implant insertion, the mean value of mesial and distal crestal bone loss for subcrestally located implants was 2 mm (SD ±0.8 mm). This value was greater than that in equicrestally and supracrestally inserted implants (Table 11).

Alveolar crest	No. of aspects mesial		No. of aspects distal		No. of aspects mesial and distal	
Equicrestal and supracrestal	27	1 mm (SD ±0.7 mm)	36	1.6 mm (SD ±0.8 mm)	63	1.4 mm (SD ±0.7 mm)
Subcrestal	12	1.9 mm (SD ±0.7 mm)	3	2.3 mm (SD ±0.1 mm)	15	2 mm (SD ±0.8 mm)

Table 11: Radiological equicrestal and supracrestal /subcrestal location of implants

5.6. Soft tissue parameters

5.6.1. Pocket depth

At 6 months after insertion, the result of pocket proping on the 40 implants showed that 10 (25%) implants (from the mesial aspect), and 39 (97.5 %) implants (from the distal aspect) have a pocket depth of 2 mm. While at 12 months after insertion 39 (97.5%) implants from the mesial aspect, and 35 (87.5%) implants from the distal aspect have a pocket depth of 2 mm. In addition, 4 (10%) implants have shown distal

pocket depth value of 3 mm. The non parametric Mann-Whitney *U* Test showed no correlation between pocket depth and crestal bone loss.

5.6.2 Plaque index

Of the 40 implants, 14 (35 %) implants showed plaque accumulation after one year. At implants with mPI = 1, the crestal bone loss was 1.7 mm and 1.8 mm for mesial and distal aspects of implant, respectively. For implants with higher mPI score = 2, the crestal bone loss was 1.5 mm and 1.6 mm for mesial and distal aspects of implants, respectively (Table 12). The non parametric Kruskal-Wallis-Test showed no correlation between mPI and crestal bone loss.

mPI	No. of implant	Mes. bone loss	Dis. bone loss
0	26	1.6 (SD ±0.76)	1.5 (SD ±0.67)
1	8	1.7 (SD ±0.4)	1.8 (SD ±0.61)
2	6	1.4 (SD ±1.1)	1.6 (SD ±1.12)

Table 12: mPI: Modified Plaque index, No.: Number, Mes: mesial, Dis: Distal, bone loss in mm

5.6.3 Bleeding index

Of the total of 40 implants, 7 (17.5 %) implants showed a score of 1, and 2 (5%) implants showed a score of 2 according to mBI. At implants with mBI = 1, the mean crestal bone loss was 2.2 mm and 1.8 mm for mesial and distal aspects of implant respectively. There were only two implants with higher mBI score of 2, while the mean crestal bone loss was 0.5 mm and 1.1 mm for mesial and distal aspects of implants, respectively (Table 13). The non-parametric Mann-Whitney *U* Test showed no correlation between mBI and crestal bone loss after one year.

mBI	No. of implant	Mes. bone loss	Dis. bone loss
0	31	1.5 (SD ±0.6)	1.6 (SD ±0.7)
1	7	2.2 (SD ±1.1)	1.8 (SD ±1.1)
2	2	0.4 (SD ±0.0)	1.1 (SD ±0.0)

Table 13: Crestal bone loss relative to the mBI score after one year (mBI: Modified Bleeding index, No.: Number, mes: mesial, Dis: Distal, bone loss in mm)

The results of clinical parameter probing are summarized in the following Table 14.

Clinical Parameter	Score	At 6 months	After one year
mBI	0	37	31
	1	3	7
	2	0	2
mPI	0	30	26
	1	8	8
	2	2	6
Pocket Depth mesial	1	29	4
	2	10	29
	3	1	6
	4	0	1
Pocket depth distal	1	1	1
	2	39	35
	3	0	4

Table 14: clinical parameters

5. 5.7. Statistical analysis of factors influencing bone resorption

Using the non-parametric Mann–Whitney *U* Test, the crestal bone loss according to the influencing factors was not significant ($p < 0.05$) (Table 15).

		Influencing factors	P value	
			Mesial	Distal
Patient		Gender	0.11	0.43
		Age	0.15	0.07
Implant		Implant diameter (4,3 / 5)	0.68	0.71
		Implant length (11 / 13)	0.79	0.82
	Hard tissues	Implant location (maxilla /mandible)	0.81	0.96
		Implant location (Posterior(Max / Man))	0.61	0.92
		Bone quality (D3 /D4)	0.24	0.57

Table 15: Overview of factors influencing bone resorption.

Gender

The mean crestal bone loss after one year in females was 1.8 mm (SD ±0.8 mm) and 1.8 mm (SD ±0.8 mm) in the mesial and distal aspects of the implants, respectively. At the same time point, the crestal bone loss was less than in males, which was 1.4 mm (SD ±0.7 mm) and 1.5 mm (SD ±0.6 mm) in the mesial and distal aspects, respectively. Using the Mann Whitney *U* Test, the difference was not statistically significant (Table 16).

	Gender	N	Mesial (mm)	Distal (mm)
at six months	male	14	0 .7 (SD ±0.5 mm)	0.6 (SD ±0.6 mm)
	female	21	0.7 (SD ±0.5 mm)	0.6 (SD ±0.6 mm)
after one year	male	18	1.4 (SD ±0.7 mm)	1.5 (SD ±0.6 mm)
	female	21	1.8 (SD ±0.8 mm)	1.8 (SD ±0.8 mm)

Table 16: crestal bone loss by gender

Age

Using the Spearman's rank correlation coefficient, there is no correlation between age and crestal bone loss (P = 0.15, 0.07 mesial and distal, respectively).

Diameter

After one year, the mean crestal bone loss in implants with a diameter of 4.3 mm was 1.5 mm (SD ±0.7 mm) and 1.6 mm (SD ±0.7 mm) for mesial and distal aspects of the implant respectively. Similarly, the mean crestal bone loss in implants with a diameter of 5 mm was 1.6 mm (SD ±0.9 mm) and 1.6 mm (SD ± 0.8 mm) for mesial and distal aspects of implants respectively. Using the Mann-Whitney *U* Test, those two implant diameters showed no significant difference (P < 0.05). The group of implants with diameter of 3.5 mm was excluded from this test because there are only 4 implants in the group. Also, the Kruskal-Wallis Test was performed for all diameters and the difference in crestal bone loss and was not significant (Table 17).

		at six monthes		after one year	
Diameter in mm	Nr	mesial	Distal	mesial	Distal
3,5	4	0.8 (SD ±0.2 mm)	1.1 (SD ±0.7 mm)	2.0 (SD ±0.7 mm)	1.7 (SD ±1.1 mm)
4,3	20	0.7 (SD ±0.6 mm)	0.7 (SD ±0.7 mm)	1.5 (SD ±0.7 mm)	1.6 (SD ±0.7 mm)
5	16	0.6 (SD ±0.4 mm)	0.5 (SD ±0.4 mm)	1.6 SD ±0.9 mm)	1.6 (SD ±0.8 mm)

Table 17: diameter of implants to crestal bone loss

Length

After one year, the mean crestal bone loss in implants with a length of 11 mm was 1.7 (SD ±0.8 mm) and 1.7 (SD ±0.8 mm) for mesial and distal aspects of implants respectively. And it was greater than in implants with the length of 13 mm 1.6 (SD ± 0.7 mm) and 1.7 (SD ±0.7 mm) for mesial and distal aspects of implants respectively. The difference was not statistically significant using the Mann-Whitney *U* Test ($P < 0.05$). The group of implants with the length of 9 mm was excluded from this test because there are only 2 implants in this group (Table18).

		at six months		after one year	
Length in mm	Nr.	Mesial	Distal	Mesial	Distal
9	2	0.9 (SD ±0.4 mm)	0.6 SD ±0.4 mm)	1.3 (SD ±0.6 mm)	1.0 SD ±0.3 mm)
11	12	0.7 SD ±0.7 mm)	0.6 SD ±0.8 mm)	1.7 SD ±0.8 mm)	1.7 (SD ±0.8 mm)
13	26	0.7 (SD ±0.4 mm)	0.7 (SD ±0.6 mm)	1.6 (SD ± 0.7 mm)	1.7 (SD ±0.7 mm)

Table 18: Implants' length relative to crestal bone loss

Maxilla vs. Mandible

The mean crestal bone loss for implants located in the maxilla after one year was 1.6 (SD ±0.8 mm) and 1.6 (SD ±0.7 mm) for mesial and distal aspects of implants respectively. In the mandible, the mean crestal bone loss was 1.6 (SD ±0.6 mm) and 1.6 (SD ±0.8 mm) for mesial and distal aspects of implants respectively. Mann-Whitney *U* Test was used to show the difference between crestal bone loss in implants according to their location in the maxilla or the mandible. The test showed no significant differences in crestal bone loss between the two jaws (Table 19).

	at six months		After one year	
	mesial	Distal	mesial	distal
maxilla	0.6 (SD ±0.3 mm)	0.6 (SD ±0.6 mm)	1.6 (SD ±0.8 mm)	1.6 (SD ±0.7 mm)
mandible	0.8 (SD ±0.6 mm)	0.7 (SD ±0.7 mm)	1.6 (SD ±0.6 mm)	1.6 (SD ±0.8 mm)

Table 19: implants' location (maxilla/ mandible) relative to crestal bone loss

The median value of mesial and distal crestal bone level relative to implant surface one year after insertion into the maxilla was 1.8 mm (max: 2.9 mm, min: 0.7 mm) and 2.2 mm (max: 3.1 mm, min: 1.0 mm), respectively. At the same time point, the median value of mesial and distal crestal bone level relative to implant surface for the mandible was 1.4 mm (max: 2.4 mm, min: 0.7 mm) and 1.8 mm (max: 2.9, min: 1.0) respectively (Fig. 8).

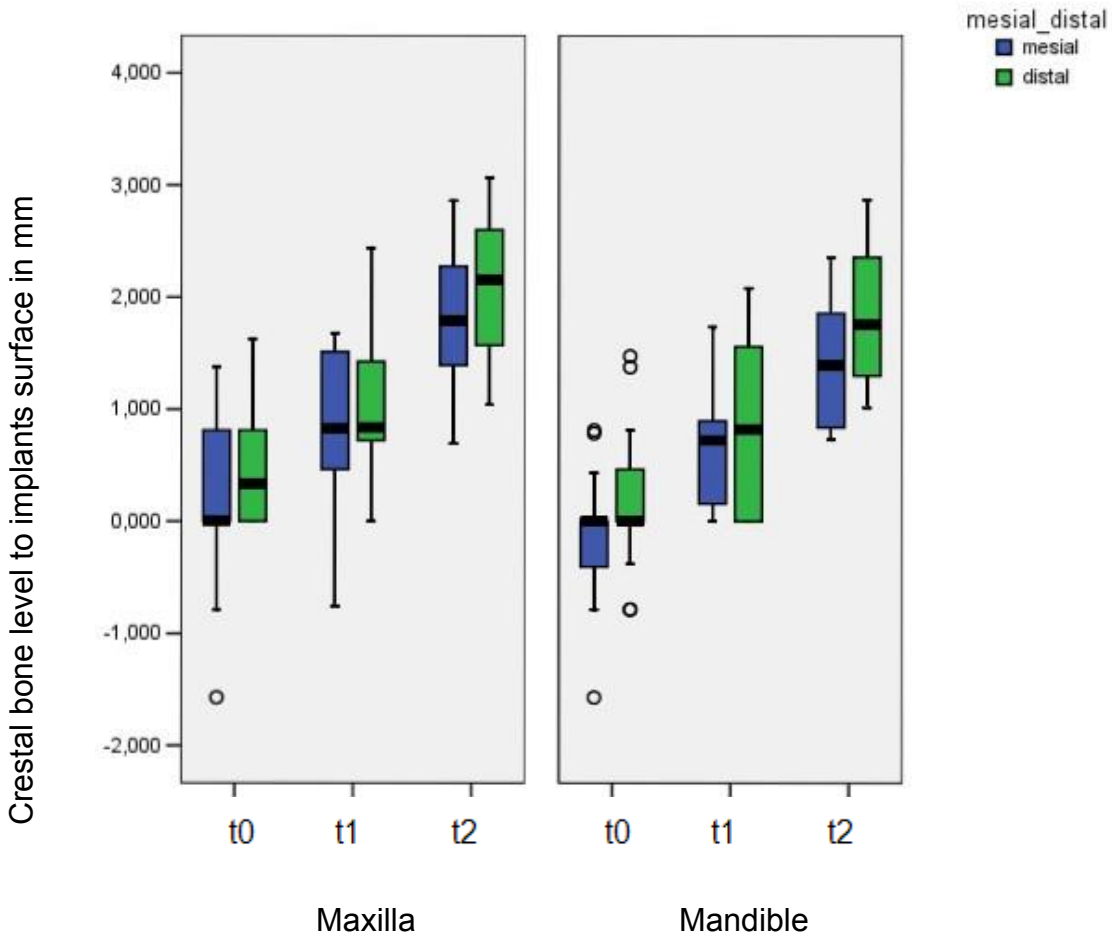

Figure 8: Box-plot expressing crestal bone level at implant surface in mm, measured with respect to the reference point for implants at time point from t0-t2 (maxilla vs. mandible).

Implant location in the jaw anteriorly/posteriorly

In the maxillary posterior regions, the mean crestal bone loss after one year was 1.6 (SD ± 0.9 mm) and 1.6 (SD ±0.6 mm) for mesial and distal aspects of the implants respectively, while in the posterior region of the mandible it was 1.5 mm (SD ±0.6

mm) and 1.6 mm (SD ± 0.8 mm) for mesial and distal aspects of implants respectively. The Mann-Whitney *U* Test was used to show the differences in crestal bone loss according to the location of implants in the jaws. The test showed no significant differences between the mandible and the maxilla (Table 20).

	at six months		after one year	
	Mesial	Distal	Mesial	Distal
Maxilla anterior	0.6 (SD ±0.3 mm)	0.5 (SD ±0.3 mm)	1.7 (SD ± 0.7 mm)	1.7 (SD ± 0.9 mm)
Maxilla side	0.7 (SD ± 0.4 mm)	0.7 (SD ± 0.6 mm)	1.6 (SD ± 0.9 mm)	1.6 (SD ± 0.6 mm)
Mandible side	0.8 (SD ± 0.6 mm)	0.7 (SD ±0.7 mm)	1.6 (SD ± 0.6 mm)	1.6 (SD ± 0.8 mm)
Mandible anterior	--	--	--	--

Table 20: Implant location (anterior / posterior) relative to crestal bone loss

Bone density

In the upper jaw in the area with bone density of D3, the mean crestal bone loss after one year was 1.8 mm (SD ±0.8 mm) and 1.6 (SD ±0.8 mm) for mesial and distal aspects of implants respectively. While in the area with bone density of D4, the crestal bone loss was 1.4 mm (SD ±0.9 mm) and 1.8 mm (SD ±0.5 mm) for mesial and distal aspects of implants respectively. The Mann-Whitney *U* Test was used to show the difference in crestal bone loss between implants according to the bone density in the maxilla. The test showed no significant differences between the two densities (Table 21).

		at six months		after one year	
Bone density	n	Mesial	Distal	Mesial	Distal
D2	18	0.8 (SD ±0.6 mm)	0.7 (SD ±0.7 mm)	1.6 (SD ±0.6 mm)	1.6 (SD ±0.8 mm)
D3	15	0.6 (SD ±0.3 mm)	0.5 (SD ±0.4 mm)	1.8 (SD ±0.8 mm)	1.6 (SD ±0.8 mm)
D4	7	0.7 (SD ±0.5 mm)	0.9 (SD ±0.7 mm)	1.4 (SD ±0.9 mm)	1.6 (SD ±0.5 mm)

Table 21: Crestal bone loss to bone quality

5.8. Statistical Comparison

Within the observation period of 12 months, a comparison was performed of the maxilla vs. mandible, anterior vs. posterior, mesial vs. distal, male vs. female, patients' age, implant diameters, implant lengths.

Statistical analysis was accomplished using SPSS 17 for Windows, and Mann-Whitney *U* Test and Spearman's rank-order correlation was performed, P value < 0.05 was considered significant. The cumulative implant crestal bone loss rates showed no significant difference between gender (male/female), patients' age, jaw (maxilla/mandible) or implant location (anterior/posterior region), implant diameter, implant length.

6. Discussion

The aim of this prospective study was a radiological and clinical evaluation of acid-etched single tooth implants (Prowital implant system) for one year, and to evaluate possible factors influencing the crestal bone changes such as gender, jawbone, implant location and implant diameter. A prospective study of the properties of a new implant system is the best way to answer the relevant clinical questions. On one hand, there is no previous clinical study on Prowital® dental implant system except one parallel study that was performed in edentulous patients (Heberer S, Hohl L et al. 2010). On the other hand, the prospective study offers controlled experimental conditions with a standard protocol (Tetsch P 1990; Henry, Rosenberg et al. 1995). The crestal bone behaviour around implants was assessed by means of reproducible standardized radiographs. The measurement of structures on X-ray images can be applied using scanning slides and a magnifier or even with digital systems and the appropriate software. The present radiological investigation of the periimplant bone level was assessed on the basis of conventionally prepared Orthopantomogram or intraoral periapical images.

Based on the X-rays of three-dimensional structures that demonstrate only the mesial and distal bone contours, the vestibular and oral bone walls cannot be assessed due to overlapping in the two-dimensional demonstration. Gómez found in a study that there are no significant differences between the various X-ray procedures with an accuracy of 1 mm (Gómez-Román G and Schröer A 1999). Jansen found in another study after comparing implants clinically that accuracy greater than 1 mm could not be reached through the Orthopantomogram (Jansen VK and Augthun M 1993). De Smet found, by exposing dental implants in human corpses, that the largest deviation between real measurement and radiological evaluation for all radiological recording techniques does not exceed 0.5 mm (De Smet, Jacobs et al. 2002).

As mentioned above, the evaluation of bone structures around implants is difficult in the X-ray images, however, the periimplant structures could be assessed and reasonably controlled with these procedures (Gomez-Roman 1995; Behneke A and N. 1999; Gómez-Román G and Schröer A 1999). Due to the fact that X-rays are summation images of hard and soft tissue, they present difficulties in displaying the accurate details of the periimplant bone contours (Meijer, Steen et al. 1992), so that special care has to be taken when measuring the crestal bone level around implants.

Therefore, the measurement was carried out three times to minimize the human measuring error. All images were standardized and produced with the aid of individual reproducible silicon bite-blocks to minimize the measuring inaccuracy and to be able to reproduce the X-ray at the same angle in a patient at the check-up, so that a comparison of the current X-rays with the previous recording is possible (Szabo G and Keck B 1991; Thanyakarn, Hansen et al. 1992; Weber, Buser et al. 1992; De Smet, Jacobs et al. 2002). With this solution it could be expected to have a higher precision and significance of the measurements, thanks to minimized projection mistakes (Döring K 2003).

Three private dental practices and the Clinic for Oral and Maxillofacial Surgery, Charité Campus Virchow participated in this prospective study. A high degree of standardization of all subsequent observations over the entire period of the study was addressed. The study was carried out on 35 patients with 40 implants over a mean period of one year. The patients' recall was accomplished according to study protocol and gingival parameters were monitored as planned. Study implant protocols included a two-stage surgical procedure and a healing period of 6 weeks for the mandible and 12 weeks for maxilla. Nowadays these time periods are acceptable through the modification of implant surfaces (Zubery, Bichacho et al. 1999; Aparicio, Rangert et al. 2003; Esposito, Grusovin et al. 2007; Nelson, Semper et al. 2008) .

Patients' age and implant allocation

The average age of the patients (male/female 17/18) was 55 years (range from 23 to 72 years), which is relatively high for patients with single tooth implant. However increased age does not appear to affect the clinical potential of osseointegration or the rate of crestal bone resorption observed around oral implants (Bryant 1998; Bryant and Zarb 2003; Blanes, Bernard et al. 2007; Arvidson, Esselin et al. 2008). Of the 40 implants, 22 (52.5 %) were placed in maxilla, and 18 (47.5%) in mandible. Although some studies represent higher success rates in the mandible than in the maxilla in term of osseointegration, the results of the current study could not show a significant difference (Bryant 1998; Semper, Heberer et al. 2010).

Implant macro and micro design

The Prowital® implant is a screw-type implant. In spite of that, a titanium implant of

any shape can achieve osseointegration if primary stability is obtained (Hansson 1999; Ivanoff, Grondahl et al. 1999; Carlsson 2000). Today, screw-type threaded implants are greatly preferred in implant dentistry. Threaded implants offer two major advantages compared to press-fit cylindrical implants (Zitter and Plenk 1987; Albrektsson, Dahl et al. 1988; Albrektsson and Sennerby 1991; Albrektsson, Sennerby et al. 2008). First, the implant threads improve primary implant stability, which is important to avoid micro movements of the implant until osseointegration is achieved. Second, the threads seem to play an important role in the load transfer from the implant to the surrounding bone (Quirynen, Naert et al. 1992; Hutton, Heath et al. 1995; Karoussis, Bragger et al. 2004). The manufacturer of the Prowital® implants states that the implant surface is acid-etched. The manufacturer has attempted to improve implant anchorage in the bone by modifying the surface characteristics of titanium (Wennerberg, Ektessabi et al. 1997; De Leonardis, Garg et al. 1999; Carlsson 2000; Barewal, Oates et al. 2003; G Juodzbalys, MSapragoniene et al. 2003; Sul, Byon et al. 2008). Chemical etching of the titanium implant surface is hypothesized to increase the rate of osseointegration (Klokkevold, Nishimura et al. 1997; Klokkevold, Johnson et al. 2001). The implant has a micro-rough acid-etched surface, which reaches up to the implant platform. Surface roughness was extensively analyzed at scales above the cell size (macro-roughness) or below the cell size (micro-roughness) by calculation of relevant classic amplitude parameters. In the study “Improvement in the morphology of Ti-based surfaces, a new process to increase in vitro human osteoblast response” Bigerelle et al. concluded that when the topography is considered below the cell scale, human osteoblasts appreciate their smooth surface, but when the topography is considered above the cell scale, they appreciate a rough isotropic landscape formed by the numerous ‘bowl-like nests’ that favour their adhesion (Bigerelle, Anselme et al. 2002). The in vitro experimental studies have demonstrated that the attachment of osteoblastic cells was enhanced on submicron scale structures but not on smooth surfaces (Anselme, Bigerelle et al. 2002; Bigerelle, Anselme et al. 2002; Zhu, Chen et al. 2004). The implant shoulder in the present study is wider than the implant body and the connection between them makes an angel similar to other implant systems such as Osseotite (3i Implant Innovations Deutschland GmbH) and Brånemark (Mk III, Nobel Biocare Deutschland GmbH) (Bertelmann 2008). The crest module design can transmit different types of force to bone. A polished collar and a straight crest module design transmit shear

force. A rough surface on an angled collar may transmit some compressive force to bone (Oh, Yoon et al. 2002). The crest module of an implant body is defined as the transosteal region of the implant and serves as a region which receives the crestal stresses of the implant after loading (Misch CE 1999). The microgap and implant crest module are the most likely contributing causes for the early crestal bone loss phenomenon (Oh, Yoon et al. 2002). Using finite elements analysis, Bozkaya investigated in his study the effects of external geometry and occlusal load magnitude on bone failure modes of 5 commercially available dental implant systems. He had found that with Brånemark implants whose macro design is similar to that of the implant in the present study, the bone failure area is located at the top of the crestal region at the angle of the implant shoulder (Bozkaya, Muftu et al. 2004). In the present study, the macro design (shoulder design) and micro design (characteristic of the surface of the implant) might play role in the crestal bone loss.

Osseointegration and success rate

As a two-stage implant system, all 40 dental implants healed covered/subcrestally, and at the time of planned uncovering, which was 6 weeks in the mandible and 12 weeks in the maxilla, all implants appeared clinically osseointegrated and immobile. The radiological data of one implant at one year was missing, but it should not be assumed to be a drop out, because the clinical data was available. Based on the histomorphometric results of a clinical study, there was sufficient bone for functional loading on a dual acid-etched surface after 2 months of healing in the posterior maxillary arch (Trisi, Lazzara et al. 2003). A multicenter prospective study indicates that Osseotite dual acid-etched endosseous implants can achieve successful osseointegration when loaded after 2 months of healing and remain stable for 5 years of function with a post-loading success rate of 99.4% (Sullivan, Vincenzi et al. 2005). Multiple studies show that implants with acid-etched surface allow short term healing. Other studies on single tooth implant have shown a high short-term success rate which varied between 91% and 100%. In a study of Schropp on implants the survival rate was 91% in the immediate insertion group and 96% in the delayed loading group (Schropp, Kostopoulos et al. 2005). The survival rate of the early loaded implants (Brånemark TiUnite MkIII®) in the test group in Turkyilmaz study was 94.4%, while other studies have reported 100% success (Ericsson, Nilson et al. 2000; Calandriello,

Tomatis et al. 2003; De Bruyn, Atashkadeh et al. 2009). In spite of the high success rate in the present study, the one year monitoring period is too short to evaluate the success rate of single tooth implants (Andersson, Odman et al. 1998; Scheller, Urgell et al. 1998).

Subcrestal inserted implants

Out of 80 mesial and distal aspects of the inserted implants at the time point of implantation only 15 (18.75%) aspects were subcrestal; the mean value of crestal bone level to implant surface was 0.8 mm and range from 0.1 mm to 1.6 mm. The mean crestal bone loss for the mesial and distal aspects was 1.9 mm and 2.3 mm respectively. The mean crestal bone loss of subcrestally inserted implants for all aspects is 2 mm, and it is significantly greater than that of equicrestal and supracrestal inserted implants, whose mean value is 1.4 mm. The results of the present study agree with those of Hermann et al. reported in his study on the canine mandible (Hermann, Buser et al. 2000). His comparison of the amount of crestal bone loss among 6 implant types (3 submerged and 3 non-submerged) with different insertion levels to the alveolar crest revealed that the greatest bone loss is observed around implants that are inserted below the alveolar crest (Hermann, Buser et al. 2000). The supraimplant crestal bone does not contribute to the anchorage and support of the implant, but remains important for the soft tissue. If an implant is subcrestally inserted, the supraimplant bone decreases and cannot hold the mucosa (Gomez-Roman 1995).

Discussion of Results

The importance of the present study is that there are only few studies about acid-etched single-tooth implants, whereas in literature there are numerous studies, which are about radiological and clinical evaluation of single-tooth implants. While some protocols begin to measure and assess the bone-to-implant contact after implant insertion, others begin to measure the bone-to-implant contact after uncovering the implant or after crown placement without considering the initial bone height and the bone loss in the healing period. In the present study the measurements of crestal bone alteration were performed at the time of insertion of the implants and up to one

year after insertion. It is difficult to make an accurate comparison between the present study and others studies, because of the different time point of measurements. The mean value of the mesial and distal crestal bone loss one year after insertion was 1.4 mm and 1.6 mm respectively. In a study of Schropp on single-tooth implant with acid-etched surfaces Osseotite® implant (3i Implant Innovations Inc.,Palm Beach Gardens, FL, USA), the mean mesial and distal crestal bone loss 9 months following insertion is 1.3 mm and 1 mm respectively (Schropp, Kostopoulos et al. 2005). The mean values of crestal bone loss is less than in the present study, but the evaluation time is 9 months instead of one year in the present study and also no x-ray images were made directly after implant insertion and no standardization of the X-rays was made. In a study on TiUnite® Brånemark System MK III implants which have a macro-design similar to that of the implants of the present study, the crestal bone loss one year after insertion is 0.7 mm and 0.8 mm for the early and delayed loading protocols respectively (Turkyilmaz, Avci et al. 2007). The crestal bone loss is less than in the present study. In another study on TiUnite® Brånemark System MK III implants, the mean crestal bone loss one year after loading was 1.5 mm (De Bruyn, Atashkadeh et al. 2009). Despite of that the crestal bone loss in the study mentioned is the same as in the present study; the measurement of the bone loss was performed one year after loading without regarding the initial loss. No standardization of X-rays was made in the study of Calandriello using the implant system (TiUnite® Brånemark System MK III). The crestal bone loss after one year was 1.3 mm using an immediate loading protocol. Also no standardization of X-rays was made in a study by Scheller on single tooth implants of the Brånemark® system (Nobel Biocare, Göteborg, Sweden). The mesial and distal crestal bone loss one year after loading was 0.5 mm and 0.4 mm respectively (Scheller, Urgell et al. 1998). The measurement of the bone loss was performed without considering the initial bone height and the bone loss within the healing period. Cardaropoli in his study on single tooth implants (Brånemark implant system®, Nobel Biocare, Göteborg, Sweden) referred to the great bone loss during the interval between abutment connection and crown placement (time interval about 1 month)(Cardaropoli, Lekholm et al. 2006). One year after connecting the abutment to the implant body the crestal bone resorption was 1.6 mm. Cardaropoli et al. study stated that at the time of the implant-insertion the bone level was 3 mm coronal to the implant plateau. But the assessment of bone loss in this study didn’t include the amount of bone located

coronal to the implant plateau at the time of implant-insertion neither the resorption of the crestal bone during the 6-month healing time. Ericsson in his study with an immediate loading protocol (Brånemark System®, Nobel Biocare AB, Göteborg, Sweden) recorded a gain of 0.05 mm in the mesial crestal bone and a loss of 0.19 mm in the distal crestal bone during the observation period of 6-18 months (Ericsson, Nilson et al. 2000). No information is available about the location of crestal bone to the surfaces of implants at time point of implant insertion. In a study of Andersson on Brånemark implants (Brånemark System®, Nobel Biocare AB, Göteborg, Sweden) a mean crestal bone loss of 1.3 mm after the first year of function was recorded (Andersson, Odman et al. 1995). In the study mentioned, no attention was given to the location of crestal bone level to the surface of the implants after their insertion. And the bone loss for the interval between the insertion of implant and loading (3-6 months) was not assessed. In spite of that the general crestal bone loss is less than in the present study, the comparison between the studies is not really possible for the reasons mentioned above. In a study of Engquist, as in the last study, the mean mesial and distal crestal bone loss after one year of function was 0.5 mm and 0.8 mm respectively and less than in the present study (Engquist, Nilson et al. 1995). But this study also did not referred to the bone loss during the initial healing period. And no standardization of X-rays was made in the last two studies of Andersson and Engquist. In the present study it seems, that the crestal bone loss for an observation time of one year is equal to or higher than that of other study. The differences in the study protocols make the comparison not equitable. However, the great crestal bone loss may be due to the macro and micro characteristic of the implant system of the present study.

Patient's age and gender

The mean mesial and distal crestal bone loss at the time point one year after implant insertion is in male 1.4 (SD ±0.7 mm), 1.5 (SD ±0.6 mm) respectively, and in female 1.8 (SD ±0.8 mm), 1.8 (SD ±0.8 mm) mesial and distal respectively. The mean crestal bone loss was greater in females than in males but statistically not significant. Also, there is no significant correlation between age and marginal bone loss, other studies have confirmed the same result (Bryant and Zarb 2003; Chou, Morris et al. 2004; Hall, Payne et al. 2006; Blanes, Bernard et al. 2007; Hall, Payne et al. 2007).

In a study conducted by Kim, he found that gender was significantly related to the mean crestal bone loss at years 1, 3, 5 and 10, with male subjects exhibiting more bone loss than female ones (Kim, Badovinac et al. 2008).

Implant dimensions

The results of the present study showed that crestal bone loss was lower in implants with a diameter of 4.3 mm than in those with a diameter of 5 mm, but statistically this was not significant. The only four implants with a diameter of 3.5 mm were excluded from the comparison because of statistical considerations. A comparison between implants with lengths of 11 and 13 mm has shown that crestal bone loss was greater in implants with a length of 11 mm than in those with a length of 13 mm, but it was not significant. The comparison did not include the implants with a length of 9 mm, because there were only 2 implants of that size. In contrast, Sun found that more attention should be paid to the diameter than to the length in cylinder implants (Sun, Kong et al. 2007). Many studies found no significant relationship between crestal bone loss and implant length or diameter (Winkler, Morris et al. 2000; Aalam and Nowzari 2005; Romeo, Lops et al. 2006; Mumcu, Bilhan et al. 2010). However, many studies and the present one reveal a certain importance of diameter and length.

Jawbone

Rangert found in his study that posterior implants - due to mastication forces - receive two times extra forces compared to the anterior implants. In spite of that, there was no significant difference in crestal bone loss between anterior and posterior inserted implants (Rangert, Jemt et al. 1989). Pikner has found in his study on turned Brånemark implants significantly greater bone loss on lower jaw implants (Pikner, Grondahl et al. 2009). Moreover, results have shown that there is no significant difference in crestal bone loss between mandible and maxilla. This is consistent with Quirynen's results (Quirynen, Naert et al. 1992). In contrast, Weber et al. found that the crestal bone loss in the maxilla was greater than in the mandible (Weber, Buser et al. 1992; Semper, Heberer et al. 2010).

Mesial to distal crestal bone loss

After one year, the mean value of mesial crestal bone loss is 1.4 mm and it is lower than distal crestal bone loss, whose mean value is 1.6 mm. But statistically this difference is not significant. The results of present study agree with those of Ericsson study (Ericsson, Nilson et al. 2000). Other studies showed greater crestal bone loss at mesial aspects (Scheller, Urgell et al. 1998; Schropp, Kostopoulos et al. 2005).

Bone quality

It is known that the periimplant bone quality is of importance when it comes to increasing the long-term prognosis of the implant (Romanos 2009). Ivanoff did not see in his study any relationship between crestal bone loss and bone quality or quantity (Ivanoff, Grondahl et al. 1999). Also, many studies did not find any differences in marginal bone level changes between implants placed in bone tissue of different density (Aalam and Nowzari 2005; Bergkvist, Koh et al. 2010). Strietzel found in his study a significant correlation between bone quality and the change of the peri-implant marginal bone height level 6 months after implant installation (Strietzel, Nowak et al. 2002). The present study did not find significant correlation between the bone density and the crestal bone loss. The result of the present study is in agreement with results of other studies (Chou, Morris et al. 2004; Hall, Payne et al. 2006; Blanes, Bernard et al. 2007; Hall, Payne et al. 2007).

Soft tissue

In addition to pocket probing depth to evaluate the soft tissue status, the amount of plaque accumulation was scored using the modified plaque index (mPI). The degree of inflammation of the peri-implant mucosa was also recorded using the modified Bleeding Index (mBI) (Mombelli, van Oosten et al. 1987). The effect of plaque accumulation on periodontal structure is known. Thus, the role of plaque accumulation in the formation of gingivitis is obvious (Leonhardt, Berglundh et al. 1992).

In the present study, a correlation between the formation of plaque and the progress of crestal bone loss around the implant could not be found. In contrast, Berglundh and Lindhe in their studies assumed that periimplant disease with bone resorption is primarily induced with plaque (Berglundh, Lindhe et al. 1992; Lindhe, Berglundh et al.

1992). Other studies confirm the result (Adell, Lekholm et al. 1986; Lekholm, Adell et al. 1986). In contrast, Teixeira et al. found a relationship between mucositis and periimplant bone loss (Teixeira, Sato et al. 1997). Regarding the periodontal diagnosis around the implants, the periodontal parameters have limited significance compared to readiological assessment, however, they should be put in consideration (Weber and Cochran 1998; Behneke A and N. 1999). With respect to implant micro-rough surface, the study of Karbach indicated that different degrees of roughness of the implants showed no effect on inflammation at the implant sites. Microorganisms were found at both minimally rough and rough implant site (Karbach, Callaway et al. 2009). But Pier-Francesco's in vitro study found a significant reduction in adhesion of Bacteria (Porphyromonas gingivalis) to materials categorised as being 'very smooth' (Pier-Francesco, Adams et al. 2006).

7. Summary

The aim of this prospective study was the radiological and clinical evaluation of acid-etched single tooth implants (Prowital implant system) over a period of one year. The periimplant crestal bone loss of 35 patients (40 implants) was examined using standardized orthopantomogramms or intraoral periapical images with a luminescent screen, magnifying glasses and a digital measuring gauge. Measurements of the bone level were performed three times mesially and distally of all implants immediately after insertion, at six months and one year. The follow-up examination with the investigation of clinical parameters mBI, mPI and pocket depth was performed at 6 months and 12 months after implant insertion. The mean crestal bone loss one year following insertion was 1.4 mm and 1.6 mm mesially and distally respectively. In spite of the complexity, an accurate comparison between the present study and others studies is limited as other studies lack precise measurement time-points.

The results of the radiographic evaluation demonstrated that bone loss was not significantly affected by implant aspects such as implant location, bone quality, length of implant, dimension of implant, and patient's age and gender. Regarding bone loss at the implant, significant difference between subcrestal and equicrestal insertion was observed. The subcrestally inserted implant showed significantly greater crestal bone loss.

No correlation was found between clinical parameters (plaque accumulation, bleeding and pocket depth) and crestal bone loss one year following insertion.

7. Zusammenfassung

Das Ziel dieser prospektiven Studie war die radiologische und klinische Bewertung von säuregeätzten Einzelzahnimplantaten (Prowital Implantat-System) über einen Zeitraum von einem Jahr. Der periimplantäre krestale Knochenverlauf von 35 Patienten (40 Implantate) wurde mit Hilfe standardisierter radiologischer Aufnahmen evaluiert. Die Messungen erfolgten mesial und distal an den Implantaten sofort nach dem Einsetzen, nach sechs Monaten und nach einem Jahr. Die Kontrolluntersuchungen und die Erhebung der klinischen Parameter fanden in definierten Abständen von sechs und zwölf Monaten nach den Implantatinsertionen statt. Dabei wurden neben den mesialen und distalen Taschentiefen, der modifizierte Sulkus-Blutungs-Index (mBI) sowie der Plaqueindex (mPII), an den Implantaten erfasst.

Der mittlere krestale Knochenverlust betrug ein Jahr nach der Implantatinsertion mesial 1,4 mm und distal 1,6 mm. Die statistische Auswertung zeigte, dass der Knochenabbau weder von der Lokalisation, Knochen-Qualität, Länge und dem Durchmesser des Implantats noch vom Patientenalter und -geschlecht abhängig ist. Ein signifikanter Unterschied in der Menge des Knochenabbaus war zwischen den subkrestal und equicrestal inserierten Implantaten zu beobachten. Das subkrestal eingesetzte Implantat zeigte einen signifikant höheren krestalen Knochenverlust. Es wurde keine Korrelation zwischen den klinischen Parametern (Plaqueakkumulation, Blutungen und Taschentiefe) und dem krestalen Knochenverlust 1 Jahr nach Implantatinsertion gefunden.

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Curriculum vitae (Lebenslauf)

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Own Work Declaration

„Ich, Anas Akminasi, erkläre, dass ich die vorgelegte Dissertationsschrift mit dem Thema: "**Radiological and clinical evaluation of acid-etched single tooth implants: 1-year prospective study**" selbst verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt, ohne die (unzulässige) Hilfe Dritter verfasst und auch in Teilen keine Kopien anderer Arbeiten dargestellt habe."

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