Clinical consequences when changing position of the implant-abutment interface

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Clinical consequences when changing the position of the implant-abutment interface

Paul van Eekeren

Clinical consequences
when changing the position
of the implant-abutment interface

Comparing implants placed
at bone and soft tissue level

Paul van Eekeren

VRIJE UNIVERSITEIT

Clinical consequences when changing the position of the implant-abutment interface

Comparing implants placed at bone and soft tissue level

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad Doctor
aan de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof.dr. V. Subramaniam,
in het openbaar te verdedigen
ten overstaan van de promotiecommissie
van de Faculteit der Tandheelkunde
op vrijdag 1 juli 2016 om 13.45 uur
in de aula van de universiteit,
De Boelelaan 1105

door

Paul Johannes Aloysius van Eekeren
geboren te Eindhoven

promotor:

prof.dr. D. Wismeijer

copromotor:

dr. A. Tahmaseb

De kans dat iets gebeurt is altijd 50%.
Het gebeurt simpelweg wel of niet.

Paul van Eekeren

Contents

All of the research reported in this thesis is published earlier or is accepted for publication.

Chapter 2

van Eekeren PJA, Wismeijer D, Tahmaseb A. Crestal bone changes around implants with the implant-abutment connection epicrestal or above: systematic review and meta-analysis.
Int J Oral Maxillofac Implants. 2016 Jan-Feb;31(1):119-24

Chapter 3

van Eekeren PJA, Tahmaseb A, Wismeijer D. Crestal bone changes in macro geometrically similar implants with the implant-abutment connection at the crestal bone level or 2,5 mm above: a prospective randomized clinical trial.
Clin Oral Implants Res. 2015 Mar 21. [Epub ahead of print]

Chapter 4

van Eekeren PJA, Said C, Tahmaseb A, Wismeijer D. Resonance frequency analysis of thermal acid-etched, hydrophilic implants during the first 3 months of healing and osseointegration in an early loading protocol.
Int J Oral Maxillofac Implants. 2015 Jul-Aug;30(4):843-50

Chapter 5

van Eekeren PJA, van Elsas P, Tahmaseb A, Wismeijer D. The influence of initial mucosal thickness on crestal bone change in similar macro geometrically implants: a prospective randomized clinical trial.
Clin Oral Implants Res. 2016 Jan 22. doi: 10.1111/clr.12784 [Epub ahead of print]

Chapter 6

van Eekeren PJA, Aartman IH, Tahmaseb A, Wismeijer D. The effect of implant placement in patients with either Kennedy Class II and III on the Oral Health Related Quality of Life.
J Oral Rehabil. 2016 Apr;43(4):291-6

Chapter 1

General Introduction

General introduction

One of the treatment options to replace a missing tooth is the insertion of a dental implant. Dental implants are available in various surface characteristics, lengths, shapes and designs. The ultimate goal of any dental implant is to simulate the function of a tooth root. As it is not composed of natural body-own material it is of course a compromise, supporting a super-structure replacing the natural crown. Since the initial introduction of implants to dentistry, a lot has changed in treatment planning, treatment execution, the design of dental implants and their surface.

Directly after insertion of a dental implant a cascade of biological events occur during the bone healing process (Terheyden et al. 2012). The change in bone shape and consistency is a result of this bone healing process is, in contrary to a possible pathological bone loss (Cochran & Nevins 2012, Hermann et al. 2000, Hermann et al. 2001, Linkevičius & Apse 2008). Osseointegration is considered to be the phenomenon of direct apposition of bone on an implant surface, which subsequently undergoes structural adaptation in response to a mechanical load (Laney et al. 2008). Over time the shape of crestal bone around the implants changes both horizontally and vertically (Ericsson et al. 1996, Ericsson et al. 1995). One of the criterions for success of dental implant treatment is the amount of crestal bone change. Various factors, such as position of the implant-abutment interface, the position of smooth and rough implant surfaces, loading protocols and platform switching have been described to control and ideally minimize this remodeling process (Hanggi et al. 2005, Schwarz et al. 2013).

The implant-abutment interface (IAI) is the common contact surface area between an implant-abutment and the supporting implant. At this IAI a microgap is present and it is usually considered to be a source of irritation. The microbiome, which is present in this microscopic space, creates a chronic inflammatory response. Hence the connection of the implant to the abutments may influence the bone remodeling process (Cochran et al. 1997, Hermann et al. 2000, Hermann et al. 2001, Hermann et al. 2011). A systematic review of the literature on the
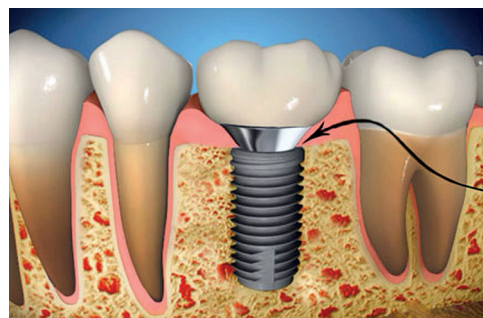
Figure 1: Microgap.
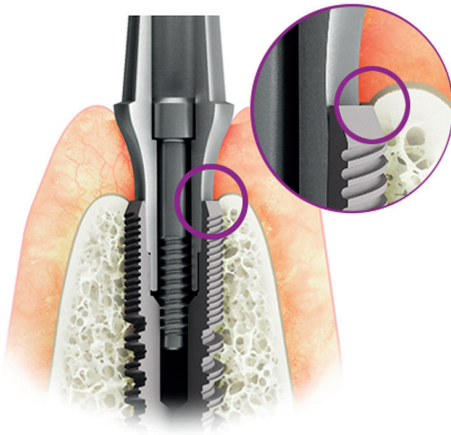
Figure 2: *Platform switch concept: relocating the biological width horizontally.*

vertical position of the implant-abutment connection was performed. The location of the microgap changes which could influence the biological width. There is however lack of evidence to support any conclusions (Schwarz et al. 2013). A mismatch between the implant and a smaller diameter abutment relocates the implant-abutment interface horizontally. This idea was originally designed to trick the biological width from vertical to horizontal length (Hurzeler et al. 2007, Vandeweghe & De Bruyn 2012). This so-called platform switching between the abutment and implant is thought to contribute to the preservation of bone (Atieh et al. 2010). A meta-analysis, which studied the role of changing an implant-abutment to one with a smaller diameter (the platform-switch approach), showed that the epithelial connection was elongated (Atieh et al. 2010).

All dental implant systems make use of different drilling protocols, implant surface configurations, implant macro and micro geometries, prosthetic components, diameters and lengths. Furthermore according to the manufacturers guidelines most implant types are applicable for all indications. Prior to every treatment a surgical and prosthetic planning should be considered to ensure a well-prepared case. A critical part of this planning is the choice of implant design.

In general there is a choice between two design approaches: an epicrestal IAI (also called bone level implant) or supracrestal IAI (also called soft tissue level implant). There is however, no indication suggested by the manufactures for either of these implants. Both implant designs can be indicated in all situations. The design of the implant however is not the only parameter that might be responsible for the success of implant related treatment. There are patient specific aspects such as general health, site-specific hard- and soft-tissue characteristics and off course aftercare and maintenance in the long term that also influence treatment success. Furthermore surgical protocols, loading protocols, design of superstructure and for example the expertise of the care provider may also contribute to the health, esthetical and functional behavior of these implants.

A systematic review and meta-analysis of the current literature on the influence of the position of the implant-abutment interface could provide us with more insight. A PICO question was formed to address the issue; P: patients with loaded implants for a minimum of 1 year, I: Implant placed with prosthetic connection at bone level, C: Implant placed with prosthetic connection at soft tissue level and O: crestal bone level change between placement and minimal one year of loading. Is there any difference on crestal bone change in implants with the implant-abutment connection at crestal bone level or above? (Chapter 2) The primary outcome of this literature study are changes in crestal bone levels at either mesial, distal or both sides on the control and test implants. Significant more crestal bone change was seen, radiographically, in the soft tissue level group ($P < 0.00001$). Within the limitations of this study, dental implants with the prosthetic connection at bone level showed significant less crestal bone changes after one year of loading when compared to implants with the prosthetic connection above the crestal bone level. However, none of these implants had the same macro geometrical shape, were loaded under the same conditions and all fixed dental prosthesis were cemented. So, these results should be interpreted with caution. Despite the fact that there is a statistical significant difference between both types of implants on micrometer level, measured on an X-ray. This study leads to the question: May we conclude from these facts that bone level implants are subjected to less bone loss when compared to soft tissue level implants? (Chapter 3)

Another factor, which has been extensively described in the literature, are implant-loading protocols. Loading protocols have changed since Brånemark in Sweden and Schroeder in

Figure 3: Soft Tissue Level Implant; Supracrestal IAI.
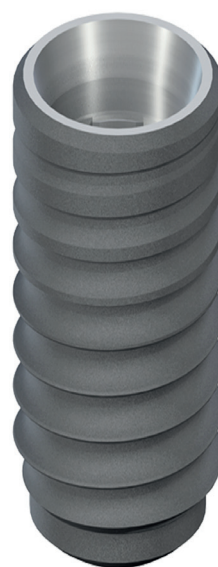
Figure 4: Bone Level Implant; Epicrestal IAI.

Switzerland introduced the first dental implants. Proceedings of the third International Team for Implantology (ITI) consensus meeting defined loading categories according to the time of implant placement (Weber et al. 2009). Conventional: a minimum of 3 months, early: at least 48 hours and no later than 3 months and immediate: within 48 hours after implant placement. The early loading definition is however tenuous as the timespan could make a significant difference in stages of healing (Attard & Zarb 2005). The primary stability; a site-specific characteristic that is determined by many factors such as the bone quality, bone type, drilling protocol and implant design, degrades over time when osteoclast and osteoblast activities start to remodel bone. The secondary stability is the ingrowth of cells on the surface of the implant. Many studies measured the stability of implants using Resonance frequency analysis (RFA). Most of these studies tested the RFA at the time of implant placement and after 3 months of healing (Andersson et al. 2013, Bogaerde et al. 2010, Stoker & Wismeijer 2011, Zembic et al. 2010). Furthermore an Implant stability quotient (ISQ) value, which varies between 1-100, might provide information to safely load the implant (Manresa et al. 2014). This is within certain boundaries and, on the other hand, only of value, when there are previous reference values. As the primary stability is a site-specific characteristic that increases during healing; a variation in secondary stability value can be expected. Close RFA follow-up during this healing period could be of interest as it shows the stability track of individual implants. The question has risen: could there also be a difference between bone and soft tissue level implants? (Chapter 4)

Yet another factor influencing bone remodeling is the anatomical situation involving bone and surrounding tissues. One of these site-specific characteristics is flap thickness. This has been associated with postoperative bone loss. A significantly higher amount of bone loss was observed in tissue thickness less than two mm (Linkevičius et al. 2009). More studies showed comparable results (Caram et al. 2014, Linkevičius et al. 2014, Puisys & Linkevičius 2015, Schrott et al. 2009, Vervaeke et al. 2014). In most of these human and canine studies a statically significant cut-off value was seen at 2 mm of soft-tissue thickness surrounding the dental implants. Also a statistically significant difference was seen when using a allogenic membrane to thicken the soft-tissue after implant insertion when soft-tissue is thinner than 2 mm. Furthermore a study by (Schwarz et al. 2013) demonstrated a higher occurrence of peri-implantitis when soft-tissue thickness was reduced (less than 2 mm) when compared to thicker mucosa. If this initial softtissue thickness provides a more stable future for the implants and related restoration which effect can be expected when comparing bone and soft tissue level implants? (Chapter 5)

Patients' satisfaction and Quality of Life are other factors that could be affected by dental treatments. The Oral Health Related Quality of Life (OHRQoL) may measure these. OHRQoL has been the subject of many publications in the past. (Awad et al. 2014, Babbush 2012, Borges et al. 2011, Fillion et al. 2013, Furuyama et al. 2012, Gates et al. 2014, Grover et al. 2014, Harris et al. 2013, Jabbour et al. 2012, Jofre et al. 2013, Kuoppala et al. 2013, Misumi et al. 2015, Mumcu et al. 2012, Oh et al. 2016, Swelem et al. 2014, Tan et al. 2014, van der Meulen et al. 2008, van der Meulen et al. 2012, Wismeijer et al. 2013, Zembic & Wismeijer 2014). The main goal of any dental treatment should be carefully fulfill the wish of the patients to improve the OHRQoL. The OHRQoL changes negatively when a tooth is lost. A dental implant could be part of the treatment to enhance the OHRQoL. The result of an implant treatment should be functional, in the absence of pain and inflammation and esthetical pleasing; thus all influence the OHRQoL. In this study we used the Oral Health Impact Profile 14 to evaluate the effect of implant placement in patients with a unilateral shortened dental arch or a unilateral diastema. (Chapter 6)

Considering all the above-mentioned dilemmas, we designed a prospective, randomized clinical trial where bone level and soft tissue level implants are loaded under similar circumstances and conditions, in the hope this could provide us with some answers. The implants should have the same macro geometrical shape and the fixed dental prosthesis should be screw-retained instead of cement retained preventing bias to cement related issues. Therefore the aim of this thesis is to address various issues related to the vertical displacement of the implant-abutment interface, e.g. bone and soft tissue level implants. Is the crestal bone affected observing geometric similar implants with the prosthetic connection at the crestal bone level or 2,5 mm above? (Chapter 3) What is
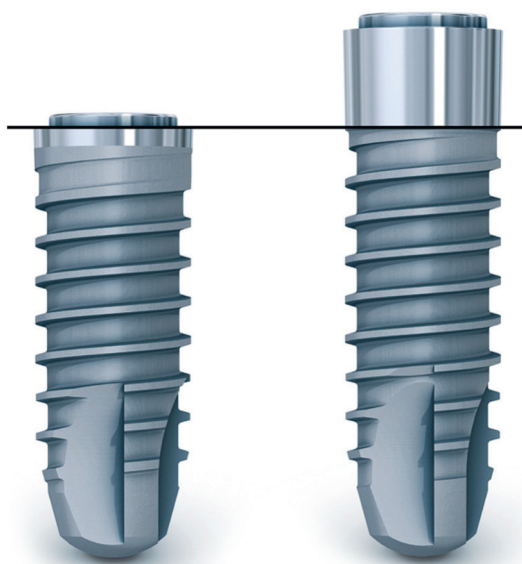
Figure 5: *Macro geometrically similar implants as were used for this study.*

the pattern of development in implant stability during osseointegration in implants with the prosthetic abutment connection at the crestal bone level or 2,5 mm above? (Chapter 4) Does the initial mucosal thickness affect the crestal bone level around bone and soft tissue level implants? (Chapter 5) What is the effect of an early-loaded 2 implant supported fixed partial denture in patients with a Kennedy Class II and III on the OHRQoL? (Chapter 6)

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Chapter 2

Review and Meta-analysis
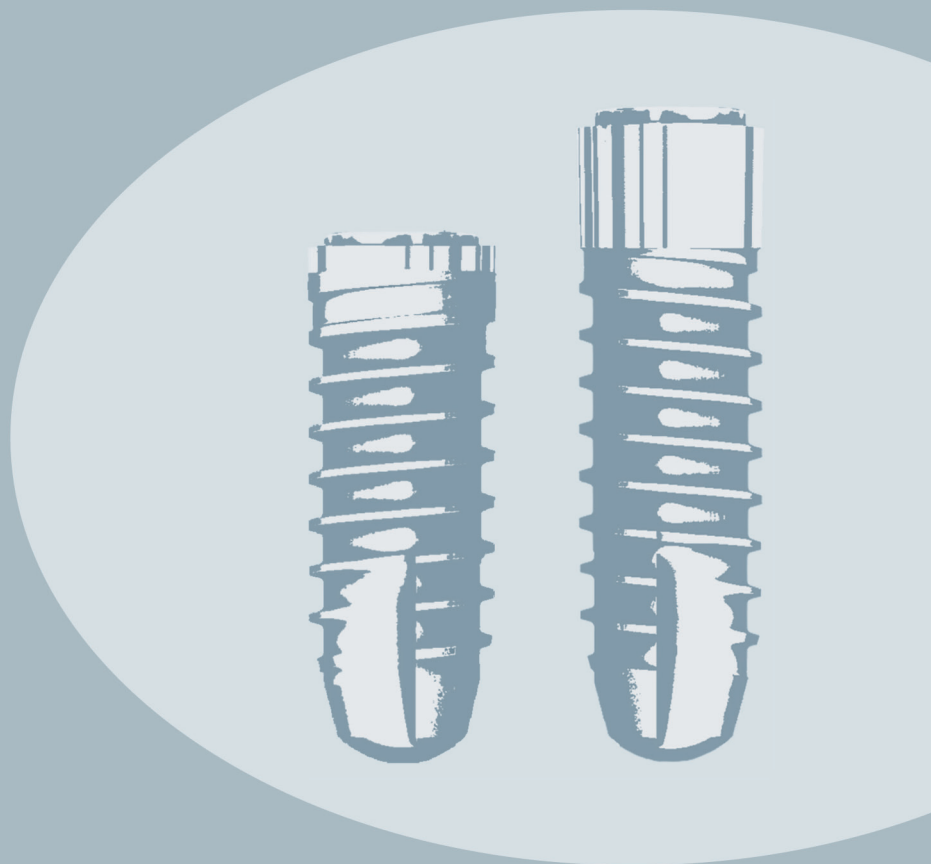
Crestal bone changes around implants with the implant-abutment connection epicrestal or above: systematic review and meta-analysis

van Eekeren PJA, Wismeijer D, Tahmaseb A.

Abstract

Purpose: The choice of dental implants to be used for root replacement is growing. All types of implants may be divided into two types, e.g. the placement of a dental implant should be epicrestal or supracrestal. The main difference is the position of the implant-abutment connection. Biological reactions are involved in this choice.

The aim of this systematic review and meta-analysis was to evaluate crestal bone changes around implants when placing the implant-abutment connection at the crestal bone level or above.

Materials & Methods: Medline (Pubmed), EMBASE and Cochran Library up to January 2014 were electronically and hand searched for any publications which evaluated radiographic crestal bone changes around non-submerged, rough surfaced implants in healed sites, humans and were loaded for a minimum of one year.

Results: The search yielded 1122 (n = 1122) publications. 1106 could not be included. 16 full text articles were read and subjected inclusion and exclusion criteria, 4 were included. The mean difference was -0.29 mm (95% CI, -0.58 mm to -0.01 mm). Heterogeneity between studies was observed (I^2 = 95%). Significant more crestal bone change was seen in the epicrestal implant-abutment (bone level) connection group when compared to implants with the prosthetic connection above the crestal bone level (soft tissue level) ($P < 0.00001$).

Principal Findings: Some randomized clinical trials have been performed to study the difference in bone remodeling in both types of implants.

Interpretation: Dental implants at bone level show significant less crestal bone change after one year of loading than a soft tissue level implant.

Crestal bone changes around implants with the implant-abutment connection epicrestal or above: systematic review and meta-analysis

Introduction

Dental implants are widely used to replace missing teeth. They can have various surface characteristics, lengths, shapes and design. All these factors can influence crestal bone change. The amount of crestal bone loss around a dental implant is a criterion for success. After placing dental implants in edentate jawbone a cascade of biological events occur during the osseointegration process (Terheyden et al. 2012). Contrary to bone loss due to a pathological process, bone remodeling is a physiological process to achieve the biological width (Cochran & Nevins 2012, Hermann et al. 2000, Hermann et al. 2001, Linkevičius & Apse 2008). Directly after implant insertion, this physiological remodeling starts to ensure a healed bone site (Terheyden et al. 2012). During this process, bone reaches the rough surface of the implant locking the implant in its site. The shape of crestal bone around the implants changes both horizontally and vertically (Ericsson et al. 1996, Ericsson et al. 1995). Various factors have been described to control and ideally minimize this remodeling process (Hanggi et al. 2005, Schwarz et al. 2013). For example, anatomical situations of bone and surrounding tissues can affect the amount and shape of the bone remodeling. Also, flap thickness has been associated with bone loss. A significant higher bone loss was observed in tissue thickness less than 2.0 mm (Linkevičius et al. 2009). Other studies found that minimal invasive surgery and soft-tissue management were influencing bone resorption and revascularization of the soft and hard tissues (Burkhardt & Lang 2005, Cortellini & Tonetti 2007, Tibbetts & Shanelec 1998). More bone loss was observed when operation times were elongated, dehydration of flaps occurred or porous suture material were used (Leknes et al. 2005, Parirokh et al. 2004, Selvig et al. 1998, Tabanella 2004) (Zuhr & Hürzeler 2012). Also the connection of the implants to the abutments may also influence the bone remodeling process. A meta-analysis, which studied the role of changing an implant-abutment to one with a smaller diameter, showed that the epithelial connection is elongated (Atieh et al. 2010). This idea was originally designed to trick the biological width from vertical to horizontal length (Hurzeler et al. 2007, Vandeweghe & De Bruyn 2012). This so-called platform switching between the abutment and implant contributed to the preservation of bone (Atieh et al. 2010). A systematic review was performed to review the literature on the position of the implant-abutment connection. There was lack of evidence to support any

conclusions (Schwarz et al. 2013). Another item in the implant-abutment connection is the placement of the implant at epicrestal (bone level) or above (soft tissue level). The position of the microgap changes and thus a reaction on the biological width can be expected. In this manner both types of implant designs have been observed to have a minor amount of bone loss (Albrektsson et al. 2012). There is however, only limited level of evidence on bone remodeling around different type of implants when comparing bone level to soft tissue level implants. Therefore, the aim of this systematic review was to evaluate the effect of bone remodeling when using bone and soft tissue level implants.

Materials & Methods

The PICO question was formed; P: patients with loaded implants for a minimum of 1 year, I: Implant placed with prosthetic connection at bone level, C: Implant placed with prosthetic connection at soft tissue level and O: crestal bone level change between placement and minimal one year of loading (table 1). The question asked was if there was any difference on crestal bone change in implants with the implant-abutment connection at crestal bone level or above.

Table 1: PICO-question	
Population	Patients with loaded implants for a minimum of one year
Intervention	Implant placed with prosthetic connection epicrestal
Control	Implant placed with prosthetic connection above crestal bone level
Outcome	Crestal bone level change between placement and minimal one year of loading

This systematic review was performed according to the PRISMA statement (Moher et al. 2009). A thorough electronic search was performed via Medline (Pubmed), EMBASE and Cochran Library in January 2014. A hand search was performed in Clinical oral implants research and International journal of oral & maxillofacial implants. All articles were hand searched for related and relevant citations until January 2014.

The online searches were performed using Boolean operators. The Mesh terms included 'dental implants' AND '(bone remodeling OR alveolar bone loss)'.

Abstracts were read to include studies. Two reviewers looked independent of each other at the results (PvE and AT). If any doubt this was solved by discussion following the inclusion and exclusion criteria as mentioned in table 2.

Table 2: Selection criteria	
Inclusion	• English language • Human • Radio graphical follow-up • Minimal of one year loading • At bone level and soft tissue level • Prospective randomized clinical trial
Exclusion	• In vitro • Immediate placed implants • Machined implants • Non cylindrical implants • Non screwed implants • Non responding authors for missing data • Double published articles

All full texts were obtained and the following relevant data was extracted: number of control and test implants, data of publication, amount of assessors, number of patients, number of drop-outs, implant brand, length of smooth collar, follow-up period, years of loading, way of radio graphical assessment, crestal bone change and standard deviations. If any data was unclear of missing the authors of the articles were contacted. The primary outcome is any changes in crestal bone levels at either mesial, distal or both sides on the control and test implants.

For the meta-analysis of data Review Manager ((RevMan) [Computer program]. Version 5.2.8. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008) was used. Results were expressed as mean differences with 95% confidence intervals (CI). Data were pooled across studies using the random effects model by invariance weighting. The assessment of heterogeneity between studies was performed by I^2 statistical analysis (Higgins & Thompson 2002). The qualitative assessment of studies was performed according to the Cochran handbook for systematic reviews of interventions (Higgins et al. 2011).

Results

The electronic search yielded 1110 publications. The hand search and related citations resulted in 12 additional publications. Of these 1122 publications 1106 articles couldn't be included based on the inclusion criteria by reading the abstracts. The 16 remaining full text articles were read and subjected to the pre-mentioned exclusion criteria. Of these 16 publications 7 (Bratu et al. 2009, Fernández-Formoso et al. 2012, Kadkhodazadeh et al. 2013, Lee et al. 2010, Nickenig et al. 2013, Shin et al. 2006, Turk et al. 2013) were included in this systematic review and meta-analysis.
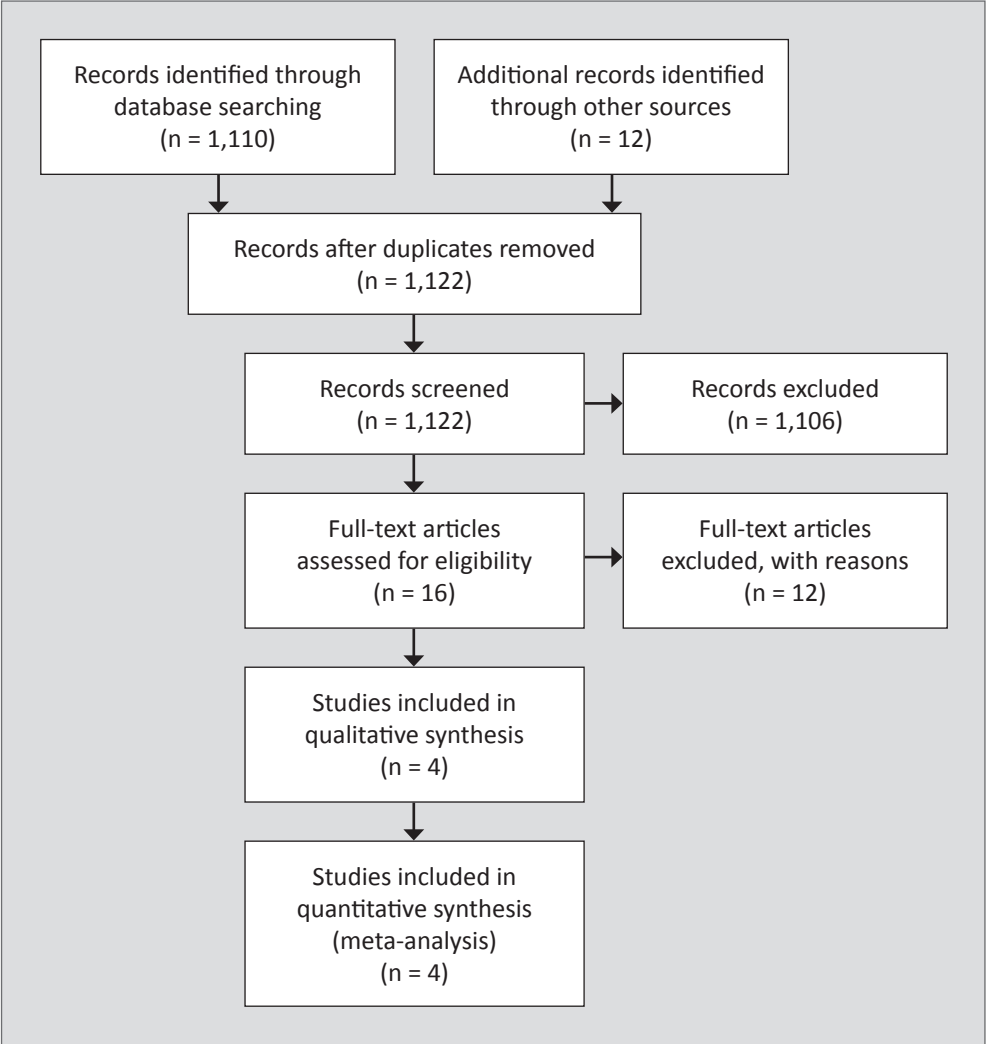
Figure 1: *Selection of articles PRISMA guidelines.*

In three publications data was not completed (Kadkhodazadeh et al. 2013, Nickenig et al. 2013, Turk et al. 2013), therefore authors were contacted. One group did not reply and was excluded (Turk et al. 2013). Two papers evaluated their study results by means of an Ortho-pantogram (OPG) and were excluded (Bratu et al. 2009, Nickenig et al. 2013) resulting in 4 eligible publications for meta-analysis (Bratu et al. 2009, Fernández-Formoso et al. 2012, Lee et al. 2010, Shin et al. 2006) (figure 1). The assessment of heterogeneity and the quality of the studies were evaluated according to the Cochran Handbook (Higgins et al. 2011) and is stated in table 3.

Table 3: Methodological quality of studies following the Cochran Handbook					
	Random sequence generation	Allocation concealment	Blinding participants	Blinding outcome assessment	Selection outcome reporting
Fernández-Formoso, Rilo et al.	+	+	+	−	+
Lee, Piao, et al.	+	+	?	−	−
Kadkhodazadeh, Heidari et al.	+	+	?	−	+
Young-Kyu Shin, Chong-Hyun Han et al.	+	+	+	−	+

In all studies different implants systems were used. Distribution of implants is shown in table 4. A total of 351 implants were placed in 198 patients between October 2002 and December 2012. The follow-up period varied from 1 to 3 years. Patients varied in age between 16-78. All studies excluded patients with general medical conditions contraindicating implant sur-gery, problematic substance users, bruxists and periodontal disease.

Table 4: Implant systems				
	Patients	Control implants	Length smooth neck	Test implants
Fernández-Formoso, Rilo et al. (Fernández-Formoso et al. 2012)	51	56 Straumann SP	1,8 mm	58 Straumann BL
Lee, Piao et al. (Lee et al. 2010)	54	45 Branemark	0,8 mm	45 Hexplant BL
Kadkhodazadeh, Heidari et al. (Kadkhodazadeh et al. 2013)	25	52 Thommen	1,0 and 1,5 mm	23 All-fit SSO BL
Young-Kyu Shin, Chong-Hyun Han et al. (Shin et al. 2006)	68	34 Stage-1	1,8 mm	38 One-plant BL
Total numbers	**198**	187 soft tissue level		164 bone level

90 Implants of 351 implants had an external connection (Lee et al. 2010). 96 Implants had a platform switch design, restored with fixed partial denture (Fernández-Formoso et al. 2012, Shin et al. 2006). All superstructures were single or multiple fixed partial dentures. All implants included in the selected studies survived and no chipping of porcelain, or screw loosening was reported. In one study dropouts were reported with a total of 15 implants (Lee et al. 2010) (table 5).

Table 5: Prosthetic connections						
	Control	Test	Platform Switch	Survival rates	Retention FDP	Follow-up
Fernández-Formoso, Rilo et al. (Fernández-Formoso et al. 2012)	IHC	IHC	Yes, test	100 %	Cemented	12 months
Lee, Piao et al. (Lee et al. 2010)	EHC	EHC	No	100 %*	Cemented	36 months
Kadkhodazadeh, Heidari et al. (Kadkhodazadeh et al. 2013)	IHC	IHC	No	100 %	Cemented	12 months
Young-Kyu Shin, Chong-Hyun Han et al. (Shin et al. 2006)	IHC	IHC	Yes, test	100 %	Cemented	12 months

IHC = internal hex connection; EHC = external hex connection. * Dropouts were mentioned in the original data.

All implants were radiographically analyzed using the intra-oral standardized long cone paralleling technique (Fernández-Formoso et al. 2012, Kadkhodazadeh et al. 2013, Lee et al. 2010, Shin et al. 2006). Images were loaded into computer software and a digital subtracting method was used to assess crestal bone change over time.

Figure 2 shows all studies data subjected to meta-analysis. The mean difference in crestal bone change was -0.29 mm (95% CI, -0.58 mm to -0.01 mm) in favor of the bone level implants. Considerable heterogeneity between studies was observed (I^2 = 95%). Because of the considerable heterogeneity between studies the random effects model could be used. Significant more crestal bone change was seen radio graphically in the control group ($P <$ 0.00001). The weighted percentages show a even distributed weight of the studies in meta-analysis.

The mean crestal bone change over all implants when weighted by the number of implants was -0.62 mm in the group with bone and -0.85 mm in soft tissue level implants. The mean crestal bone change when weighted by study weight was -0.36 mm in the bone and -0.54 in the soft tissue level group.
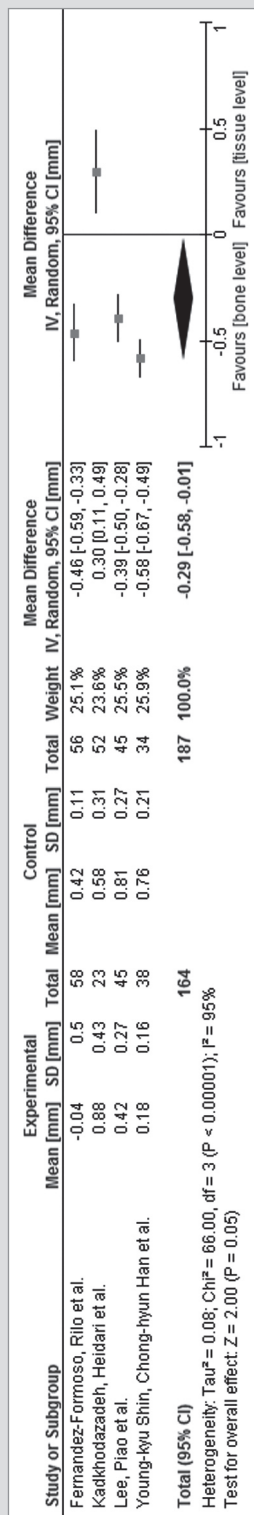
Discussion

This meta-analysis showed a significant difference in crestal bone change in bone and soft tissue level implants. The mean crestal bone change was -0.29 mm (95% CI, -0.58 mm to -0.01 mm) after one year of loading. This is consistent with the current literature (Albrektsson et al. 2012, Linkevičius et al. 2009).

In this systematic review only 4 studies could be included regarding the different locations on implant-abutment connections. All studies cemented their fixed partial dentures. This could influence the biological width as cement could be retained around the implant. A systematic review by Wittneben et al. looked at the clinical performance of screw- versus cement-retained fixed implant-supported reconstructions (Wittneben et al. 2014). They showed that there was no statistical significant difference in failure rates after 5 years of loading in between cemented or screw retained when grouped for single crowns or fixed partial dentures. Furthermore they concluded that the abutment type did not influence the failure rate. There was however statistical significant fewer technical ($P < 0.01$) and biological ($P < 0.001$) events when reconstructions were screw retained.

Linkevičius et al. demonstrated tissue thickness as an influencing factor on crestal bone change. They showed a change of 0.44 ± 0.06 mm mesially and 0.47 ± 0.07 mm distally in thick tissues or thin tissues thickened with an allogeneic membrane. Thin tissues however show 1.65 ± 0.08-mm bone loss mesially and 1.81 ± 0.06 mm distally crestal bone change after one year of follow-up (Linkevičius & Apse 2008). Furthermore Linkevičius performed another study in which the implants were placed super-crestal and crestal to evaluate the effect of the position of the microgap. There was no significant difference found, except when the implants were placed in thin tissue (Linkevičius et al. 2009).

Study or Subgroup	Experimental Mean [mm]	SD [mm]	Total	Control Mean [mm]	SD [mm]	Total	Weight	Mean Difference IV, Random, 95% CI [mm]
Fernandez-Formoso, Rilo et al.	-0.04	0.5	58	0.42	0.11	56	25.1%	-0.46 [-0.59, -0.33]
Kadkhodazadeh, Heidari et al.	0.88	0.43	23	0.58	0.31	52	23.6%	0.30 [0.11, 0.49]
Lee, Piao et al.	0.42	0.27	45	0.81	0.27	45	25.5%	-0.39 [-0.50, -0.28]
Young-kyu Shin, Chong-hyun Han et al.	0.18	0.16	38	0.76	0.21	34	25.9%	-0.58 [-0.67, -0.49]
Total (95% CI)			164			187	100.0%	-0.29 [-0.58, -0.01]

Heterogeneity: Tau² = 0.08; Chi² = 66.00, df = 3 (P < 0.00001); I² = 95%
Test for overall effect: Z = 2.00 (P = 0.05)

Favours [bone level]   Favours [tissue level]

Figure 2: Meta-analysis of crestal bone change.

All studies incorporated in this systematic review (Fernández-Formoso et al. 2012, Kadkhodazadeh et al. 2013, Lee et al. 2010, Shin et al. 2006) the macro geometry of the implants were different. This could influence the marginal bone level and bias the effect of the position of the implant-abutment connection. Bratu et al. placed macro geometry similar implants with a 1.0 mm machined collar of the implant below the bony crest. They observed in a similar macro design of the implant that microthreads could preserve marginal bone when compared to a similar macro design machined neck implant. They concluded that the absence of a machined neck or presence of microthreads could influence the marginal bone loss. When placing the machined collar beneath the bony crest this could contribute to the larger amount of bone loss seen in this study (Bratu et al. 2009), when compared to supracrestal placement of the machined neck (Fernández-Formoso et al. 2012, Kadkhodazadeh et al. 2013, Lee et al. 2010, Nickenig et al. 2013, Shin et al. 2006).

Cochran et al. studied another macro geometrical difference. They showed the influence of mismatching the abutment and the implant depth placement in a study. They placed 6 implants in the canine mandible to test the effect on crestal bone change when placing the microgap at other positions. 3 implants were submerged and 3 non-submerged. The first implant was placed even with, the second one mm below and the third one mm above the boy crest. They found a significant difference of crestal bone change in every group, -0.34, -1.29, and 0.04 mm, respectively. This indicates that the placement of the microgap could promote bone remodeling and crestal bone loss. Furthermore they concluded that the mismatching of the abutment-implant connection induced less crestal bone change and influences the crestal bone change significantly (Cochran et al. 2009). This platform switch concept in which the biological width is elongated has been proven to prevent crestal bone change (Albrektsson et al. 2012, Atieh et al. 2010, Vandeweghe & De Bruyn 2012). In two of the studies used in this meta-analysis the platform switch concept has been used in the test group (Fernández-Formoso et al. 2012, Shin et al. 2006). Both studies showed less mean crestal bone change in these test groups. The other implants in the test group however did show also fewer bone loss than the control group.

Koo et al. described significant more crestal bone change in implants when using a external hex connection (Koo et al. 2012). Implants with an internal connection showed no significant crestal bone level change after 1 year of loading. An external connection did however. Furthermore a study showed

The assessment of crestal bone change over time was performed in two studies by an orthopantogram (OPG), while the gold standard should be a standardized intra-oral x-ray (Bratu et al. 2009, Nickenig et al. 2013). An older study shows a significant difference in bone measurements in between OPG and intra-oral x-rays (Sakka et al. 2005). More recent studies show no significant differences in these different x-ray techniques (Kullman et al. 2007, Zechner et al. 2003). Both studies did conclude a larger deviation in intra-examiner accuracy in OPG's than in intra-oral x-rays. For this reason we only included studies in this systematic review, which used a long cone parallel radiography. Furthermore underestimations of the x-ray bone levels when compared to the probed crestal bone level were shown. OPG's and intra-oral x-rays are only a mesial and distal reference without having any knowledge about the buccal and lingual bone levels. A regular x-ray provides only 2 dimensional images. 3 dimensional bone level changes could be over time evaluated using a cone beam computed tomography. However no studies show any long-term results using this technique.

Only two studies (Fernández-Formoso et al. 2012, Kadkhodazadeh et al. 2013) report of an intra- of inter-observer value to calibrate or analyze the reliability each of the measurements. Various studies in the past have shown the need for intra and inter-observer calibration or testing as these values tend to differ in extend (Kullman et al. 2007, Meijer et al. 1993, Sakka et al. 2005, Zechner et al. 2003).

Only one study in this meta-analysis reported longer follow-up periods than 12 months (Lee et al. 2010). We extracted data from the 12 months, which was reported in this publication. The crestal bone loss at 36 months in the control group in comparison with baseline was 0.95 ± 0.27 mm and in the test group 0.59 ± 0.30 mm (Lee et al. 2010). This could suggest that crestal bone level changes are not stable over time and keep on changing. This is however not consistent with the current literature. A review by Allbrektsson et al. (Albrektsson et al. 2012) on 3 modern rough surfaced implants more than 10 years of function shows less bone loss than reported by Nickenig et al. depending on the implant brand. There was however no consensus in bone changes over time. They concluded that rough-surfaced implant have better outcomes for the upper jaw over time when compared to previously used machined implants. Furthermore Albrektsson found a tendency that more crestal bone change in soft tissue level implants when compared with bone level implants.

Conclusion

Within the limitations of this study, dental implants with the prosthetic connection at bone level show significant less crestal bone change after one year of loading when compared to implants with the prosthetic connection above the crestal bone level.
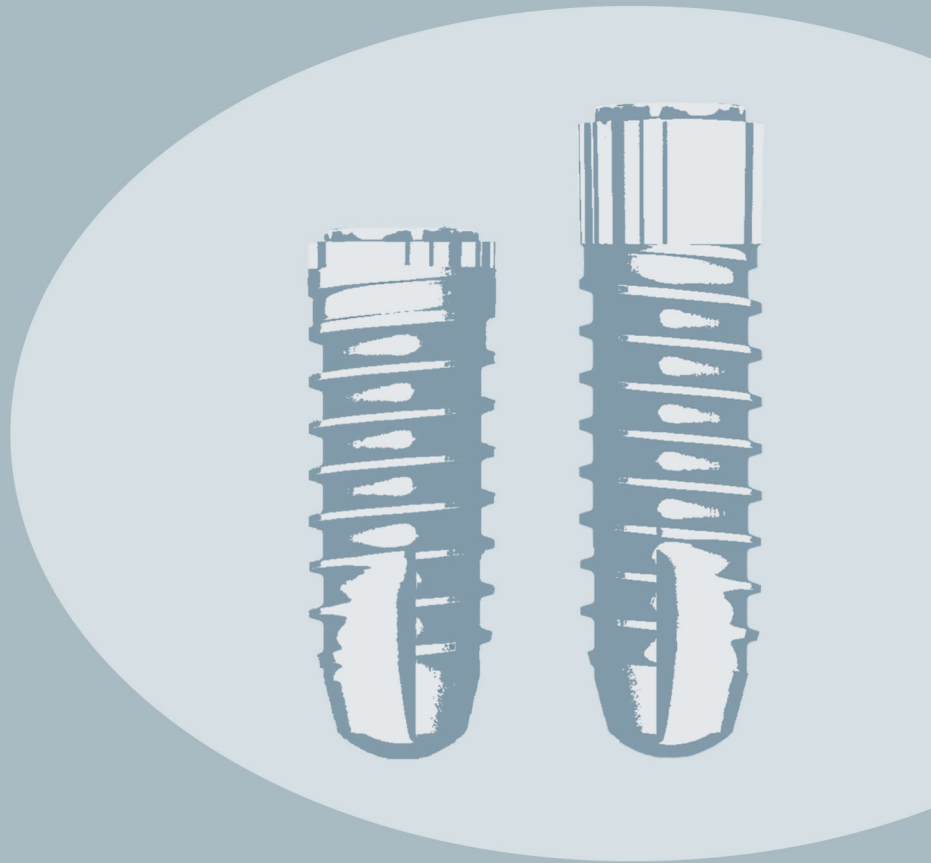
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Chapter 3

Changing the Implant-Abutment Interface Position

Crestal bone changes in macro geometrically similar implants
with the implant-abutment connection at the crestal bone level or 2,5 mm above:
a prospective randomized clinical trial

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Abstract

Objective: Crestal bone loss around dental implants is a criterion for success as this could prevent loss of implant and superstructure. The macro geometry of the implant could influence bone remodeling when the implant-abutment connection is placed at crestal bone level or above. The aim of this study was to evaluate crestal bone remodeling in a randomized clinical prospective trial in macro geometrical similar implants with the prosthetic connection at the crestal bone level and 2,5 mm above. The null hypothesis was that there was no difference in crestal bone loss after 1 year of early loading.

Materials & Methods: Patients were referred to ACTA for implant placement. Patients were subjected to inclusion and exclusion criteria and received a minimum of 2 implants: an implant with the prosthetic abutment connection at the crestal bone level (MC, bone level) and one with the prosthetic abutment connection 2,5 mm supra crestal (LC, soft tissue level). The mesial or distal position of each implant type was blinded for the patient and randomized. The implants were loaded splinted after 3 weeks of healing. The primary outcome was bone level changes assessed after one year of loading.

Results: 33 patients fulfilled the inclusion criteria. 39 Thommen SPI-ELEMENT LC implants and 39 MC were placed and each fixed dental prosthesis was supported by one LC and one MC implant. The intra-class correlation of measures performed by the first and second x-ray examiner was on the mesial side of the MC implant 0.990 (0.980-0.995; 95 % CI). 0.980 (0,962-0,990; 95 % CI) on the distal side of the MC implant. 0,979 (0.959-0.989; 95 % CI) and 0,988 (0.978-0.994; 95 % CI) mesial and distal of the LC implant respectively. The mean bone loss of the MC implant was 0.4 ± 0.4 mm. The mean bone loss of the LC implant was 0.2 ± 0.5 mm. The paired-samples test showed a statistical significant difference ($P < .05$) between the MC and LC implants.

Conclusion: Dental implants at bone level show statistical significant ($P < .05$) more crestal bone change after one year of loading than a soft tissue level implant.

Crestal bone changes in macro geometrically similar implants with the implant-abutment connection at the crestal bone level or 2,5 mm above: a prospective randomized clinical trial

Introduction

Dental implants are a predictable long-term method for replacing tooth roots (Astrand et al. 2004, Lekholm et al. 2006). The osseointegration process provides a sturdy connection to bone and the grade IV titanium by in growth of osteoblasts (Terheyden et al. 2012, Terheyden et al. 2013). The remodeling of bone starts directly after preparation of the implant bed as well as the bone healing process. Osteoblast adhesion to the implant surface and the osseointegration process starts approximately three weeks postoperatively (Terheyden et al. 2012). During this healing process bone remodeling occurs (Iezzi et al. 2013, Schwarz et al. 2013). This is often resulting in crestal bone loss (Hermann et al. 2000, Hermann et al. 2001, Piattelli et al. 2013).

The quality of the soft- and hard tissue are described as dominating factors in bone healing and thus in successful long-term integration, early bone loss and bone remodeling (Linkevičius et al. 2009, Linkevičius et al. 2013).

A review (Oh et al. 2002) describes possible contributing factors to early bone loss and bone remodeling. They concluded that reformation of biological width; microgap, implant crest modules and occlusal overload are the most contributing factor. They expressed however their need for well-controlled randomized clinical trials to determine each contributing factor. Another review (Tatarakis et al. 2012) studied the possible causes of early bone loss. They defined host-related factors; implant design, the surgical and restorative protocol as contributing. They found that a steady state of the peri-implant tissues was established after execution of the surgical and restorative protocol regardless of the implant type and surgical protocol. The role of the position of the microgap, as an important determinant during the formation of the biological width, however was still unclear.

Bone remodeling is expected to occur when the body is trying to recover or establish a biological width (Cochran & Nevins 2012). Biologic width is the defense line in which the mucosa fits like a cuff of a sleeve around the trans mucosal part of the implants (Broggini

et al. 2006, Broggini et al. 2003). This is described as an inflammatory response of tissues (Broggini et al. 2003, Cochran et al. 1997). Furthermore osseointegration is an active process involving remodeling of existing bone and new bone formation from the first moment the implant is inserted. Research shows that early loading can positively enhance bone formation possibly due to micromovements, which stimulate osteoblasts (Duyck et al. 2006, Esposito et al. 2013).

Most of the dental implants can be differentiated as either bone level or soft tissue level implants. The main difference is in the connection of the implant to the abutment (Hermann et al. 2001). The space between the implant and abutment is described as the microgap. Some authors described the shape of the implant-abutment interface contributing to crestal bone loss (Hermann et al. 2001, Weng et al. 2010). Others the shape of the microgap for example the steepness of the Morse taper, butt-joint with external hex connection (Weng et al. 2010). The thickness and type of soft-tissue may also have his contribution to bone remodeling or crestal bone loss (Linkevičius et al. 2009). In patients with a thick biotype and presence of a wide zone of keratinized mucosa (Hanggi et al. 2005, Linkevičius et al. 2009a, Linkevičius et al. 2009b, Linkevičius et al. 2010) less crestal bone loss is seen around dental titanium implants.

In a bone level implant, the abutment is connected at bone level, making the connection through the mucosa, thus the soft tissue is not around the implant but around the abutment and the microgap is at the crestal bone level. Soft tissue level implants make their connection to the abutment at a distance from the bone; the soft-tissue is around the implant and the microgap is at a distance from the bone. To study the influence of the position of the implant-abutment connection on crestal bone remodeling in similar geometrical implants a randomized prospective trial is the advisable research setup.

The aim of this study was to evaluate crestal bone remodeling in a prospective randomized clinical trial observing geometric similar implants with the prosthetic connection at the crestal bone level or 2,5 mm above. The null hypothesis was that there was no difference in crestal bone loss after 1 year of early loading.

Materials & Methods

All procedures were performed at the Department of Implantology, Academic Centre of Dentistry Amsterdam (ACTA) and approved by the medical ethics committee of the Free

University (METc VUMC registration number 2009/221) and according the Declaration of Helsinki. Patients were referred by their respective dentists to the ACTA for implant-supported 3-unit fixed restorations in the posterior maxilla or mandible. This study was performed between November 2012 and June 2013. Based on a power calculation a minimum sample size of 16 was determined. Patients aged between 25 and 85 years were eligible for inclusion in the study on fulfilling all the following criteria: (1) Requirement of a 3-unit fixed dental prosthesis supported by 2 implants in a molar/premolar area, (2) adequate bone height for implant placement without any bone regeneration, (3) agreeable to visiting every 3 months for a strict oral hygiene protocol, (4) adequate oral hygiene, and (5) willing to sign the informed consent.

Patients were excluded from the study if they fulfilled any of the following criteria: (1) medical conditions that contraindicate surgery, e.g., severe cardiac and pulmonary disorders, uncontrolled diabetes or chronic liver disease, (2) suffering from periodontitis, or (3) problematic substance users.

At the time of inclusion in the study, patients were advised regarding the nature of the study, and the clinical procedures and possible risks involved. At intake an OPG (Orthopantomograph OP-100 D) was taken to assess the available bone height for implant placement. An impression was made with irreversible alginate impression material (CA 37; Cavex, Haarlem, Holland) and working casts (type III dental stone (Moldano)) were made by the dental technician. Mandibular and maxillary casts were mounted in a semi-adjustable articulator. On these casts a prosthetic set-up was made. A vacuum retainer was fabricated (1 mm Biolon, Dreve Dentamid GmbH, Unna, Germany) to assess the correct position during placement of the implants. Furthermore an individualized x-ray film holder (Rinn-holder and 1 mm Biolon, Dreve) was designed in a way that future x-rays have reproducible settings and directions. A week before the surgery, all patients received a precise overview of the treatment and an informed consent was obtained. The oral hygiene was examined according to the Dutch periodontal screening index (DPSI). General surgery-related instructions were provided and the patients were again advised about the procedure and risks involved. One and the same clinician carried out the surgical procedure. The clinician also carried out the prosthetic procedures and the fixed dental prostheses were provided by the same dental laboratory (Tandtechnisch Laboratorium Zutphen, Zupthen, the Netherlands).

Patients received prior to surgery a non-steroidal anti-inflammatory medication (600 mg Brufen bruis, AbbVie S.r.l., Campoverde di Aprilia, Italy) and mouth rinsing for 1 minute with
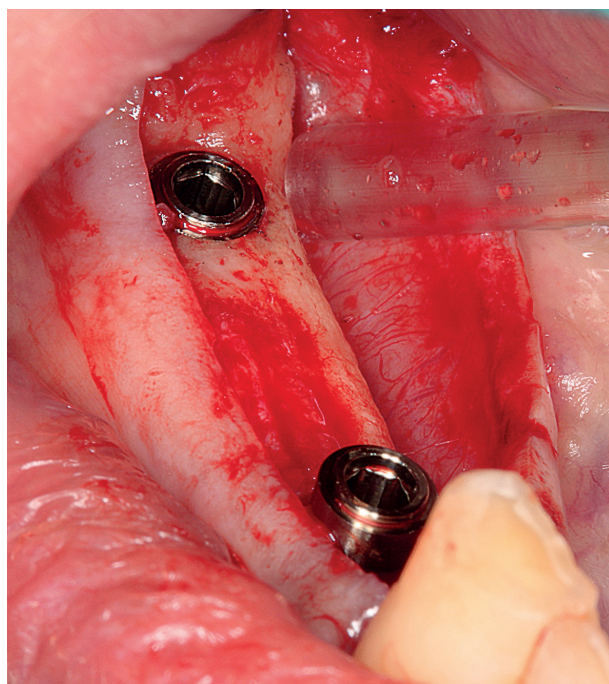
Figure 1: The bone level (minimized collar, MC. 0,5 mm machined neck for crestal placement) and soft tissue level implant (long collar, LC. 2,5 mm machined neck for trans mucosal placement) directly after implant placement.

0.2 % chlorhexidine (Corsodyl; GlaxoSmithKline, Utrecht, the Netherlands). Implant placement was performed under local anaesthesia (articaine hydrochloride 4% with epinefrine 1:100000; Ultracain ds forte, Aventis). After a crestal and partial sulcular incision on neighboring elements a flap was deflected. To perform minimum invasive surgery no releasing incisions were used. The osteotomies were performed using the prosthetic set-up vacuum retainer and the position of the implants was decided such that a fixed dental prosthesis with three premolar sized units could be placed post surgically. The operator and the patient were blind to the random allocation of the bone level (minimized collar, MC. 0,5 mm machined neck for crestal placement) and soft tissue level implant (long collar, LC. 2,5 mm machined neck for trans mucosal placement) on the either mesial or distal implant site (figure 1). This random allocation was performed by the supervisor and dental assistant by chance of a dice. Because of the similar shape of both implants, the osteotomies were identical until placement of the implants. Implants were conditioned chair side to achieve a hydrophilic implant surface (APLIQUIQ®). 2 implants with similar length (SPI ELEMENT INICELL, Thommen Medical AG, Grenchen, Switzerland) were placed following manufactures guidelines. The implants were slowly threaded into its final position either with torque wrench or contra-angle hand piece at a maximum speed of 30 rpm. The machined polished implant collar of the MC implant should be positioned under the crest (according to the manual). A torque wrench was used to measure insertion torque at the correct bone level. A healing cap was placed and all wounds were tension free sutured with polypropylene 6/0 (Hu friedy, Chicago, IL, USA). Healing caps heights were chosen in way that the patient was blinded for the position of each implant type. All implants were placed one-stage.

All patients received a prescription postoperatively for 0.2 % chlorhexidine mouth rinse (Corsodyl; GlaxoSmithKline, Utrecht, the Netherlands) 3 times a day for two weeks. No pain-killers were prescribed, and patients were advised to use acetaminophen when necessary. Furthermore extensive, intermittent, extra-oral cooling with cold-packs was advised for 24 hours.

2 Weeks post operation the sutures were removed. When insertion torques at implant place-ment were higher than 10 Ncm the healing abutments were removed and a 16mm long cy-lindrical impression coping (Thommen Medical AG, Grenchen, Switzerland) was fitted. Both posts were splinted with dental floss (Johnson & Johnson, New Brunswick, New Jersey, USA) and an autopolymerising acrylic resin (Protemp, 3M ESPE, Seefeld, Germany). In patients with a reduced mouth opening the impression copings could be reduced in length accord-ing to the manufactures guidelines. Custom impression trays (lightplast base plates; Dreve Dentamid GmbH, Unna, Germany) were fabricated with openings for the screw retained splinted posts. A full arch polyether material (Impregum F, 3M ESPE, Seefeld, Germany) was taken where after the healing caps were replaced.

One week later (3 weeks after surgery) healing caps were removed and the porcelain fused to metal fixed dental prosthesis were fitted. All FDP's were screw retained. The fit was checked by x-ray on passive fit. The occlusion was designed to minimize occlusal force onto the im-plants and to maximize force distribution to adjacent natural teeth. To accomplish these objects, anterior and lateral guidance should be obtained in natural dentition. The occlusal force in ICP: light contact (30µ) in heavy bite and no contact in light bite. The internal screws were tightened at 15 Ncm. The screw-access hole was closed with Teflon tape and a tem-porary filling material (Cavit-W, 3M ESPE, Seefeld, Germany) for easy access after 12 weeks.

All patients received a thorough dental hygiene instruction using interdental brushes (Inter-prox plus, Dentaid Benelux, B.V. Houten, the Netherlands).

Nine weeks later (12 weeks after surgery) the fixed dental prosthesis was removed and ISQ measurements were taken. When necessary the dental hygiene was adjusted. The fixed dental prosthesis was screwed into position with 25 Ncm torque, according to manufactures guidelines. Polytetrafluoroethylene tape (Gastec QA, Apeldoorn, the Netherlands) was con-densed into the screw-access hole and opaque composite (Filtek™ Supreme XTE, 3M ESPE, Seefeld, Germany) was used to seal the screw-access hole.

Forty weeks later (52 weeks after surgery) an x-ray was taken with an individualized film. To assure a reproducibility of the dental x-rays, an individualized x-ray film holder (Rinn-holder and 1 mm Biolon, Dreve) was made for each patient. The radiographs were made with a square tube using the long-cone paralleling technique (Meijndert et al. 2004). It was fitted onto the antagonist jaw so that the first x-ray after placement was directed the same as the one and 12 months. This is because the fixed dental prosthesis was not fitted until week 3.

A phosphor plate x-ray (Durr Dental, Bietigheim-Bissingen, Germany) was used and the x-ray tube (Planmeca, Helsinki, Finland) had the same setting in each patient. Image J (1.47 V Wayne Rasband, National institutes of health, USA) software was used to assess the mesial and distal bone levels. Each radiographic picture was randomly numbered and the measurement moment (T0 or T12) was blinded for the examiners. The scale was set and calibrated by the width of the dental implant. This yielded a pixel/mm ratio. Radio graphical bone levels were calculated between placement and 12 months. Two examiners made independent of each other measurements in a darkened room to assure most accurate measurements. The primary goal was to assess bone level changes, which were seen on x-ray.
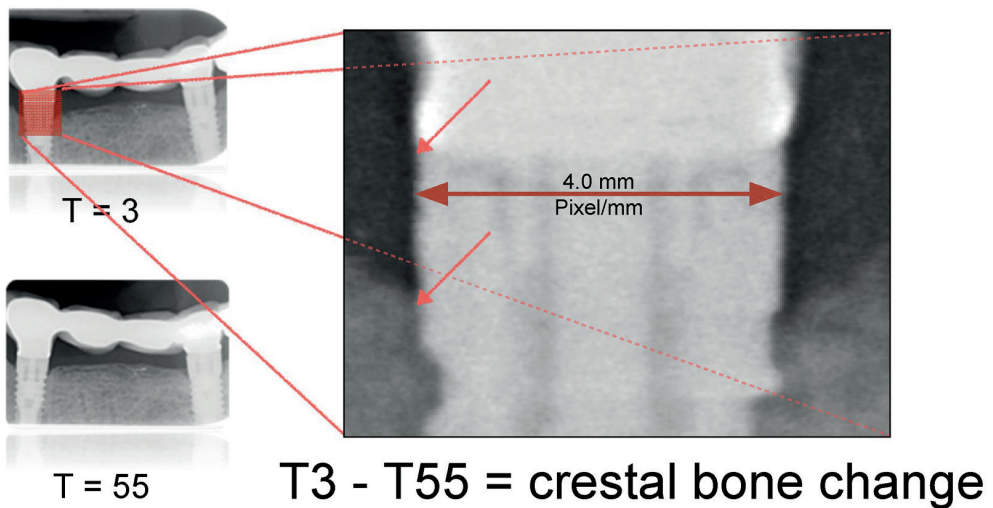

Figure 2: The standardized x-ray was used to obtain the radiographical bone levels.

Statistical Analysis

For statistical analysis, the SPSS statistical package (SPSS 21, SPSS Inc., Chicago, IL) was used. The inter-examiner score was assessed and yielded an intra-class correlation coefficient (ICC) and a 95 % confidence interval (CI). The analysis of mean crestal bone loss for the mesial a distal aspect was performed by a paired-samples t-test. The scores of the worst case, i.e. the most crestal bone loss of either the mesial or distal side of each implant, were used for statistical testing. A Shapiro-Wilk's test was used to test the null hypothesis that the data is normally distributed. In patients with multiple fixed partial dentures only one fixed partial dentures was randomly selected for statistical testing.

According to the intent to treat analysis all patients were treated as intended and thus no effort was made to correct statistically for the early or conventional loading of the implants. The patient, that lost one MC implant was retreated 3 months later and was however excluded from further statistical testing because both implants were not loaded at the same moment and thus could bias our results.

Results

The patients were prospectively followed-up over a period more than 1 year. 33 consecutive patients (20 women and 13 men), with a mean age of 61 (range 36–85) years, fulfilled the inclusion criteria set for this randomized trial. 78 implants were placed; 39 Thommen SPI-ELEMENT LC implants and 39 Thommen SPI-ELEMENT MC. 1 patient received 8 implants, 3 patients 4 and 29 patients 2 implants. One LC and one MC implant supported every fixed dental prosthesis.

5 implants showed insertion torque values lower than 10 Ncm (6%). In accordance with the study-protocol all 10 implants involved were not loaded until 3 months of healing. One patient lost a MC implant owing to an infection in week 3 (1,3%). One patient was lost in the one-year follow-up because of death. The death was of natural causes and not related to the treatment. 66 implants were loaded 3 weeks after the placement of the implants (85%).

A Shapiro-Wilk's test ($P > .05$) showed that the data was approximately normally distributed for the worst MC and LC implants, with a skewness of -0.35 (SE = 0,42) and a kurtosis of -0,58 (SE = 0,82) for the MC implants and a skewness of -0.31 (SE = 0,42) and a kurtosis of -0,375 (SE = 0,82) for the LC implants.

The intra-class correlation of measures performed by the first and second x-ray examiner was on the mesial side of the MC implant 0.990 (0.980-0.995; 95 % CI). 0.980 (0,962-0,990; 95 % CI) on the distal side of the MC implant. 0,979 (0.959-0.989; 95 % CI) and 0,988 (0.978-0.994; 95 % CI) mesial and distal of the LC implant respectively.

The mean bone loss of the MC implant was 0.4 ± 0.4 mm; with maximum, minimum and median of respectively 0.37, -1.29 and -0.36. The mean bone loss of the LC implant was 0.2 ± 0.5 mm; with maximum, minimum and median of respectively 0.68, -1.11 and -0.11. The paired-samples test t (30) = -2.4, P = 0.023 showed a statistical significant difference (P < .05) between the MC and LC implants.

Discussion

The aim of this study was to evaluate the crestal bone changes if the position of the implant-abutment connection differs, in implants with similar macro geometry. In this study a statistical significant difference in favour of the LC (soft tissue level implants) (P < 0.05) was measured when placing the implant-abutment connection at the crestal bone level or 2,5 mm above.

The amount of mean bone loss in the first year of loading is consistent with the current literature (Albrektsson et al. 2012, Linkevičius et al. 2009). The difference in bone and soft tissue level implants isn't. These results are conflicting with the current literature (Fernández-Formoso et al. 2012, Kadkhodazadeh et al. 2013, Lee et al. 2010, Shin et al. 2006). In a clinical study (Fernández-Formoso et al. 2012) the change in marginal bone levels when using Straumann implants was looked at. Patients were randomized in a control and a test group. Patients in the test group received a bone level implant with a platform switched abutment. Patients in the control group received a soft tissue level implant with a standard matching abutment. The mean crestal bone change in implants with the prosthetic connection at the crestal bone level demonstrated a bone gain of 0.04 mm +/- 0.50 mm, while the implants with the prosthetic connection above the crestal bone level lost 0,42 mm +/- 0,11 mm. All these single crowns were cemented and not loaded under similar circumstances. Not every subject received an implant of both type and the macro geometry is very different. All these factors could influence the crestal bone change.

In the present study macro geometrically similar implants were used with the smooth collar above the crestal bone level as the placement below the crestal bone could influence the

bone remodeling. In a clinical randomized trial this effect was studied (Bratu et al. 2009). Similar macro geometrically implants were placed in test and control groups. The implants in the control group had a 1 mm machined smooth collar, while the test group had microthreads in this position. A mean bone change of 0,69 +/- 0,25 mm was seen in the test group while a loss of 1,47 +/- 0,4 mm was seen in the control group. They concluded that the presence of microthreads could influence the crestal bone change. The position of the smooth collar however beneath the bony crest could negatively influence the bone level. as well.

In a canine model (Cochran et al. 2009) the influence of the implant placement depth and the mismatching of the implant-abutment (platform-switch) was tested They placed 6 implants in the canine mandible to test the effect on crestal bone change when placing the microgap at different heights from the bony crest. 3 implants were submerged and 3 non-submerged. The first implant was placed even with, the second one mm below and the third one mm above the bony crest. They found a significant difference of crestal bone change in every group, 0.34, -1.29, and 0.04 mm, respectively. This indicates that the position of the microgap could promote bone remodeling and crestal bone loss.

The influence of the position of the microgap has been described in earlier research. A meta-analysis (Atieh et al. 2010), which studied the role of changing the implant-abutment connection to one with a smaller diameter, showed that the epithelial connection is elongated. This idea was originally designed to 'trick' the biological width from vertical to horizontal length. This platform-switching concept between the implant and the abutment could contribute to the preservation of bone (Hurzeler et al. 2007, Vandeweghe & De Bruyn 2012).

The effect of the smooth collar beneath the bony crest could explain the negative difference in crestal bone change in the MC (bone level implants) in this study. The manufactures' guidelines stated that the minimized collar of 0,5 mm should be below the bony crest. In numerous cases this meant we had to remove bone during surgery to flatten the processes alveolaris at the MC position. A clinical study (Ikeda & Takeshita 2014) described factors and mechanisms involved in the resorption and formation of bone. Removal of cortical bone activates the cascade involving bone formation and resorption and could contribute to difference in between the bone and soft tissue level implants. The bone remodeling however was limited in almost all the cases in the smooth-rough junction on the MC and LC implants.

A systematic review (Wittneben et al. 2014) described another factor, which could influence the bone remodeling, in a systematic review. They looked at the clinical performance of screw- versus cement-retained fixed implant supported reconstructions. They showed that there was no statistical significant difference in failure rates after 5 years of loading in between cemented or screw retained when grouped for single crowns or fixed dental prostheses. Furthermore they concluded that the abutment type did not influence the failure rate. There was however statistical significant fewer technical ($P < 0.01$) and biological ($P < 0.001$) events when reconstructions were screw retained. Most of the studies, which report of differences in bone and soft tissue level implants, contain cement retained fixed dental prosthesis. All our fixed dental prosthesis was screw-retained to cope with this potentially negative influencing factor.

In this study every patient received randomly assigned a bone and soft tissue level implant within the same fixed dental prosthesis. In this way both implants are really comparable as they are loaded and have similar etiological factors, which could influence bone remodeling. A systematic review (Hsu et al. 2012) on all biomechanical complications of dental implant treatments concluded that occlusal overloading of a dental implant could be the primary etiologic factor in biomechanical complications and marginal bone loss. Albrektsson et al. (2012), Oh et al. (2002), Tatarakis et al. (2012) have described this contributing factor as well.

In conclusion, the present study shows that similar macro geometrical implants with the implant-abutment connection at the crestal bone level demonstrate statistically significant ($P < 0.05$) more initial bone loss than when the implant-abutment connection is 2,5 mm above the crestal bone level. The effect on the marginal bone loss in relation to the position on microgap should however be followed-up over a longer period of time. Furthermore the loading of 2-splinted implants in the (pre) molar area at week 3 is a predictable treatment option when torque values are above 10 Ncm.

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Chapter 4

Resonance Frequency Analysis & Osseointegration

Resonance frequency analysis of thermal acid-etched, hydrophilic implants during the first 3 months of healing and osseointegration in an early loading protocol

Abstract

Purpose: Safe loading of dental implants requires an optimal osseointegration. This osseointegration process during healing could be analyzed by resonance frequency analysis (RFA). The purpose of the study is to evaluate RFA changes during healing in splinted, early loaded, thermal acid-etched, hydrophilic implants over time.

Materials & Methods: Patients received a minimum of 2 implants: an implant with the prosthetic abutment connection at the crestal bone level (MC, bone level) and one with the prosthetic abutment connection 2,5 mm supra crestal (LC, soft tissue level). Implant stability (RFA) was measured at weeks 0, 2, 3, and 12 using the Osstell™ device.

Results: 76 implants were placed in 32 patients. Early loaded soft tissue level implants showed a significant drop in ISQ values by 2.2 ± 3.6 ISQ ($P < 0.001$) by week 2. Changes in ISQ values were significant between weeks 3 and 12, and also between weeks 0 and 12, with mean differences of 4.2 ($P < 0.001$) and 2.8 ISQ ($P < 0.001$) respectively. Early-loaded bone level implants show a significant change in ISQ by 2.3 ± 3.7 ISQ at week 2 ($P < 0.01$) and at T12 when compared to T3 of 2.9 ± 4.9 ISQ ($P < 0.01$). Bone level implants achieved higher ISQ values compared to soft tissue level implants in weeks 0, 2, 3 and 12, with mean differences of 3.8 ± 5.5 ISQ ($P < 0.01$), 3.8 ± 6.1 ISQ ($P < 0.01$), 3.7 ± 6.7 ISQ ($P < 0.01$), 2.3 ± 5.8 ISQ ($P < 0.05$) respectively.

Conclusion: A significant dip in ISQ values was observed, with the lowest point at week 2. ISQ values remained higher in bone level implants throughout the process of healing and osseointegration.

Resonance frequency analysis of thermal acid-etched, hydrophilic implants during the first 3 months of healing and osseointegration in an early loading protocol

Introduction

Immediate implant stability has increased significantly with the introduction of acid-etched implants (Bornstein et al. 2009). Proceedings of the third International Team for Implantology (ITI) consensus meeting defined loading categories according to the time of implant placement (2004) and were similar to earlier published data by the Sociedad Española (Aparicio et al. 2003). Conventional: a minimum of 3 months, early: at least 48 hours and no later than 3 months and immediate: within 48 hours after implant placement (2004) (Aparicio et al. 2003). The early loading definition was however 'tenuous' as the span in time could make a significant difference in stages of healing and was in need of further accurate descriptions in the future (Attard & Zarb 2005). Further, it has been suggested that when using implants with hydrophilic properties, the healing period shortens and treatment predictability increases (Bornstein et al. 2010).

Implant stability is critical to the long-term success of osseointegrated implants (Anil & Al Dosari 2015). Initially, the stability is provided by macro retention to the bony walls. Resorption of bone takes place within a few days of implant insertion resulting in a loss of mechanical retention (Terheyden et al. 2012). Further, the loss of mechanical retention and the process of osseointegration do not occur simultaneously, thus causing a temporary decrease in implant stability (Raghavendra et al. 2005, Barewal et al. 2012, Sim & Lang 2010, Zembic et al. 2010).

Several factors are believed to influence the existence and pattern of a dip in stability, such as the quality of bone (Herekar et al. 2014), insertion torque (Filho et al. 2014), and more importantly, the implant design (Simunek et al. 2012). Surface topography, chemistry, charge, and wettability are important factors that determine the design of an implant (Bornstein et al. 2009, Buser et al. 2004, Ferguson et al. 2006, Oates et al. 2007, Schwarz et al. 2007). To measure implant stability, resonance frequency analysis (RFA) can be used (Herekar et al. 2014). With RFA, it is possible to assess changes in implant stability over time, in a clinical and non-invasive manner (Anil & Al Dosari 2015). RFA is used to measure the axial stabil-

ity of the implant. It yields a measurement scale called the implant stability quotient (ISQ). ISQ values range from 1 to 100 (Filho et al. 2014). Higher ISQ values indicate higher implant stability. Clinically stable implants generally demonstrate ISQ values between 40 and 80 (Andersson et al. 2013, Aparicio et al. 2006, Barewal et al. 2012, Bogaerde et al. 2010, Herekar et al. 2014, Manresa et al. 2014, Schwarz et al. 2009). Ideally, ISQ values reveal information about the stiffness of an implant within the surrounding bony walls but do not necessarily reflect the actual BIC (Anil & Al Dosari 2015, Manresa et al. 2014).

An ISQ value is not a predictor of osseointegration, but gives some information about the stability of an implant (Herekar et al. 2014). Therefore, to gather useful information about osseointegration, ISQ values of individual implants should be measured over a period of time. By studying the changes that occur in the ISQ values, conclusions can be drawn about the pattern of osseointegration of individual implants.

Related studies (Andersson et al. 2013, Bogaerde et al. 2010, Stoker & Wismeijer 2011, Zembic et al. 2010) have only measured the ISQ values directly after implant placement and after healing of the implant. This does not provide adequate information to determine the pattern in which implant stability develops. More frequent measurements are necessary to ascertain this information. The occurrence and timing of the dip in implant stability, the duration thereof, and the extent of decrease can be useful during treatment planning in case of early loading protocols.

The aim of the present study was to examine the pattern of development of implant stability during osseointegration in splinted, early loaded, acid-etched dental implants with hydrophilic surface characteristics. Other objectives during this research were to determine whether there was a difference in stability between implants with the prosthetic abutment connection at the crestal bone level or 2,5 mm above during osseointegration, and to analyze whether there was a correlation between ISQ at placement and insertion torque.

Materials & Methods

All procedures were performed at the Department of Implantology, Academic Centre of Dentistry Amsterdam (ACTA) and approved by the medical ethics committee of the Free University. (METc VUMC registration number 2009/221). Patients were referred by their respective dentists to the ACTA for implant-supported 3-unit fixed restorations in the posterior maxilla or mandible. This study was performed between November 2012 and June 2013.

Patients aged between 25 and 85 years were eligible for inclusion in the study on fulfilling all the following criteria: (1) requirement of a 3-unit fixed dental prosthesis supported by 2 implants in the molar/premolar area, (2) adequate bone height for implant placement without any bone regeneration, (3) agreeable to visiting every 3 months for a strict oral hygiene protocol, (4) adequate oral hygiene, and (5) willing to sign the informed consent.

Patients were excluded from the study if they fulfilled any of the following criteria: (1) medical conditions that contraindicate surgery, e.g., severe cardiac and pulmonary disorders, uncontrolled diabetes or chronic liver disease, (2) suffering from periodontitis, or (3) problematic substance users

The patients were then prospectively followed-up over a period more than 1 year. Thereafter, 32 patients (19 women and 13 men) were selected, with a mean age of 61 (range 36–85) years.

At the time of inclusion in the study, patients were advised regarding the nature of the study, and the clinical procedures and possible risks involved.

A week before the surgery, all patients received a precise overview of the treatment and signed the informed consent. The oral hygiene was examined according to the Dutch periodontal screening index (DPSI). The patients received a prescription of chlorhexidine 0.2% oral rinse to be used post-surgically for 1 min, 3 times a day. General surgery-related instructions were provided and the patients were again advised about the procedure and risks involved.

Implant placement was performed under local anaesthesia (articaine hydrochloride 4% with epinefrine 1:100000; Ultracain ds forte, Aventis). Prior to the surgery, patients were instructed to rinse their mouth with chlorhexidine 0.2%. Implant placement was carried out according to the manufacturer's guidelines.

All patients received at least 2 SPI-ELEMENT implants with a thermal acid-etched surface (INICELL®) (Thommen Medical AG, Grenchen, Switzerland). Implants were conditioned chair side to achieve a hydrophilic implant surface (APLIQUIQ®). One implant was placed with the prosthetic abutment connection at the crestal bone level (bone level; MC). The other implant with the prosthetic abutment connection 2,5 mm supra crestal (soft tissue level;

LC). The position (whether anterior or posterior) was determined by random selection. The position of the implants was decided such that a fixed dental prosthesis with three premolar sized units could be placed post surgically. All implants were placed one-stage.

At the time of implant placement, the insertion torque for both the implants was assessed using the torque wrench (MONO, Thommen Medical AG, Grenchen, Switzerland)) provided in the surgery kit. All implants were intended to be loaded within 3 weeks after implant placement (early). If the insertion torque of one of the implants was lower than 10 Ncm both the implants were loaded after 3 months (conventional).

ISQ values were measured by attaching an abutment with a magnet (Smartpeg; Osstell, Gothenberg, Sweden) into the implant and using the contact-free probe of the Osstell™ device (Osstell, Gothenberg, Sweden) for measurement. The ISQ values were assessed immediately after implantation (T0). Thereafter, healing abutments were seated, wounds were sutured with polypropylene 6/0, and postoperative instructions were given.

Two weeks after surgery, sutures were removed, ISQ values were assessed (T2), and impressions for the 3-unit fixed dental prosthesis were obtained.

In the third week after surgery, ISQ values were again measured (T3), and the porcelain-fused-to-metal fixed dental prosthesis was mounted. The screw-access holes were closed temporarily using a Teflon tape and temporary filling material (Cavit-W; 3M ESPE, Seefeld, Germany) for easy access after 12 weeks (T12).

After 3 months (T12), the screw-retained fixed dental prosthesis was removed, ISQ values were measured and the implants were now restored permanently. All restorations were screw-retained. The screw-access holes were covered using a Teflon tape and composite resin (Filtek Supreme XTE; 3M ESPE, Seefeld, Germany).

Statistical Analysis

One fixed partial denture was randomly selected to account for the dependency when patients received multiple constructions. Using intent to treat analysis would fill in the missing data in patients when early loading was not possible and the implants were conventional loaded. The data would be missing at week 2 and 3, as these RFA measurements are not

possible. This would give a statistical and methodical error and it was decided to analyze this group of patients separately.

The repeated measures ANOVA test was performed to determine whether the changes in ISQ over time were statistically significant. The Pearson sample t-test was then used to identify the ISQ measurements between which the differences were statistically significant. For the comparison of ISQ values in bone and soft tissue level implants, the independent samples t-test was used. The Pearson's correlation was performed to determine whether there was a correlation between ISQ at baseline (T0) and the insertion torque. P levels of < 0.05 were considered to be significant. For statistical analysis, the SPSS statistical package (SPSS 21, SPSS Inc., Chicago, IL) was used.

Results

A total of 76 SPI-ELEMENT implants – 38 bone level (MC) and 38 soft tissue level (LC) implants – were placed in 32 patients. Totally 20 implants were placed in the maxilla and 56 in the mandible.

4 implants showed insertion torque values lower than 10 Ncm. In accordance with the study protocol, these implants were loaded by the conventional method. In these cases, it was possible to assess ISQ values only at the time of implant placement and after 3 months. One patient lost a mandibular bone level implant owing to an infection in week 3. This patient was excluded from the research. All other implants – 66 placed in 27 patients – showed no signs of infection or loss of retention (98.6%) and were loaded early, at 3 weeks. 3 patient's received 4 implants and one patient received 8 implants.

ISQ values of the 27 early-loaded implants soft tissue level (LC) implants ranged from 64 to 80 with a mean 74 ± 4,2 ISQ at baseline ISQ measurements at week 2 (T2) were significantly lower ($P < 0.01$) than at T0, with a mean difference of 2.2 ± 3.6 (95% CI, 0.8 to 3.7 ISQ). Between T2 and T3, the ISQ values increased by 0.8 ± 3.1 (95% CI, -2.0 to 0.4 ISQ), however, this was not significant. By T12, the ISQ values had increased by 4.2 ± 3.1 (95% CI, -5.9 to -2.5 ISQ) and were significantly higher than those at T3 ($P < 0.001$). ISQ measurements at T12 were significantly higher than the baseline values T0 ($P < 0.001$), with a mean difference of 2.8 ± 3.7 (95% CI, -4.3 to -1.4 ISQ). Bone level implants (MC) showed a significant mean difference of -2.3 ± 3.7 (95% CI, 0.8 to 3.7 ISQ) ($P < 0.01$) between T0 and T2 and ranged at baseline 60 to 86 with a mean 77.8 ± 6.0. Comparing T2 with T2, a difference of 0.7 ± 2.4

(95% CI, -1.6 to 0.2 ISQ) ISQ was observed, which was not significant. T3 and T12 showed a increase of 2.8 ± 4.9 (95% CI, -4.8 to -1.0 ISQ) reflecting significantly higher ISQ values ($P <$ 0.01). The measurements obtained at T12 showed no significant mean difference of 1.3 ± 4.7 (95% CI, -3.2 to 0.6 ISQ) compared to those at T3. (table 1 & 2 & figure 1)

Table 1: Descriptive statistics on ISQ values					
	N	Minimum	Maximum	Mean	Std. Deviation
Soft tissue level T0	27	64,0	80,0	74,0	4,2
Soft tissue level T2	27	60,0	78,0	71,8	4,6
Soft tissue level T3	27	60,0	80,0	72,6	5,0
Soft tissue level T12	27	66,0	83,0	76,8	4,1
Bone level T0	27	60,0	86,0	77,8	6,0
Bone level T2	27	63,0	84,0	75,6	5,4
Bone level T3	27	63,0	84,0	76,3	5,9
Bone level T12	27	60,0	86,0	79,1	4,8
Valid N (listwise)	27				

Significantly lower ISQ values at baseline were found in soft tissue level implants (LC) when compared to bone level implants of 3.8 ± 5.5 (95% CI, -6.0 to -1.6 ISQ) ($P < 0.01$). After 2 weeks a mean difference of 3.8 ± 6.1 (95% CI, -6.2 to -1.4 ISQ) ($P < 0.01$) was seen. At T3 bone level implants showed 3.7 ± 6.7 (95% CI, -6.3 to -1.0 ISQ) ($P < 0.01$). The mean difference at T12 in bone level implants was still significantly higher 2.3 ± 5.8 (95% CI, -4.6 to 0 ISQ) ($P < 0.05$) (table 3).

4 patients with the conventional loading were measured at baseline and at T12. The mean difference in bone level implants was not significant with a mean change of 5.0 ± 4.4 (95% CI, -12.0 to -2) ISQ. Soft tissue level implants show a significant increase of 17.3 ± 8.6 (95% CI, -30.9 to -3.6 ISQ) $P < 0.05$. (table 4 & 5)

All the 76 implants originally selected for this study were used to determine the correlation between the insertion torque and ISQ values measured directly after implantation. A highly significant correlation of $r^2 = 0.801$ was found ($P < 0.001$).

Table 2: Paired-samples test					
	Paired Differences				
			95% Confidence Interval of the Difference		Sig. (2-tailed)
	Mean	Std. Deviation	Lower	Upper	
Soft tissue level T0-T2	2,2	3,6	,8	3,7	,004
Soft tissue level T2-T3	-,8	3,1	-2,0	,4	,177
Soft tissue level T3-T12	-4,2	4,3	-5,9	-2,5	,000
Soft tissue level T0-T12	-2,8	3,7	-4,3	-1,4	,000
Bone level T0-T2	2,3	3,7	,8	3,7	,004
Bone level T2-T3	-,7	2,4	-1,6	,2	,134
Bone level T3-T12	-2,9	4,9	-4,8	-1,0	,005
Bone level T0-T12	-1,3	4,8	-3,2	,6	,159

Table 3: Paired-samples test on the difference in time per implant type					
	Paired Differences				
			95% Confidence Interval of the Difference		Sig. (2-tailed)
	Mean	Std. Deviation	Lower	Upper	
Soft tissue level - Bone level T0	-3,8	5,5	-6,0	-1,6	,001
Soft tissue level - Bone level T2	-3,8	6,1	-6,2	-1,4	,004
Soft tissue level - Bone level T3	-3,7	6,7	-6,3	-1,0	,009
Soft tissue level - Bone level T12	-2,3	5,8	-4,6	,0	,046

Table 4: Descriptive statistics on ISQ values conventional loading					
	N	Minimum	Maximum	Mean	Std. Deviation
Soft tissue level T0	4	37,0	58,0	49,8	9,3
Soft tissue level T12	4	60,0	78,0	67,0	8,1
Bone level T0	4	58,0	78,0	70,0	8,8
Bone level T12	4	65,0	85,0	75,0	8,5
Valid N (listwise)	4				

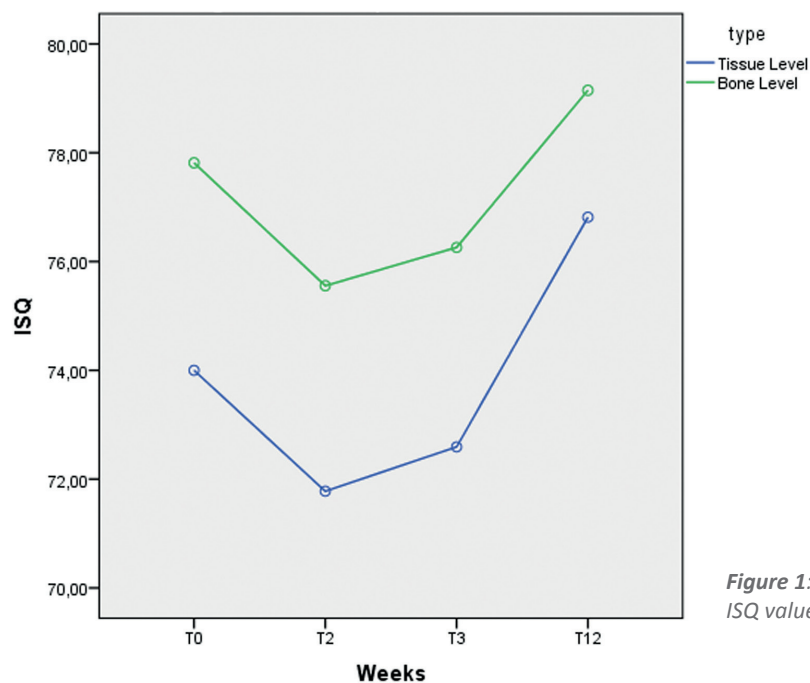| Table 5: Paired-samples test in the conventional loading protocol					
	Paired Differences				
			95% Confidence Interval of the Difference		
	Mean	Std. Deviation	Lower	Upper	Sig. (2-tailed)
Soft tissue level T0 – Soft tissue level T12	-17,3	8,6	-30,9	-3,6	,028
Bone level T0 – Bone level T12	-5,0	4,4	-12,0	2,0	,107

Figure 1: Development on ISQ values over time.

Discussion

Two weeks after implant insertion; a drop of 2.2 ISQ indicates a statistical significant dip in implant stability. This dip in stability would correspond to the process of loss of mechanical retention during the early phase of healing (Terheyden et al. 2012). Thereafter, ISQ values seemed to increase at week 3, although this was not significant. This increase in stability would indicate new bone formation. After 3 months, ISQ values had risen and were significantly higher compared to not only values at week 3, but also to the baseline measurements.

 For successful osseointegration, a functional connection between bone and the implant surface is needed. The newly formed bone ensures this biological bonding with the implant surface (Manresa et al. 2014, Sim & Lang 2010). When analyzing the quality of the connection between bone and the implant surface, several factors can be assessed, for e.g., the bone to implant contact (BIC), effective implant length (EIL), and bone volume density (BVD). These parameters, however, can only be used in histological studies due to their invasive nature (Manresa et al. 2014, Sim & Lang 2010). As clinical, non- invasive, but not as accurate alternatives, insertion torque and RFA are used. Assessment of insertion torque is easy, but can only be performed at implant placement. The assessment of ISQ values, however, can be done even after implant placement.

In an animal study (Manresa et al. 2014), however, no correlation was found between RFA and BIC. Research by Park et al. using rabbit tibia showed a correlation between ISQ values directly after implant placement and the percentage of BIC after 4 weeks of healing. ISQ measurements assessed later in the process of healing showed no correlation with the percentage of BIC (Park et al. 2011). During the current research, we analyzed the development in ISQ values during healing, to draw conclusions about the pattern of osseointegration. To obtain reliable information about the BIC, however, histological evaluation is needed (Park et al. 2011). Thus, while RFA does not reflect the actual BIC, it gives us information about the implant stability (Han et al. 2010).

In our study, the dip in stability was highest at week 2. Generally, in implants with no hydrophilic surface, the dip in stability is at its lowest point during weeks 3 and 4 (Makary et al. 2012, Simunek et al. 2012). A study by Buser et al. also reported promising results when using implants with hydrophilic properties. They observed faster healing periods and enhanced bone apposition. They also found higher BIC within the first 4 weeks and 60% more

bone within 2 weeks, in comparison to the regular sandblasted acid etched surfaces (Buser et al. 2004).

The modified implants reached stability values similar to those at baseline after 6 to 7 weeks, in contrast to the regular implants which needed 12 weeks to reach baseline ISQ values (Schatzle et al. 2009). During this study, significantly higher ISQ values were observed at week 12 compared to the measurements at baseline, suggesting a shorter healing period for the implants researched during this investigation, compared to the healing period of regular implants.

Although promising results have been reported in literature, there is still no consensus on whether the process of osseointegration is indeed faster in chemically modified implants. Han et al., for instance, found no difference between the healing periods of SLA and SLActive implants. Moreover, both implants had their lowest point of the dip at week 3 (Han et al. 2010). Furthermore, there are studies that don't report a dip in implant stability at all (Simunek et al. 2012). This, however, might be the result of insufficient number of measurements per implant over time.

During this investigation, implants were loaded 3 weeks after insertion, thus representing an early loading protocol. However, in 8 cases, it was decided to delay loading because of low insertion torque values of 4 implants. In the literature, while the importance of good primary stability is reported, the importance of good implant stability during healing is also highlighted (Herekar et al. 2014, Makary et al. 2012). All these implants were placed in the maxilla. It is mentioned that the quality and quantity of bone are important factors in the success of implant therapy and that the bone in the mandible is of better quality and quantity than that of the maxilla (Filho et al. 2014, Turkyilmaz et al. 2007). Compared to the mandible, bone in the maxilla is softer and of smaller volume (Balleri et al. 2002, Friberg et al. 1999). The current literature shows that higher ISQ values directly after placement can be found in type II bone compared to type IV bone (Balleri et al. 2002, Filho et al. 2014, Friberg et al. 1999, Manresa et al. 2014, Moon et al. 2010). Generally, type II bone can be found in the mandible and type IV in the maxilla. It has been observed that implants in the maxilla generally present with ISQ values of less than 60, and implants in the mandible demonstrate ISQ values of 60 or more (Friberg et al. 1999). It has been said that higher bone quality is related to higher implant stability in the period following surgery (Filho et al. 2014, Herekar et al. 2014, Moon et al. 2010). It has also been stated that the quality of bone can influence

the pattern of the dip in stability and therefore affect the success rate of the treatment (Huang et al. 2002, Simunek et al. 2012). Further, it has been suggested that implants with low implant stability at placement show less than adequate osseointegration (Friberg et al. 1999). Moreover, a higher occurrence of failure was observed in the maxilla, especially when implants were loaded early (Balleri et al. 2002, Friberg et al. 1999, Turkyilmaz et al. 2007). Therefore, it was advisable to prolong the healing period before loading under these circumstances, considering that implant stability increases over time.

In the current study, bone level implants yielded significantly higher stability at weeks 0, 2, and 12, compared to soft tissue level implants. However, during healing, the development of implant stability did not differ significantly between bone level and soft tissue level implants. This might indicate that for the process of osseointegration, the design of the implant is not of influence. Nonetheless, it is interesting to note that the bone level implants yielded significantly higher ISQ values throughout this process.

The difference found in implant stability between bone and soft tissue level implants might be explained by the height of the collar of the implant. The bone level implants used in this study had a short collar of 0.5 mm and were, as a consequence, placed in a more crestal position. The soft tissue level implants, on the other hand, had a collar height of 2.5 mm, and were therefore placed in a supra crestal position. In the bone level implants, the distance between the shoulder of the implant and the alveolar ridge was smaller compared to that of the soft tissue level implants, conceivably resulting in a more rigid connection between the bone crest and the implants at the time of measuring the ISQ. In soft tissue level implants, however, the collar was partially extended above the bone crest, possibly resulting in more flexibility of the implant. This could explain why soft tissue level implants showed lower ISQ values than bone level implants. However, further research is needed to fully comprehend the mechanism behind the difference in ISQ values between bone and soft tissue level implants as there are no publications discussing this subject.

The high correlation between insertion torque and implant stability that was found during this study suggests that implants with high insertion torque values generally have higher implant stability. Insertion torque is generally seen as an indirect indicator of implant stability immediately after surgery (Filho et al. 2014, Makary et al. 2012). It has, however, been suggested that insertion torque can also be seen as an indicator of the local bone quality (Turkyilmaz et al. 2007). A significant correlation of $r^2 = 0.853$ ($P < 0.001$) between ISQ values

after placement and insertion torque values was observed (Turkyilmaz et al. 2007). This corroborates the results found during this investigation ($r^2 = 0.801$, with a significance level of $P < 0.001$). A similar significant correlation was also reported (Makary et al. 2012). Further, the researchers also found a positive correlation between insertion torque and the process of osseointegration. This corresponds with the findings that lower implant stability is achieved when implants are placed in bone of lower quality and quantity, such as in the maxilla. Regarding the limitations of this study, the criteria for patient selection were stringently adhered to, so as to ensure that no other factors, such as systemic diseases or periodontitis, could influence the outcomes. Furthermore, all implant insertions were performed by the same operator (PVE), as were all the prosthodontic procedures and ISQ measurements. Measurements were repeated in order to decrease the risk of errors. The literature shows that ISQ measurements have a high degree of repeatability, and a variation of less than 1% can be found when measuring ISQ values of an implant (Schatzle et al. 2009).

Conclusion

A drop in ISQ values by 2.2 in soft tissue level and 2.3 in bone level implants after 2 weeks of implant insertion indicates a significant dip in implant stability. After osseointegration, significantly higher implant stability was seen compared to the stability directly after placement.

During healing, no differences in the development of ISQ values between bone and soft tissue level implants were observed, indicating no differences in the process of osseointegration between the two types of implant design.

Furthermore, the high correlation between insertion torque and implant stability at placement suggests that implants with high insertion torque values generally have higher implant stability at placement. On the basis of the insertion torque values, 91% of the implants were loaded after 21 days of healing. This early loading concept using Thommen Medical implants has been shown to be predictable when torque values are above 10 Ncm and crowns are splinted.

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Chapter 5

Influence of Initial Mucosal Thickness on Crestal Bone
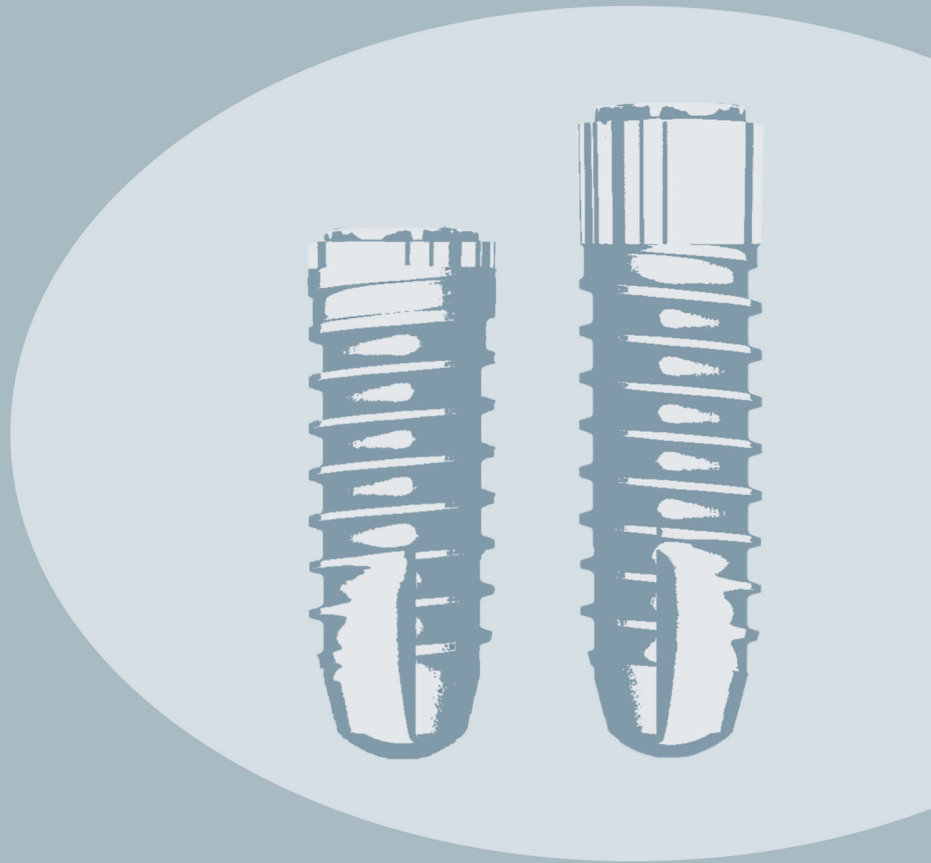
The influence of initial mucosal thickness on crestal bone change
in similar macro geometrically implants: a prospective randomized clinical trial

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Abstract

Objective: To evaluate crestal bone changes around bone and soft tissue level implants related to initial mucosal thickness.

Materials & Methods: Patients received at least 2 implants: one with the prosthetic abutment connection at the crestal bone level (MC) and one with the prosthetic abutment connection at 2.5 mm supra crestal (LC). Flap thickness measurements were taken using a periodontal probe after raising the buccal flap. Patients were divided into 2 groups according to mucosal thickness – Group A (thickness, ≤ 2 mm) and Group B (thickness, > 2 mm).

Results: Our study included 33 patients and 78 implants. Each patient received at least 1 implant of each type: Group A (MC), 17 implants, with a mean bone change of -0.6 ± 0.5 mm; Group B (MC), 20 with a mean bone change of -0.2 ± 0.4 mm; Group A (LC), 15 with a mean bone change of -0.1 ± 0.5 mm; and Group B (LC), 22 with a mean bone change of -0.2 ± 0.4 mm. A paired-samples t-test for Group A (MC) and B (MC) yielded a statistically significant difference (P = .003); there was no statistically significant difference for Groups A (LC) and B (LC) (P = .518).

Conclusion: If the initial mucosal thickness surrounding bone level implants is more than 2 mm, there is significantly less crestal bone change compared to bone level implants placed in initial mucosal thicknesses of 2 mm or less. This difference is not statistically significant when soft tissue level implants are used and the implant-abutment connection is 2.5 mm above the crestal bone level.

The influence of initial mucosal thickness on crestal bone change in similar macro geometrically implants: a prospective randomized clinical trial

Introduction

The clinical application of dental implants has demonstrated highly predictable outcomes. Crestal bone changes have been reported as a key factor for success when using dental implants (Albrektsson et al. 2012, Cochran et al. 1997). The less bone remodeling occurs, the greater is the chance for long-term, stable implant success. Various factors have been described as contributing to this success, including implant characteristics (Buser et al. 2004, Fernández-Formoso et al. 2012, Lee et al. 2010, Kim et al. 2009); type and length of surgery (Burkhardt & Lang 2005, Cortellini & Tonetti 2007); location of the implant-abutment microgap (Broggini et al. 2003, Hanggi et al. 2005, Hermann et al. 2001, Hermann et al. 2011, Oh et al. 2002, Schwarz et al. 2013, Tatarakis et al. 2012, Weng et al. 2010); and biologic width (Cochran et al. 1997, Cochran & Nevins 2012, Hermann et al. 2000, Hermann et al. 2001, Linkevičius & Apse 2008). Most dental implants can be differentiated as either bone level or soft tissue level implants; the main difference is in the epi- or supracrestal connection of the Implant-abutment Interface (IAI) (Hermann et al. 2001). At this IAI a microgap is present and it is usually considered to be a source of irritation. The microbiome which is present in this microscopic space creates an chronic inflammatory response. Hence the connection of the implant to the abutments may influence the bone remodeling process. Bone remodeling around these implants is expected to occur when the body is trying either to recover or to establish the biologic width (Cochran & Nevins 2012). Biologic width is the defense line in which the mucosa fits like a sleeve cuff around the transmucosal part of the implants (Broggini et al. 2006, Broggini et al. 2003), described as an inflammatory tissue response (Broggini et al. 2003, Cochran et al. 1997). Tissue thickness surrounding the implant could influence the marginal bone level.

Crestal tissue quality, quantity, and composition have been linked to marginal bone changes and risk of inflammatory complications. Multiple studies describe the need for keratinized tissue around the implant neck (Adibrad et al. 2009, Chung et al. 2006, Kim et al. 2009, Schrott et al. 2009). A reduced peri-implant keratinized mucosa width (< 2mm), however, does not significantly show more crestal bone changes when compared to the absence of

keratinized tissue. They do however show, higher plaque accumulation, bleeding on prob-ing, and buccal soft-tissue recession (Schrott et al. 2009).

A study (Linkevičius et al. 2009) examining initial gingival tissue thickness concluded that thicknesses of 2.0 mm or less may contribute to crestal bone loss; however, their results did not reach the level of significance. The placement of the implant at bone level could also contribute significantly to crestal bone change. In another study by the same research group (Puisys & Linkevičius 2015), they placed 97 bone level implants in 97 patients divided into 3 groups and found that Group T1 showed initial soft-tissue thickness of < 2mm; Group T2, initial soft thickness of < 2 mm and the use of an allogenic membrane; and Group C, initial soft-tissue thickness of 2 mm or more. After 1 year of loading, their results showed a statis-tically significant difference (P = .0000) between Groups T1/C and T1/T2, but no statistical significant difference in groups T2/C (P = .909). They concluded that the use of an allogenic membrane in thin biotypes could prevent crestal bone loss. The macro geometrical shape of these implants however is different and this could lead to a bias in the results.

The need for wide, thick, keratinized tissue around implants seems to be an important con-tributing factor in the prevention of crestal bone loss. Our aim was to evaluate crestal bone changes around macro geometrical similar bone and soft tissue level implants in relation to initial crestal mucosal thickness at surgery. The null hypothesis is that there is no difference in crestal bone change, irrespective of whether the mucosal thickness is greater or less than 2 mm.

Materials & Methods

All procedures were performed at the Department of Implantology, Academic Centre of Dentistry Amsterdam (ACTA), and approved by the medical ethics committee of the Free University (METc VUMC registration number 2009/221) and carried out according the Dec-laration of Helsinki. Patients were referred by their respective general practitioners to the ACTA for specialist implant therapy. In this study, implant-supported, 3-unit fixed restora-tions were placed in the posterior maxilla or mandible. This study was performed between November 2012 and June 2013. Based on a power calculation, a minimum sample size of 16 was determined. Patients between the ages of 25 and 85 years were eligible for inclusion in the study on fulfilling all of the following criteria: (1) a 3-unit fixed dental prosthesis (FDP) supported by 2 implants in a molar/premolar area; (2) adequate bone height and width for implant placement without any bone regeneration; (3) agreement to visiting every 3

months for a strict oral hygiene protocol; (4) had adequate oral hygiene; and (5) were willing to sign the informed consent. Patients were excluded from the study if they met any of the following criteria: (1) medical conditions that contraindicated surgery (e.g., severe cardiac and pulmonary disorders, uncontrolled diabetes, or chronic liver disease; (2) suffered from untreated periodontitis; or (3) had a substance abuse problem.

At the time of inclusion in the study, patients were advised regarding the nature of the study, as well as the clinical procedures and the possible risks involved. At intake, a panoramic radiograph (Orthopantomograph OP-100 D; GE Healthcare, Little Chalfont, Buckinghamshire) was taken to assess the available vertical bone dimensions for implant placement. An individualized X-ray film holder (Rinn-holder and 1-mm Biolon, Dreve; Dentsply Rinn, York, Penn) was designed in a way that future x-rays would have reproducible settings and directions. A week before the surgery, all patients received a precise treatment overview, and informed consent was obtained. The patients' oral hygiene was examined according to the Dutch Periodontal Screening Index (DPSI). General surgery-related instructions were provided, and the patients were again advised about the procedure and risks involved. A single clinician (P. V. E.) carried out the surgical and prosthetic procedures.

Prior to surgery, patients received a non-steroidal anti-inflammatory medication (600 mg Brufen bruis; AbbVie S.r.l., Campoverde di Aprilia, Italy) and were asked to rinse their mouths for 1 min with 0.2 % chlorhexidine (Corsodyl; GlaxoSmithKline, Utrecht, the Netherlands). Implant placement was performed under local anesthesia (Articaine hydrochloride 4% with epinefrine 1:100000, Ultracain d-s forte; Sanofi-Aventis, Gouda, the Netherlands). After a crestal and a partial sulcular incision on neighboring elements, a full-thickness flap was deflected only on the buccal side. To perform minimally invasive surgery, no releasing incisions were used. During the flap deflection, initially only the buccal was raised, in order to accurately measure flap thickness at the lingual side of the crestal incision line using a periodontal probe (Hu-Friedy, Chicago, Ill) (figure 1). Both the operator and the patient were blind to the random allocation of the bone level (minimized collar, with the prosthetic abutment connection at the crestal bone level [MC], 0.5-mm machined neck for crestal placement) and tissue level (long collar, with the prosthetic abutment connection at 2.5 mm supra crestal [LC], 2.5-mm machined neck for transmucosal placement) implant on either the mesial or the distal implant site. Because of the similar shape of both implants, the osteotomies were identical until placement of the implants. Implants were conditioned chair side to achieve a hydrophilic implant surface (APLIQUIQ®; Thommen Medical AG, Grenchen,

Switzerland). Two implants, one MC and one LC, with similar lengths (SPI ELEMENT INICELL; Thommen Medical AG) were placed following manufacturer's guidelines. The implants were slowly threaded into their final positions either using a torque wrench or a contra-angle hand piece at a maximum speed of 30 rpm. The machined-polished implant collar of the MC implant should be positioned under the crest (according to the manufacturers guidelines). A healing cap was placed, and all wounds were sutured tension-free with polypropylene 6/0 (Hu-Friedy). Healing cap heights were chosen in such a way that patients were blinded to the position of each implant type. All implants were placed 1-stage.

All patients received a postoperative prescription for 0.2% chlorhexidine mouth rinse (Corsodyl; GlaxoSmithKline) and were instructed to use it 3 times a day for 2 weeks. No painkillers were prescribed; patients were advised to use acetaminophen when necessary. Further, extensive, intermittent, extra-oral cooling with cold-packs was advised for 24 h postoperatively.

The sutures were removed 2 weeks postoperatively. In all patients in whom both implants had reached minimum insertion torques of 10 Ncm, impressions were taken during the suture removal visit. One week later after impressions taking (3 weeks after surgery) healing caps were removed and the porcelain-fused-to-metal FDPs were fitted. All FDPs were screw retained, with the internal screws tightened at 15 Ncm. All patients received thorough dental hygiene instructions using interdental brushes (Interprox plus; Dentaid Benelux, B.V. Houten, the Netherlands).

To assure reproducibility of the dental x-rays, an individualized x-ray film holder (Rinn-holder and 1 mm Biolon, Dreve) was made for each patient. The radiographs were taken at weeks 3 and 55 with a square tube using the long-cone paralleling technique (Meijndert et al. 2004). We used a phosphor plate x-ray (Durr Dental, Bietigheim-Bissingen, Germany); the x-ray tube (Planmeca, Helsinki, Finland) had the same setting for each patient. It was fitted onto the antagonist jaw so that the first x-ray after placement was directed in the same place at both the 1- and 12-month visits, as the FDP was not fitted until week 3. We used Image J software (1.47 V Wayne Rasband; National Institutes of Health, Bethesda, Md) to assess the mesial and distal bone levels. Each radiographic picture was randomly numbered, and the measurement moment (T0 or T12) was blinded for the examiners (P.V.E. & D.W.). The scale was set and calibrated by the width of the dental implant, which yielded a pixel/mm ratio. Radiographical bone levels were calculated between placement and 12 months. The 2 ex-

aminers made measurements independently of each other in a darkened room, in order to assure the most accurate measurements (figure 2). The primary outcome measurement was the mean worst crestal bone change per implant type and the mucosal gingival thickness.

Statistical Analysis

For statistical analysis, we used the SPSS statistical package (SPSS version 21; SPSS Inc., Chicago, Ill). The inter-examiner score was assessed and yielded an intra-class correlation coefficient and a 95% CI. A Shapiro-Wilk's test was used to test the null hypothesis that the data are normally distributed. The scores of the worst case scenario (i.e., the most crestal bone change of either the mesial or distal side of each implant), were used for statistical testing. All implants were divided into 4 groups according to gingival thickness and implant types: MC implants with an initial mucosal thickness of 2.0 mm or less (Group A [MC]), MC implants with a initial mucosal thickness greater than 2.0 mm (Group B [MC]); LC implants with an initial mucosal thickness of 2.0 mm or less (Group A [LC]); and LC implants with a initial mucosal thickness greater than 2.0 mm (Group B [LC]). A paired-samples *t*-test was used for the analysis of the mean crestal bone changes per implant per group. According to the intent-to-treat analysis, all patients were treated as intended and thus no effort was made to correct statistically for the early or the conventional loading of the implants.
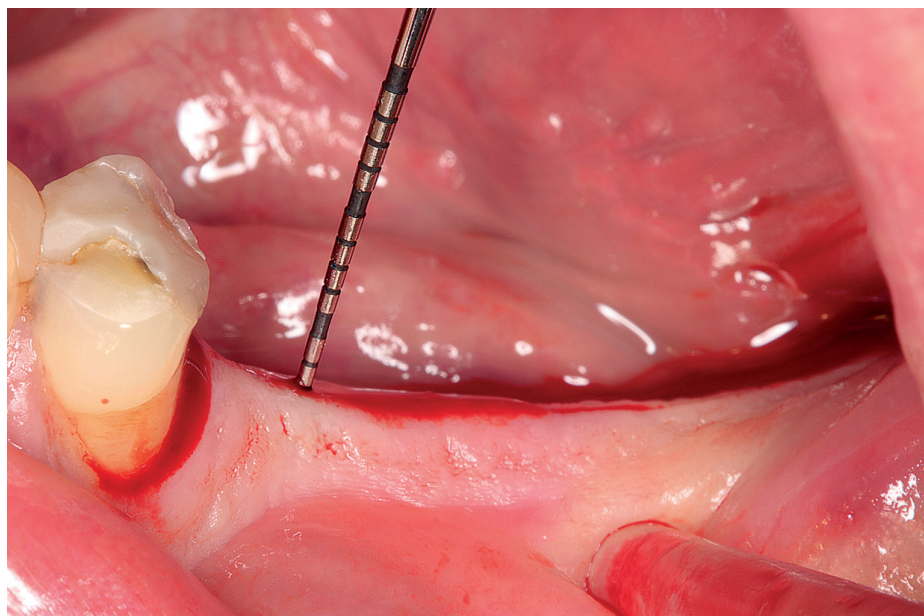

Figure 1: *The periodontal probe used to measure flap thickness at the lingual side of the crestal incision line.*
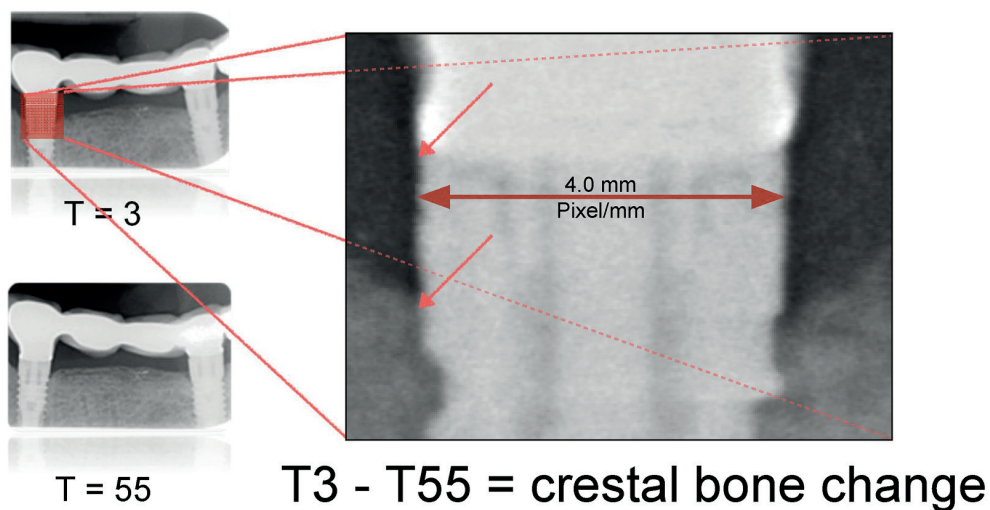
Figure 2: The standardized x-ray was used to obtain the radiographical bone levels.

Results

The patients were prospectively followed-up for at least 1 year, and 33 consecutive patients (20 women and 13 men), with a mean age of 61 years (range: 36–85 years), fulfilled the inclusion criteria for this randomized trial. A total of 78 implants were placed: 39 Thommen SPI-ELEMENT LC implants and 39 Thommen SPI-ELEMENT MC implants, with 29 patients receiving 2 implants, 3 receiving 4 implants, and 1 receiving 8 implants. Every FDP was supported on 1 LC and 1 MC implant. One patient lost an MC implant to infection at week 3 (1.3%), and 1 patient deceased during the 1-year follow-up. A Shapiro-Wilks' test ($P > .05$) showed that the data were approximately normally distributed and that parametric statistical tests could be applied.

The intra-class correlation of measurements performed by the first and second x-ray examiner was 0.990 on the mesial side of the MC implant (95% CI: 0.980–0.995); 0.980 (95% CI: 0.962–0.990) on the distal side of the MC implant; 0.979 on the mesial side of the LC implant (95% CI: 0.959–0.989); and 0.988 on the distal side of the LC implant (95% CI: 0.978–0.994), respectively.

Group A (MC) consisted of 17 implants with a mean crestal bone change of -0.6 ± 0.5 mm (Min -1.8, Mdn -0.6, Max 0.4) and Group B (MC) consisted of 20 implants with a mean crestal bone change of -0.2 ± 0.4 mm (Min -1.0, Mdn -0.2, Max 0.37). Group A (LC) consisted

of 15 implants with a mean crestal bone change of -0.1 ± 0.5 mm (Min -1.4, Mdn -0.02, Max 0.7) and Group B (LC) consisted of 22 implants with a mean crestal bone change of -0.2 ± 0.4 mm (Min -1.1, Mdn -0.2, Max 0.55).

A paired-samples *t*-test for group A (MC) and group B (MC) (*t* [16] = -3.5; *P* = .003) showed a statistically significant difference (*P* < .05) when the initial mucosal thickness is greater than 2.0 mm within the MC implants. A paired-samples *t*-test for group A (LC) and group B (LC) (*t* [15] = 0.664; *P* = .518) showed no statistically significant difference (*P* > .05) when the initial mucosal thickness is greater than 2.0 mm within LC implants. For groups A (MC) and A (LC), the *t*-test (*t* [14] = -2.779; *P* = .015) did show a statistically significant difference (*P* < .05) between LC and MC implants when the initial mucosal thickness was less than 2.0 mm. However, the paired-samples *t*-test for groups B (MC) and B (LC) (*t* [19] = 0.768; *P* = .506) showed no statistically significant difference (*P* > .05) between LC and MC implants when the initial mucosal thickness was greater than 2.0 mm.

Discussion

The aim of our study was to evaluate crestal bone changes around bone and tissue level implants in relation to initial crestal flap tissue thickness. There are several techniques to measure mucosal thickness described in the literature. Schwarz et al. (2013) used a biometric scanner to assess mucosal thickness in peri-implantitis cases. In that study, more severe peri-implantitis was seen in patients with a thin mucosa (95% confidence interval [CI]: 0.23-0.42 mm) when compared to those with thick peri-implant mucosa (95% CI: 0.82-1.09 mm). The most common technique for measuring initial mucosal thickness is a partial flap deflection and the use of a periodontal probe (Linkevičius et al. 2009a, Linkevičius et al. 2009b, Linkevičius et al. 2010, Linkevičius et al. 2013, Linkevičius et al. 2014, Linkevičius et al. 2015b, Terheyden et al. 2013). Crestal bone levels are difficult to measure. Histology could serve as the gold standard; however, this method is not applicable for living humans and functioning implants. The current international literature indicates that parallel intra-oral x-rays are the most commonly used (Meijndert et al. 2004). The down side of this technique is the absence of 3-dimensional (3D) information. A cone-beam computed tomography (CBCT) scan could provide the desired 3D information on the crestal bone level; however, a study by Ritter et al. (2014) demonstrated that the measurement error on CBCT and intra-oral radiography show no statistical differences when compared to the histology of these implants in canines. Furthermore, the 'as low as reasonably achievable' (ALARA) principle is a contraindication for the use of CBCT to assess crestal bone levels.

Within its limitations, our study showed a statistically significant difference in crestal bone change after 1 year of loading when initial mucosal thickness was less than 2 mm in MC or bone level implants ($P < .05$). There was, however, no statistically significant difference if the initial mucosal thickness was less than 2 mm in LC or tissue level implants ($P > .05$). This is in accordance with the current literature. A study (Linkevičius et al. 2014) showed similar results. In their study, 80 bone level implants were placed in 80 patients. The patients were separated into 2 groups containing 40 bone level implants each. The implants in group 1 (≤ 2 mm of initial soft-tissue thickness) showed 1.17 mm of bone loss after 1 year of loading, and those in group 2 (> 2 mm of initial soft-tissue thickness) showed 0.21 mm of bone loss after 1 year of loading. The differences between both groups were statistically significant ($P < .001$), and they concluded that platform switching does not prevent crestal bone loss if the initial mucosal thickness is thin at the time of implantation. The implants in our study, however, have a butt-joint connection and thus lack the possibility to platform-switch, which could have influenced the results.

In our study, there was no statistical difference in the use of tissue level implants when the initial mucosal thickness was 2 mm or less, meaning that the implant-abutment interface was 2.5 mm away from the crest. This could be explained by the fact that the microgap was away from the bone, and thus the biologic width was more easily retained. A study conducted on this topic (Vervaeke et al. 2014) examined 79 edentulous patients with non-splinted, early loaded, bone level implants after 1 and 2 years of loading. As the initial soft-tissue thickness was not the main goal for their study, they divided these patient into 4 groups depending on the abutment height used on the implants: < 2 mm, 2 mm, and 3 mm represented the test groups; abutments higher than 4 mm represented the control group. The bone level changes were set to 0 in the control group, and they noted a crestal bone loss of 1.23 mm, 1.03 mm, and 0.41 mm for the < 2 mm, 2 mm, and 3 mm groups, respectively. This yielded a statistically significant difference between all groups when compared to the control group ($P < .01$), and Vervaeke et al. suggested that the re-establishment of biologic width may contribute to these findings, and advised deeper implant placement when the gingival thickness was thin, as well as including information about the initial soft-tissue thickness.

In a canine model (Caram, et al. 2014) 6 experimental implant-abutment interface designs and their effect on crestal bone level changes were studied. They created implant-abutment interface configurations with different distances to the bone crest in the vertical and the horizontal plane. All implants were placed with their rough-smooth border at 1-mm sub-

crestal: 2 had a straight design with either a microgap (straight abutment) or without a microgap (one piece); 1, a straight but mismatched abutment diameter according to the platform-switching concept; 3, a concave profile in the abutment to accommodate a thicker soft tissue collar around the abutment; 1, a matching diameter; 1, a mismatch (platform switch); and 1, without a microgap (one piece). In this way, they combined both different distances from the microgap to the bone, the absence of a microgap, and a different abutment profile in their study of the effect on crestal bone level changes. Standardized radiographs were taken at baseline, and at monthly intervals from 3 to 9 months after implant placement. They concluded that the most stable crestal bone levels were seen in implants with no microgap. Furthermore, there were no significant findings amongst the groups with mismatching or matching abutment diameters, or with concave abutment profiles. No information, however, was provided on the initial mucosal thickness in these canines.

Ikeda et al. described other factors and mechanisms involved in the resorption and formation of bone (Ikeda & Takeshita 2014). According to manufacturer's guidelines, the MC implants with a 0.5-mm minimized smooth collar in our study should be placed below the bony crest. In numerous cases, this resulted in having to remove bone during surgery to flatten the bony crest at the MC position. Removal of this cortical bone activates the cascade involving bone formation and resorption (bone remodeling); this could have contributed to differences between the bone and the tissue level implants. Another effect of this smooth collar beneath the bony crest could explain the negative difference in crestal bone change in the MC (bone level implants) in our study. The removal of bone and the placement of the smooth collar beneath the bony crest could have influenced the bone level. These events, however, were evenly distributed amongst the 2 mucosal thickness groups, indicating that the effect could be minimized through a thicker soft tissue at implant placement, as all 0.5-mm smooth collars are placed below the bony crest.

Conclusion

If the initial mucosal thickness surrounding bone level implants is more than 2 mm, there is statistically significant less crestal bone change when compared to bone level implants placed in initial mucosal thicknesses of 2 mm or less. This difference was not statistically significant when tissue level implants were used or when the implant-abutment connection was 2.5 mm above the crestal bone level, indicating that when treating patients with initial mucosal thicknesses of 2 mm or less, choosing a tissue level implant with the implant-abutment connection 2.5 mm above the crestal bone level could prevent crestal bone loss.

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Chapter 6

Implant Placement & Oral Health Related Quality of Life
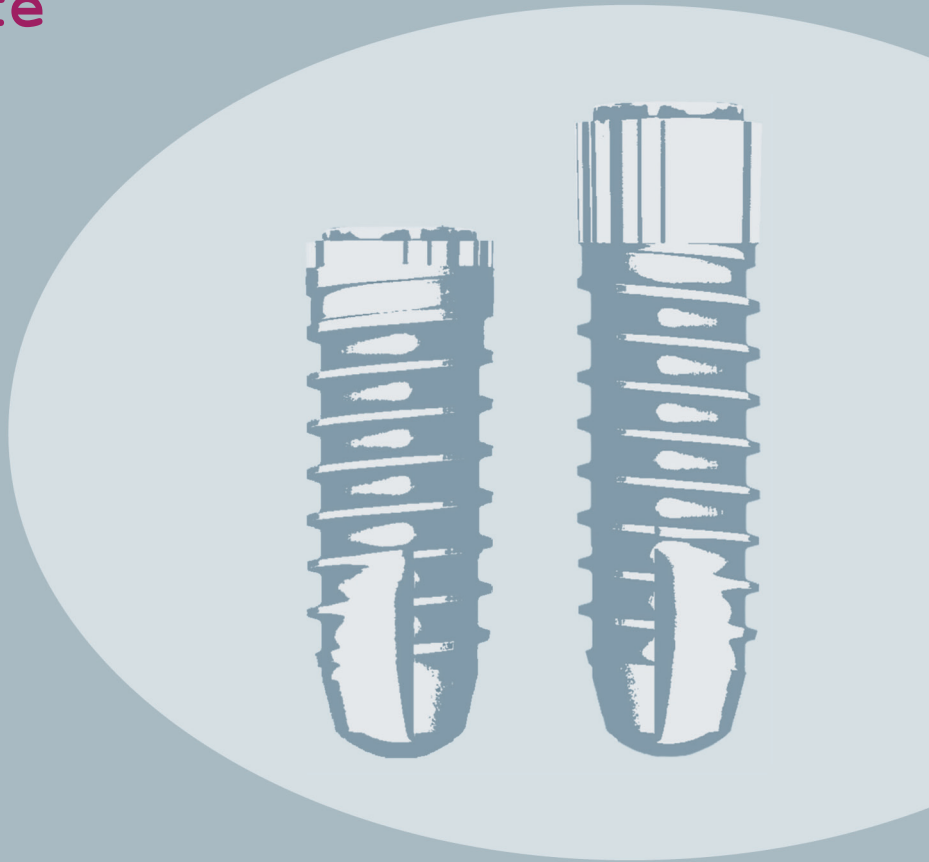
The effect of implant placement in patients with either Kennedy Class II and III on the Oral Health Related Quality of Life

Abstract

Background: There is little evidence of the effect of implants restored with fixed partial dentures on OHRQoL in partially edentulous Kennedy class II and III patients.

Objective: The aim of this study was to determine the change in Oral Health Related Quality of Life (OHRQoL) in Kennedy classification II and III patients treated with a two-implant-supported fixed dental prosthesis (FDP).

Materials & Methods: Kennedy class II and III patients received dental implants and an FDP. OHRQoL was measured by administration of the Oral Health Impact Profile-14 (OHIP-14NL) questionnaire at intake (T1), two weeks after surgery (T2), and after one year of loading (T3).

Results: The mean OHIP score at T1 was 6.5 +/− 1.2, 2.4 +/−1.0 at T2, and 0.9 +/− 0.3 at T3. There was a statistically significant difference between T1 and T2 (P = 0.002) and T1 and T3 (P < 0.001) but not between T2 and T3 (P = 0.407). The OHIP score in Kennedy II patients decreased from 4.8 +/- 3.2 at T1 to 1.5 +/− 2.0 at T2 and 1.1 +/− 1.8 at T3, and that in Kennedy III patients decreased from 8.9 +/− 9.6 at T1 to 3.6 +/− 8.9 at T2 and 0.8 +/− 2.2 at T3. There were no statistically significant differences in the reductions in Kennedy II and III patients.

Conclusion: OHRQoL changed positively in patients treated with implants and an FDP in both groups. There was no change in OHRQoL between the times of implant placement and FDP placement.

The effect of implant placement in patients with either Kennedy Class II and III on the Oral Health Related Quality of Life

Introduction

Dental implants are used widely to replace missing tooth roots, and implants provide options to support different forms of fixed and removable prostheses. The main goal of every prosthodontic treatment is to enhance patient quality of life. The impact of certain dental events on Oral Health Related Quality of Life (OHRQoL) might be measured by the Oral Health Impact Profile (OHIP) (van der Meulen et al. 2008, van der Meulen et al. 2012).

Many studies (Awad et al. 2014, Babbush 2012, Borges et al. 2011, Furuyama et al. 2012, Grover et al. 2014, Harris et al. 2013, Jabbour et al. 2012, Jofre et al. 2013, Kuoppala et al. 2013, Misumi et al. 2015, Mumcu et al. 2012, Oh et al. 2016, Zembic & Wismeij-er 2014) have been conducted to assess the effect of treatment with dental implants on patient OHRQoL. In one study, there was an increase in OHRQoL after treatment in three treatment groups (fixed implant-supported prostheses, FP; removable implant-supported prostheses, RP; or complete dentures, CD) (Oh et al. 2016). There appeared to be no significant difference between the FP and RP groups, although there were differences between the FP and CD groups. Another prospective study (Gates et al. 2014) determined the influence of implant placement in patients with a removable partial denture (RPD) in Kennedy class I and II situations. After placement of the implants and adjustment of the RPD, OHRQoL improved significantly. Similar findings have been reported for a multicenter study (Wismeij-er et al. 2013) that treated patients who were dissatisfied with their existing conventional distal extension dentures when opposing a full denture. After three years of functioning, the OHRQoL improved significantly when the RPD was supported by dental implants.

Another study (Tan et al. 2014) looked at the difference in OHRQoL between patients with a shortened dental arch (Kennedy class II) and patients with natural teeth. The authors defined a shortened dental arch as intact anterior teeth, four occlusal units, and no dental prosthesis. A total of 2750 dentate patients were tested, and no significant differences were found between the groups of patients with respect to OHRQoL.

Finally, a study (Swelem et al. 2014) comparing multiple solutions for the replacement of missing teeth with respect to OHRQoL is mentioned in the literature. Patients in this study were treated with fixed dental prostheses (FDP), with implants (ISFP) or without; combined fixed-removable restorations (COMBs); removable dental prostheses (RDP); or single crowns. The OHIP was administered before treatment, at six weeks, and at six months post-treatment; OHRQoL improved the least in patients using RPDs. Changes in OHRQoL when treated with FDPs and ISFPs were comparable. Similar treatments had different effects on OHRQoL depending on age and Kennedy class. There was, however, no evidence of a difference in OHRQoL between Kennedy class II and III.

Thus, the effect of implants on OHRQoL in patients treated with removable dentures and FDPs has been studied extensively. However, there is little evidence of the effect of implants restored with fixed partial dentures on OHRQoL in partially edentulous Kennedy class II and III patients with an implant-borne FDP. The aim of this study was to assess the changes in OHRQoL in Kennedy class II and III patients treated with an early-loaded two-implant-supported FDP.

Materials & Methods

All procedures were performed at the Department of Oral Implantology and Prosthetic Dentistry, Academic Centre of Dentistry Amsterdam (ACTA), and approved by the medical ethics committee of the Free University (METc VUMC registration number 2009/221). This study was conducted between November 2012 and June 2013. Patients were referred by their respective dentists to ACTA for implant-supported 3-unit FDP in the posterior maxilla or mandible. Thirty-five patients between 25 and 85 years of age were eligible for inclusion in the study, having fulfilled all of the following criteria: (1) requirement of a 3-unit FDP supported by two implants in the molar/premolar area, (2) adequate bone height and width for implant placement without any bone augmentation/regeneration procedures (3) agreement to visit ACTA every three months for a strict oral hygiene protocol, (4) adequate oral hygiene and (5) willingness to sign the informed consent form

Patients were excluded from the study if they fulfilled any of the following criteria: (1) medical conditions that contraindicated surgery (e.g., severe cardiac and pulmonary disorders, uncontrolled diabetes, chronic liver disease), (2) periodontitis (current), (3) problematic substance use.

At the time of inclusion in the study, patients were advised regarding the nature of the study, the clinical procedures, and possible risks involved (T1). Patients were followed up prospectively for more than one year.

Standard implant placement procedures were performed according to manufacturer's guidelines (Thommen Medical AG, Grenchen, Switzerland) and sutured, by the same clinician, with polypropylene 6/0 (Hu Friedy Mfg. Co, LLc, Chicago, USA). Two weeks after surgery, sutures were removed, and impressions for the 3-unit FDP were obtained (T2). None of the patients wore any kind of prosthesis during recruitment or treatment.

In the third week after surgery, the porcelain-fused-to-metal FDP was mounted. The screw-access holes were closed using Teflon™ tape and composite resin (Filltek Supreme XTE; 3M ESPE, Seefeld, Germany).

The Dutch version of the OHIP was presented at intake (T1) (van der Meulen et al. 2008), two weeks after the implant surgery (T2) and after one year of loading (T3). The answers to the 14 items of this questionnaire range from 0 ('never') to 4 ('always'). This yielded a total score, which was the sum of the question range (John et al. 2014). This score varied between 0 and 56. Higher scores are associated with a worse OHRQoL. The Dutch translation of this OHIP questionnaire was valid and tested as reliable for the Dutch language (van der Meulen et al. 2008).

Statistical Analysis

For the statistical analysis, SPSS 21 Statistics (IBM Corp., Armonk, USA) was used. Repeated measures ANOVA was used to assess changes in OHIP score over time at the different intervals in the entire study group. In addition, we assessed whether this change was equal for the Kennedy class II and III groups. A post-hoc Bonferroni test was used to adjust for multiple comparisons.

The effect needs to be interpreted in terms of its magnitude. The magnitude of OHIP scores was interpreted with the minimal clinically important differences for OHIP, and effect sizes were calculated using omega-squared values. The omega-squared value reflects the degree of association in the population and is an estimate of the dependent variance accounted for by the independent variable in the population for a fixed effects model (Olejnik & Algina 2003).

A reliable change (RC) index was calculated to determine which OHIP scores changed beyond a level that could be attributed to measurement error alone (Evans et al. 1998). For this purpose, the standard error (SE) of measurement of the difference was used; this takes into account two measurements. The formula is as follows: $SE_{diff} = SD_{1v}2\sqrt{1-\alpha}$, where SD_1 is the standard deviation of the baseline observations, and α is the reliability of the measure. As the reliability measure, the test-retest reliability was used, having been extracted from a similar study performed in the Netherlands using the same questionnaire (van der Meulen et al. 2008). It is assumed that change that exceeds 1.96 times this SE (i.e. the RC index) is unlikely to occur more than 5% of the time by unreliability of the measure alone (Evans et al. 1998). The level of significance was set at alpha = 0.05.

Results

35 patients were included in this study – 22 women and 13 men – with a mean age of 61 (range 36–85). One patient was lost in the one-year follow-up because of death and was excluded for further analysis. Fourteen patients were included with a Kennedy II classification and 20 with a Kennedy III classification.

Repeated measures ANOVA for time achieved a statistically significant result for both groups pooled ($F(1.946, 62.270) = 14.817$, $P < 0.001$, $\omega2 = 0.157$). The mean total OHIP-score at intake (T1) was 6.5 +/− 1.2 (95% CI; 4.1–8.8) and 2.4 +/− 1.0 (95% CI; 0.3–4.4) two weeks after surgery (T2), and 0.9 +/− 0.3 (95% CI; 0.3–1.6) after one year of loading the implants (T3). The Bonferroni post hoc procedure yielded a statistical significant difference between T1 and T2 ($P = 0.002$), and T1 and T3 ($P < 0.001$). It did not reach a statistically significant difference between T2 and T3 (figure 1).

Repeated measures ANOVA for time achieved significant results for both groups separately as well ($F(1.185, 23.691) = 22.151$, $P < 0.001$, $\omega2 = 0.328$ in Kennedy II patients and $F(1.960, 25.484) = 5.308$, $P = 0.012$, $\omega2 = 0.137$ in Kennedy III patients). The mean OHIP score decreased from 4.8 +/− 3.2 (95% CI; 1.8–7.7) at T1 to 1.5 +/−2.0 (95% CI; -1.2–4.2) at T2 and 1.1 +/− 1.8 (95% CI; 0.2–1.9) at T3 in Kennedy II patients and from 8.9 +/− 9.6 (95% CI; 5.4–12.5) at T1 to 3.6 +/− 8.9 (95% CI; 0.4–6.8) at T2 and 0.8 +/− 2.2 (95% CI; -2.7–1.8) at T3 for Kennedy III patients. Wilks' lambda multivariate testing showed no significant difference in time effect between the two Kennedy classes $\lambda = 0.01$, $F(2, 31) = 1.6$, $P = 0.211$. An independent samples t-test of OHIP score changes from T1 to T3 demonstrated the differences between the two classes with a mean value of -4.4 (95% CI; -10.4–1.5). There were significant differ-

ences in the mean OHIP scores between the Kennedy class II and III at intake ($P < 0.001$) and two weeks after surgery ($P = 0.033$). In addition, a regression analysis was conducted with the T1–T3 OHIP difference score as the dependent variable and Kennedy class as the predictor. Both with and without adjustment for OHIP baseline, Kennedy class was not related to the OHIP change score ($P = 0.791$ and $P = 0.076$, respectively). An analysis of covariance using OHIP at T3 as the dependent variable and OHIP baseline as covariate yielded the same result ($P = 0.791$) for the difference in OHIP score between Kennedy class II and III at T3, adjusted for baseline OHIP.

The standard error of measurement of the difference was 2.9; hence, change that exceeded 1.96*2.9 = 5.8 could be regarded as reliable. Inspecting the data for T1–T2, 22 of 35 patients (63%) demonstrated a change smaller than 5.87, and thus 13 (37%) showed a reliable improvement for T1–T2. Twenty of 35 patients (57%) showed a change smaller than 5.87; thus 15 patients (43%) showed a reliable improvement for T1–T3. Two patients (6%) demonstrated a reliable improvement for T2–T3.

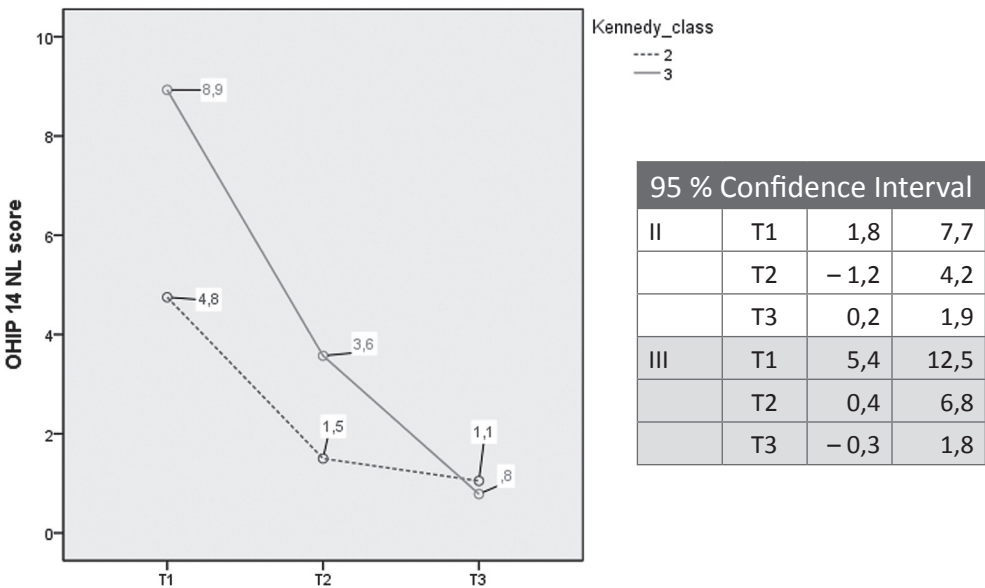| 95 % Confidence Interval			
II	T1	1,8	7,7
	T2	− 1,2	4,2
	T3	0,2	1,9
III	T1	5,4	12,5
	T2	0,4	6,8
	T3	− 0,3	1,8

Figure 1: *OHIP 14 NL Measurement time interval at T1 (intake), T2 (2 weeks after surgery) and T3 (after 1 year of loading) differentiated for Kennedy class II and III.*

Discussion

The purpose of this study was to investigate the changes in OHRQoL after patients with a Kennedy classification II and III were rehabilitated with two implants and a FDP. The results showed a significant improvement of perceived OHRQoL in 34 patients (97%) who received two implants with a FDP, regardless of whether Kennedy classification was II or III. When we corrected these results for minimally important differences using the reliable change index, 37% of all patients showed a reliable improvement for T1–T2, and 43% showed a reliable improvement for T1–T3. Only 6% demonstrated a reliable improvement for T2–T3. This positive effect of an implant treatment on OHRQoL has been noted by several recent studies (Awad et al. 2014, Babbush 2012, Borges et al. 2011, Furuyama et al. 2012, Gates et al. 2014, Grover et al. 2014, Harris et al. 2013, Jabbour et al. 2012, Kuoppala et al. 2013, Mumcu et al. 2012, Oh et al. 2016, Wismeijer et al. 2013, Zembic & Wismeijer 2014). Patients with a Kennedy III classification had a statistically significant higher OHIP score at intake (T1) and after two weeks of surgery (T2) than did patients with a Kennedy II classification. The statistical difference in quality of life between patients who had a Kennedy III and a Kennedy II classification was striking: patients had a higher OHRQoL when a unilateral shortened dental arch was present instead of a diastema in the posterior mandible or maxilla. The change in OHRQoL, however, was not statistically significant between these groups.

The mean OHIP scores decreased for the total group of patients between baseline and two weeks after surgery and between baseline and one year after loading. Surprisingly, in both groups, there was no statistically significant difference between two weeks after surgery and one year of loading, and only two patients (6%) demonstrated improved OHRQoL in this interval. This shows that the OHRQoL became higher after implant placement, even before the FDP was mounted. This study seems to lack the statistical power for a conclusive T2–T3 comparison, although it is clear that the effect size for this difference is much smaller.

Another potential study limitation is that OHRQoL might have risen simply as a result of the perception that 'something is being done about my problem'. Perhaps patients tend to score the treatment instead of their perceived OHIP. There is no dental literature to support this hypothesis. However, there is abundant literature on placebo and nocebo effects on treatment. Patient expectations could be a partial explanation for the study results, given the circumstance that placebo and nocebo effects are influenced by participants' perceptions of receiving the treatment. A review by Vase et al. describes as possible explanations for these effects verbal suggestion, emotions, and expectancy. Furthermore they underscore

that present studies have increasing placebo effects, an un-blinding risk, and demonstrated variability of the placebo effect (Vase et al. 2015).

A study on advertising by Dahlén et al. studied the effect of consumer satisfaction on future purchases (Dahlén et al. 2011). This was described in his recent consumer psychology research on optimism bias, positive uncertainty, and affective forecasting. The investigators posited as an example that the release of the first iPad tablet computer was a success before it was launched. Dahlén stated in his study that companies like Apple excel in selling 'the future'. In our study, all of these effects could help to explain the improved OHRQoL. Patients tend to have an increased positivity on future treatment, have high expectations for the treatment to come, and overestimate the advantages and perceived happiness for the new product or treatment.

This also could mean that patients might have no future frame positivity when no treatment was planned. This could explain the effects of a study (Tan et al. 2014) in which investigators looked at the effect of a shortened dental arch on OHRQoL, compared to the effect of natural teeth on OHRQoL. As stated in the introduction, 2750 dentate patients were tested; between the groups of patients, no significant differences were found in OHRQoL (Tan et al. 2014). Furthermore, another study on the effect of implants on OHRQoL in edentate patients (Jabbour et al. 2012) showed improvement of OHRQoL in both patient groups when treated with new complete dentures or implant over dentures (IOD). The magnitude of the statically significant effect in the IOD group was 1.5 times larger than in the complete denture group. The effect in the complete denture group, however, was influenced by baseline OHIP scores. Again, this effect could be explained by future frame positivity.
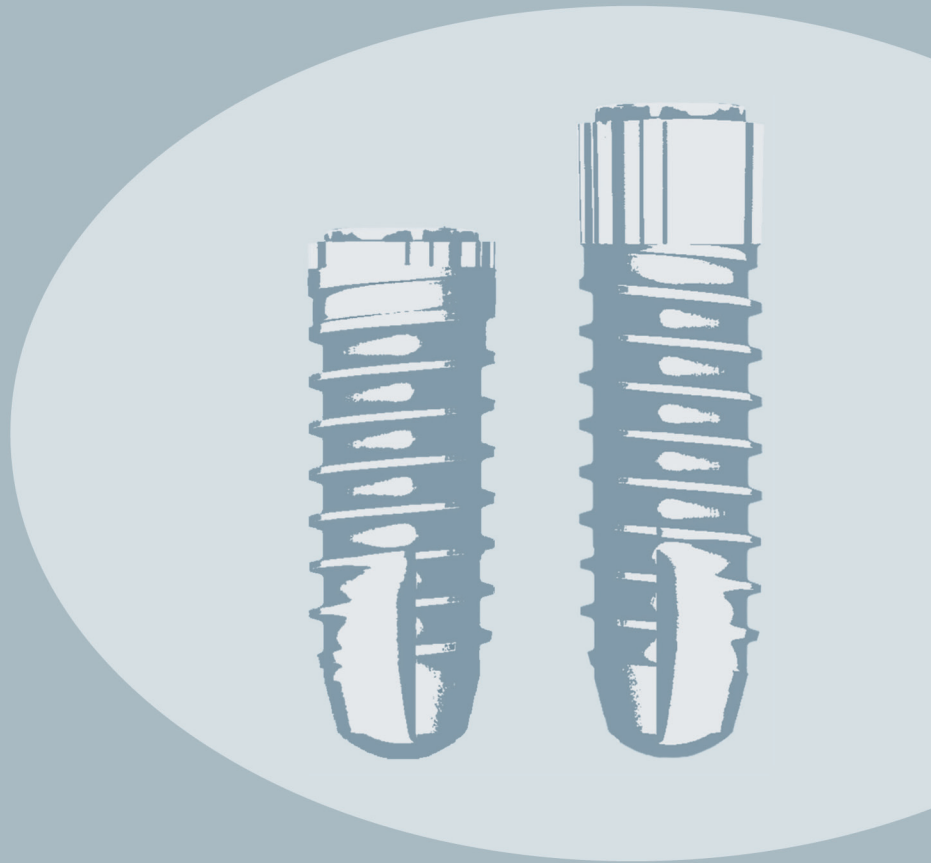
In conclusion, OHRQoL was positively changed when partially edentulous patients were treated with implants and an FDP. There was no difference in improvement of OHRQoL between patients with a Kennedy II or III classification. There was, however, a difference in OHRQoL in patients with a Kennedy II or III classification at baseline.

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Summary

Summary

The use of dental implants supporting Fixed (FDP) or Removable Dental Prostheses (RDP) provides a solution for the replacement of missing teeth. One of the clinical criterions for success of dental implant treatment has been defined as crestal bone change around the implants. Dental implants are available in various surface characteristics, lengths, shapes and designs. All these factors could influence the crestal bone change during and after the osseointegration period. Furthermore site-specific characteristics as implant loading, bone density, soft tissue quality and thickness may influence these changes as well. The delicate balance between crestal bone change and crestal bone loss is possibly determined by the biological width. This zone of tissue has the ability to cope with the bacterial leakage from the microgap at the Implant-Abutment Interface (IAI). This microgap and IAI may be placed below, at the crestal bone level or above. The clinical consequences when changing the position of the IAI, has been studied in the past. However this has not been done using similar macro geometrical implants, loaded under the same circumstances in a randomized clinical trial. Therefore, as described in **Chapter 1**, the aim of the studies described in this thesis was to assess the crestal bone change, patient satisfaction, and performance of a bone and soft tissue level implant loaded in a randomized clinical trial loaded under the same circumstances in an early loading protocol. In **Chapter 2** a systematic review and meta-analysis of the current literature was described. The PICO-question was; P: patients with functioning implants for a minimum of 1 year, I: Implant placed with prosthetic connection at bone level, C: Implant placed with prosthetic connection at soft tissue level and O: crestal bone level change between placement and a minimal one year of functioning. Is there any difference on crestal bone change around implants with the implant-abutment connection at crestal bone level or above? Significant more crestal bone change was seen (radiographically) in the soft tissue level group ($P < 0.00001$). The literature showed a mean crestal bone change over all implants of -0.62 mm in the group with bone and -0.85 mm in soft tissue level implants. Within the limitations of this systematic review, in general dental implants with the prosthetic connection at bone level showed significant less crestal bone changes after one year of loading when compared to implants with the prosthetic connection above the crestal bone level. However, none of these implants had the same macro geometrical shape, were loaded under the same conditions and all fixed dental prosthesis were cemented.

A prospective randomized clinical trial is described in **Chapter 3**. Patients were referred to ACTA for implant placement. Patients were subjected to inclusion and exclusion criteria and

received a minimum of 2 implants: an implant with the prosthetic abutment connection at the crestal bone level (MC, bone level) and one with the prosthetic abutment connection 2,5 mm supra crestal (LC, soft tissue level). The mesial or distal position of each implant type was blinded for the patient and randomized. The implants were loaded splinted after 3 weeks of healing. The primary outcome was bone level changes assessed after one year of loading. 33 Patients fulfilled the inclusion criteria. 39 Thommen SPI-ELEMENT LC implants and 39 MC were placed and each fixed dental prosthesis was supported by one LC and one MC implant. The intra-class correlation of measures performed by the first and second x-ray examiner was on the mesial side of the MC implant 0.990 (0.980-0.995; 95 % CI). 0.980 (0,962-0,990; 95 % CI) on the distal side of the MC implant. 0,979 (0.959-0.989; 95 % CI) and 0,988 (0.978-0.994; 95 % CI) mesial and distal of the LC implant respectively. The mean bone loss of the MC implant was 0.4 ± 0.4 mm. The mean bone loss of the LC implant was 0.2 ± 0.5 mm. The paired-samples test showed a statistical significant difference ($P < .05$) between the MC and LC implants.

The design of a dental implant has an influence on implant stability. Implant stability is critical to the long-term success of osseointegrated implants. Initially, the stability is provided by macro retention to the bony walls surrounding the implant. Resorption of bone due to morphological changes during healing takes place within a few days of implant insertion resulting in a loss of mechanical retention. Further, the loss of mechanical retention and the process of osseointegration do not occur simultaneously, thus causing a temporary decrease in implant stability. To measure implant stability, resonance frequency analysis (RFA) can be used and it is possible to assess changes in implant stability over time.

In **Chapter 4** the study is described in which the RFA was measured using the Implants Stability Quotient (ISQ) at implant placement (T1), 2 weeks after surgery (T2), FDP mounting (T3) and after 12 weeks of loading (T12). 76 SPI-ELEMENT implants – 38 bone level (MC) and 38 soft tissue level (LC) implants – were placed in 32 patients. Early loaded soft tissue level implants showed a significant drop in ISQ values by 2.2 ± 3.6 ISQ ($P < 0.001$) by week 2. Changes in ISQ values were significant between weeks 3 and 12, and also between weeks 0 and 12, with mean differences of 4.2 ($P < 0.001$) and 2.8 ISQ ($P < 0.001$) respectively. Early-loaded bone level implants show a significant change in ISQ by 2.3 ± 3.7 ISQ at week 2 ($P < 0.01$) and at T12 when compared to T3 of 2.9 ± 4.9 ISQ ($P < 0.01$). Bone level implants achieved higher ISQ values compared to soft tissue level implants in weeks 0, 2, 3 and 12, with mean differences of 3.8 ± 5.5 ISQ ($P < 0.01$), 3.8 ± 6.1 ISQ ($P < 0.01$), 3.7 ± 6.7 ISQ ($P <$

0.01), 2.3 ± 5.8 ISQ (*P* < 0.05) respectively. Thus a statistical significant dip in ISQ values was observed, with the lowest point at week 2. ISQ values remained higher in bone level implants throughout the process of healing and osseointegration. A site-specific characteristic is the soft tissue thickness, which contributes to the biological width and thus could influence the crestal bone change.

In **Chapter 5**, the crestal bone change is evaluated around bone and soft tissue level implants. Patients received in a prospective randomized clinical trial at least 2 implants: one with the prosthetic abutment connection at the crestal bone level (MC) and another with the prosthetic abutment connection at 2.5 mm supra crestal (LC). Flap thickness measurements were taken using a periodontal probe after raising the buccal flap. Patients were divided into 2 groups according to mucosal thickness – Group A (thickness, ≤ 2 mm) and Group B (thickness, > 2 mm). This study included 33 patients and 78 implants. Each patient received at least 1 implant of each type. The results of Group A (MC), 17 implants, showed a mean bone change of -0.6 ± 0.5 mm; Group B (MC), 20 implants showed a mean bone change of -0.2 ± 0.4 mm; Group A (LC), 15 implants showed a mean bone change of -0.1 ± 0.5 mm; and Group B (LC) and 22 implants showed a mean bone change of -0.2 ± 0.4 mm. A paired-samples *t*-test for Group A (MC) and B (MC) yielded a statistically significant difference (*P* = .003); there was no statistically significant difference for Groups A (LC) and B (LC) (*P* = .518): If the initial mucosal thickness surrounding bone level implants is more than 2 mm, there is significantly less crestal bone change compared to bone level implants placed in initial mucosal thicknesses of 2 mm or less. This difference was not statistically significant when soft tissue level implants are used and the implant-abutment connection is 2.5 mm above the crestal bone level.

The effect on the OHRQoL when the described dental implant treatment was performed was assessed in **Chapter 6**. There is a lack of evidence of the effect when implants are restored with fixed partial dentures on the OHRQoL in partially edentulous Kennedy class II (unilateral shortened dental arch) and III (unilateral diastema) patients. Kennedy class II and III patients received dental implants and an FDP. OHRQoL was measured by administration of the Oral Health Impact Profile-14 (OHIP-14NL) questionnaire at intake (T1), two weeks after surgery (T2), and after one year of loading (T3). The mean OHIP score at T1 was 6.5 +/− 1.2, 2.4 +/−1.0 at T2, and 0.9 +/− 0.3 at T3. There was a statistically significant difference between T1 and T2 (*P* = 0.002) and T1 and T3 (*P* < 0.001) but not between T2 and T3 (*P* = 0.407). The OHIP score in Kennedy II patients decreased from 4.8 +/- 3.2 at T1 to 1.5 +/− 2.0

at T2 and 1.1 +/− 1.8 at T3, and that in Kennedy III patients decreased from 8.9 +/− 9.6 at T1 to 3.6 +/− 8.9 at T2 and 0.8 +/− 2.2 at T3. There were no statistically significant differences in the reductions in Kennedy II and III patients. OHRQoL changed positively in patients treated with implants and an FDP in both groups. There was no change in OHRQoL between the times of implant placement and FDP placement.
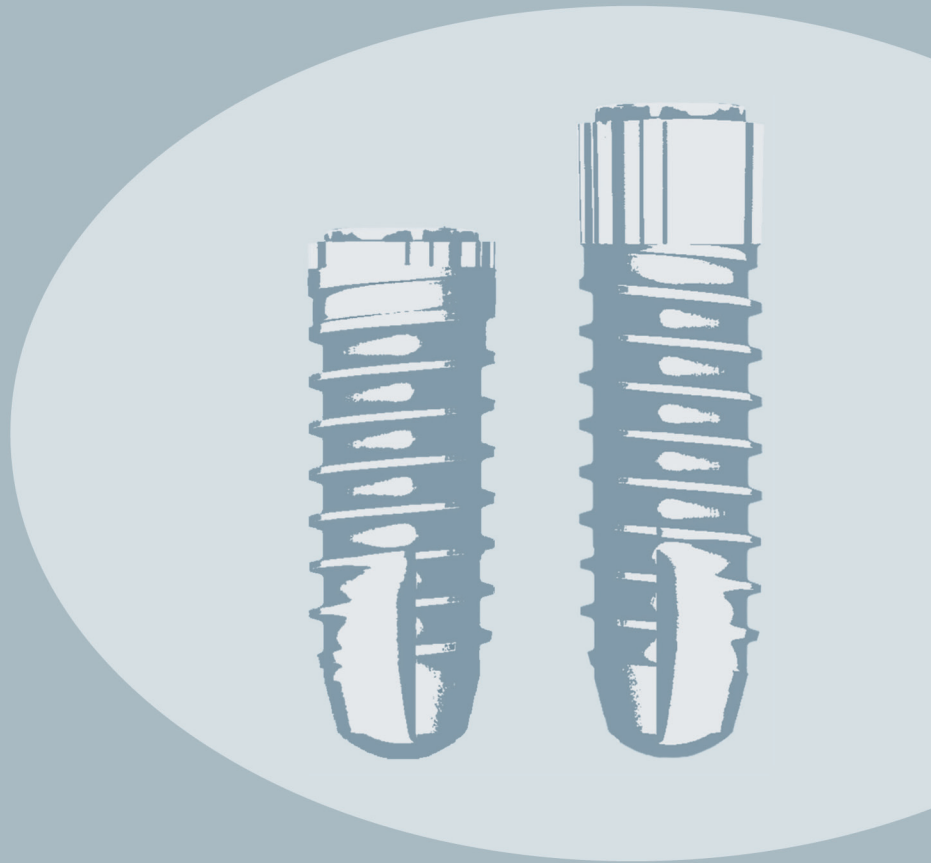
During my post-academic training in Implantology in the Academic Centre for Dentistry Amsterdam (ACTA), prior to every treatment, a surgical and prosthetic planning was being conducted. A part of this planning was the choice of dental implant system. Next to my own preference there is no protocol or guideline to help me as clinician, and thus the patient in the choice of dental implants. With the results of the studies mentioned above and the yielded conclusions several questions have now been addressed. Whether these findings are still present in, for example, 10 years remains unclear. Thus, a long-term follow-up of these patients is mandatory.

- Similar macro geometrical implants with the implant-abutment interface at the crestal bone level demonstrate statistically significant ($P < 0.05$) more initial bone loss than when the implant-abutment interface is 2,5 mm above the crestal bone level.

- The loading of 2-splinted implants in the (pre) molar area at week 3 is a predictable treatment option when torque values are above 10 Ncm.

- A drop in ISQ values by 2.2 in soft tissue level and 2.3 in bone level implants after 2 weeks of implant insertion indicates a significant dip in implant stability. After osseointegration, significantly higher implant stability is seen compared to the stability directly after placement.

- During healing, no differences in the development of ISQ values between bone and soft tissue level implants is observed, indicating no differences in the process of osseointegration between the two types of implant design.

- The high correlation between insertion torque and implant stability at placement suggests that implants with high insertion torque values generally have higher implant stability at placement. On the basis of the insertion torque values, 91% of the implants were loaded after 21 days of healing.

- If the initial mucosal thickness surrounding bone level implants is more than 2 mm, there is statistically significantly less crestal bone change when compared to bone

level implants placed in initial mucosal thicknesses of 2 mm or less. This difference is not statistically significant when tissue level implants are used or when the implant-abutment connection is 2.5 mm above the crestal bone level, indicating that when treating patients with initial mucosal thicknesses of 2 mm or less, choosing a tissue level implant with the implant-abutment connection 2.5 mm above the crestal bone level could prevent crestal bone loss.

- OHRQoL changes positively when partially edentulous patients are treated with implants and an FDP.

- There is no difference in improvement of OHRQoL between patients with a Kennedy II or III classification. There is, however, a difference in OHRQoL in patients with a Kennedy II or III classification at baseline.

Samenvatting

Samenvatting

Ontbrekende gebitselementen kunnen worden vervangen door middel van vaste (FDP) of uitneembare (RDP) implantaatgedragen prothesen. Een van de klinische criteria voor het succes van een tandheelkundige implantaatbehandeling is het intact blijven van het crestale bot rondom de implantaten. Tandwortelimplantaten kunnen zowel macro- (lengte, vorm, ontwerp) als microgeometrisch (oppervlakte-eigenschappen) verschillen. Deze verschillen kunnen tijdens en na de osseo-integratieperiode van invloed zijn op het crestale bot rondom het implantaat. Daarnaast spelen ook lokale anatomische kenmerken een rol, zoals de botdichtheid en de kwaliteit van de zachte weefsels. Het delicate evenwicht tussen crestaal botbehoud en crestaal botverlies wordt waarschijnlijk in balans gehouden door de biologische breedte. Deze weefselzone heeft de mogelijkheid om te gaan met de bacteriële lekkage die uitgaat van de microspleet tussen het implantaat en het abutment (IAI). Deze spleet kan, afhankelijk van het implantaat, onder, op of boven het crestale botniveau worden geplaatst. In het verleden zijn de klinische consequenties van het veranderen van de IAI-positie bestudeerd. Dit is echter nog niet gedaan door implantaten te gebruiken die in macrogeometrisch opzicht gelijk zijn. Daarom vormt een gerandomiseerd klinisch onderzoek waarbij implantaten met de IAI op botniveau en daarboven onder dezelfde omstandigheden belast worden, de basis van dit proefschrift.

In **hoofdstuk 2** wordt een systematisch literatuuroverzicht met een meta-analyse gegeven. De PICO-vraag was: P: patiënten met implantaten die reeds minimaal één jaar belast zijn, I: een implantaat geplaatst met prothetische aansluiting op botniveau C: een implantaat geplaatst met de prothetische aansluiting boven botniveau en O: de verandering van het crestale botniveau tussen plaatsing en na minimaal één jaar belasten. Is er een verschil van het crestale botniveau tussen deze beide typen implantaten? Het gemiddelde crestale botverlies van de implantaten met de IAI op botniveau was 0,62 mm. Bij de implantaten met de connectie boven het botniveau bedroeg het verlies 0,85 mm. Binnen de beperkingen van dit onderzoek, blijken tandheelkundige implantaten met de prothetische aansluiting op botniveau significant minder crestaal botverlies te vertonen na één jaar belasten dan implantaten met de prothetische verbinding boven het crestale botniveau ($P < 0.00001$). Geen van deze implantaten heeft echter dezelfde macrogeometrische vorm of wordt op dezelfde manier belast.

In **hoofdstuk 3** wordt een prospectief, gerandomiseerd, klinisch onderzoek beschreven. De patiënten werden onderworpen aan in- en exclusiecriteria. Zij werden behandeld met minimaal twee implantaten: één implantaat met de IAI-connectie op (MC) en één met de IAI-connectie 2,5 mm boven het crestale botniveau (LC). De mesiale of distale positie van elk type implantaat werd gerandomiseerd en niet aan de patiënt verteld. De implantaten werden na een genezingsperiode van drie weken als brugpijler gebruikt waardoor ze even zwaar werden belast. Als primaire uitkomstmaat werden de veranderingen in het botniveau gemeten, alsmede die na één jaar belasten. 33 patiënten voldeden aan de inclusiecriteria. Er werden 39 Thommen SPI-ELEMENT LC-implantaten en 39 MC-implantaten geplaatst. Elke vaste gebitsprothese (FDP) werd ondersteund door één LC- en één MC-implantaat. De intraclass correlatietoets werd uitgevoerd bij de eerste en tweede onderzoeker van de röntgenfoto's. De verandering in botniveau bedroeg aan de mesiale zijde van de MC-implantaten 0,990 (0,980-0,995; 95% CI) en 0,980 (0,962-0,990; 95% CI) aan de distale zijde van de MC-implantaten. 0,979 (0,959-0,989; 95% CI) en respectievelijk 0,988 (0,978-0,994; 95% CI) voor de mesiale en de distale zijde van de LC-implantaten. Het gemiddelde botverlies bij de MC-implantaten bedroeg 0,4 ± 0,4 mm. Het gemiddelde botverlies bij de LC-implantaten bedroeg 0,2 ± 0,5 mm. De gepaarde t-toets vertoonde een statistisch significant verschil (P < 0,05) aan tussen de MC- en LC-implantaten.

Het ontwerp van tandwortelimplantaten lijkt invloed te hebben op de stabiliteit van het implantaat. Implantaatstabiliteit is belangrijk voor het langetermijnsucces van het implantaat. Na het plaatsen wordt de stabiliteit in eerste instantie verkregen doordat het implantaat macromechanische retentie ondervindt in het kaakbot. Na een paar dagen vindt er echter botresorptie plaats rondom het implantaat. Daardoor neemt mechanische retentie af. Deze afname wordt later gecompenseerd doordat het kaakbot vergroeit met het implantaat: osseo-integratie. De afname aan mechanische retentie en het proces van osseo-integratie verlopen echter niet gelijktijdig, waardoor de stabiliteit van het implantaat tijdelijk minder groot is. Deze verandering is te meten met een resonantiefrequentie-analyse (RFA). In **hoofdstuk 4** wordt een onderzoek beschreven waarbij patiënten minimaal twee implantaten kregen: één implantaat met de IAI op (MC) en één met de IAI-verbinding 2,5 mm boven het crestale botniveau (LC). De RFA werd bepaald door de Implant Stability Quotient (ISQ) te meten. De metingen werden gedaan direct na het implanteren (T1), twee weken na de ingreep (T2), bij het plaatsen van de FDP (T3) en ten slotte na 12 weken (T12). Er werden in totaal 76 SPI-ELEMENT implantaten geplaatst bij 32 patiënten: 38 MC- en 38 LC-implantaten. De LC-implantaten vertoonden een significante daling van de ISQ in week 2 van 2,2 ± 3,6

ISQ (P < 0,001). ISQ waarden waren significant verschillend tussen week 3 en week 12 en tussen week 0 en 12, met respectievelijk gemiddelde verschillen van 4,2 (P < 0,001) en 2,8 ISQ (P < 0,001). MC- implantaten vertoonden ook een significante verandering van ISQ van 2,3 ± 3,7 ISQ in week 2 (P < 0,01), maar ook in T12 in vergelijking met T3 van 2,9 ± 4,9 ISQ (P < 0,01). MC-implantaten vertoonden hogere ISQ-waarden vergeleken met LC-implantaten in de weken 0, 2, 3 en 12, met gemiddelde verschillen van 3,8 ± 5,5 ISQ (P < 0,01), 3,8 ± 6,1 ISQ (P < 0,01), 3,7 ± 6,7 ISQ (P <0,01), 2,3 ± 5,8 ISQ (P < 0,05). Een statistisch significante daling in ISQ-waarden is bij beide typen waargenomen, met het laagste punt in week 2. De ISQ-waarden lagen hoger bij de MC-implantaten gedurende het gehele proces van genezing en osseo-integratie.

De dikte van de zachte weefsels voor het implanteren is van invloed op de biologische breedte rondom het implantaat en daardoor mogelijkerwijs op het crestale botbehoud. In **hoofdstuk 5** wordt de crestale botverandering onderzocht bij LC- en MC-implantaten. Patiënten kregen in deze gerandomiseerde klinische studie minstens twee implantaten: één met de IAI op (MC), en één met de IAI 2,5 mm boven het crestale botniveau (LC). De weefseldikte werd gemeten met behulp van een pocketsonde bij de linguale lap na het wegklappen van de buccale lap. De patiënten werden in twee groepen verdeeld op basis van de gemeten weefseldikte: groep A (dikte ≤ 2 mm) en groep B (dikte > 2 mm). Aan deze studie deden 33 patiënten en 78 implantaten mee. Iedere patiënt kreeg van elk type minstens één implantaat: Groep A (MC), 17 implantaten met een gemiddelde kaakbotverandering van -0,6 ± 0,1 mm; Groep B (MC), 20 met een gemiddelde kaakbotverandering van -0,2 ± 0,1 mm; Groep A (LC), 15 met een gemiddelde kaakbotverandering van -0,1 ± 0,1 mm; en Groep B (LC), 22 met een gemiddelde kaakbotverandering van -0,2 ± 0,1 mm. Een gepaarde t-toets voor groep A (MC) en B (MC) liet een statistisch significant verschil zien (P = 0,003). Er was geen statistisch significant verschil tussen groepen A (LC) en B (LC) (P = 0,518). Dit betekende dat als de weefseldikte rondom een MC-implantaat meer dan twee millimeter bedroeg, er aanzienlijk minder crestaal bot verdween dan wanneer de weefseldikte kleiner was dan twee millimeter. Bij de LC- implantaten was het verschil statistisch niet significant.

Het effect van een vaste implantaatgedragen constructie op de OHRQoL werd onderzocht in **hoofdstuk 6**. Er is een gebrek aan bewijs dat de OHRQoL verschilt bij patiënten met een enkelzijdig verkorte tandboog (Kennedyklasse II) en met een enkelzijdige tandboogonderbreking (Kennedyklasse III). Daarom werden Kennedyklasse II- en III-patiënten behandeld met tandimplantaten en een FDP. De OHRQoL werd gemeten met behulp van de Oral Health

Impact Profile-14 (OHIP-14NL) vragenlijst bij de intake (T1), twee weken na de operatie (T2) en na één jaar belasten (T3). De gemiddelde OHIP-score op T1 was 6,5 ±1,2; op T2 2,4 ± 1,0 en op T3 0,9 ± 0,3. Er was een statistisch significant verschil tussen T1 en T2 ($P = 0,002$) en T1 en T3 ($P < 0,001$), maar niet tussen T2 en T3 ($P = 0,407$). De OHIP-score bij Kennedyklasse II-patiënten daalde van 4,8 ± 3,2 op T1 naar 1,5 ± 2,0 op T2 en naar 1,1 ± 1,8 op T3. De score van de Kennedyklasse III-patiënten daalde van 8,9 ± 9,6 op T1 naar 3,6 ± 8,9 bij T2 en naar 0,8 ± 2,2 op T3. De OHRQoL veranderde positief bij de patiënten in beide groepen.

Tijdens mijn postacademische training in de orale implantologie heb ik voor al mijn implantologiepatiënten de chirurgische en de prothetische behandelfase gepland. Als onderdeel van deze planning moest ik een keuze maken uit een van de implantaatsystemen die in onze kliniek voorhanden waren. Naast mijn eigen voorkeur was er geen protocol of leidraad die de keuze bepaalde. De resultaten van de bovengenoemde studies stellen ons in staat een aantal vragen te beantwoorden. Onduidelijk is of deze resultaten over tien jaar nog geldig zijn. Daarvoor moeten de patiënten over een nog langere periode gevolgd worden.

- Implantaten waarbij de implantaat-abutmentovergang (IAI) óp het crestale botniveau ligt, laten een statistisch significant verschil zien in crestaal botverlies ($P < 0,05$) vergeleken met macrogeometrisch identieke implantaten waarbij de implantaat-abutmentovergang 2,5 mm bóven het crestale botniveau ligt.

- Het in week 3 belasten van twee verblokte implantaten in de (pre)molaarstreek is een voorspelbare behandeloptie als de torquewaarden boven 10 Ncm liggen.

- Twee weken na implantaatplaatsing is er sprake van een statistisch significante daling van de ISQ-waarden van 2,2 bij de implantaten met de IAI bóven botniveau. Dit is een daling van 2,3 bij implantaten met de IAI op botniveau.

- Na osseo-integratie wordt er een statistisch significant hogere implantaatstabiliteit gezien ten opzichte van de stabiliteit onmiddellijk na plaatsing.

- Het patroon van ontwikkeling van de ISQ waarden is bij beide typen implantaten gelijk. Slechts de hoogte van de waarden is statistisch significant verschillend.

- Er is een hoge correlatie tussen de ISQ waarde van het implantaat direct na plaatsen en de hoogte van de torquewaarden van hetzelfde implantaat. Op grond van deze initiële torquewaarden werden 91% van de implantaten na een genezingsperiode van drie weken belast.

- Als de mucosadikte vóór het plaatsen van het implantaat meer dan 2 mm bedraagt, is er statistisch significant minder crestaal botverlies dan bij implantaten waarbij de mucosadikte vooraf 2 mm of minder bedraagt. Dit geldt voor implantaten met de IAI óp botniveau. Bij implantaten met de IAI 2,5 mm bóven het botniveau is dit verschil statistisch niet significant.

- Bij gedeeltelijk tandeloze patiënten verandert de mondgezondheid gerelateerde levenskwaliteit (OHRQoL) positief als ze worden behandeld met implantaten en een FDP.

- Bij Kennedyklasse II- of III-patiënten verbetert de mondgezondheid gerelateerde levenskwaliteit (OHRQoL) in gelijke mate door de implantaatbehandeling.

- Er is een verschil in OHRQoL bij patiënten met een Kennedy II- of III-klasse voor aanvang van de behandeling.

Dankwoord
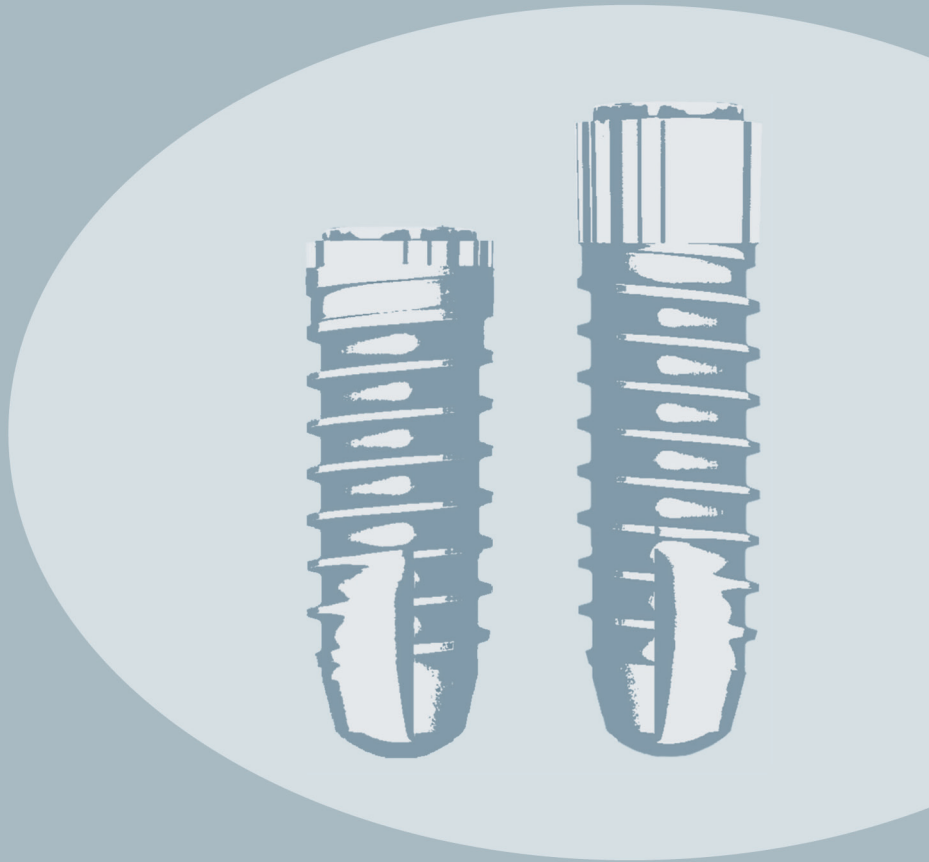
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