Implants Straumann TPS/SLA: Evaluation radiologique à 5-6 ans de résultats obtenus en pratique privée

Gheddaf Dam, Hamasat

Université de Genève

FACULTE DE MEDECINE
Section de Médecine dentaire
Division de Stomatologie, Chirurgie orale
et Radiologie dento-maxillo-faciale

Thèse préparée sous la direction du Professeur Jacky SAMSON

IMPLANTS STRAUMANN TPS/SLA : ÉVALUATION RADIOLOGIQUE À 5-6 ANS DE RÉSULTATS OBTENUS EN PRATIQUE PRIVÉE

Thèse

Présentée à la Faculté de Médecine

de l'Université de Genève

Pour obtenir le grade de Docteur en Médecine dentaire

Par

Hamasat GHEDDAF-DAM

De

Benghazi (Lybie) et Genève (GE)

Thèse n°672

Genève

2009

Table of Contents

UNIVERSITÉ
DE GENÈVE
FACULTÉ DE MÉDECINE

DOCTORAT EN MEDECINE DENTAIRE

Thèse de :

Madame Hamasat GHEDDAF-DAM
Originaire de Benghazi (Lybie) et Genève (GE)

Intitulée :

IMPLANTS STRAUMANN TPS/SLA : EVALUATION RADIOLOGIQUE A 5-6 ANS DE RESULTATS OBTENUS EN PRATIQUE PRIVEE

La Faculté de médecine, sur le préavis de Monsieur Jacky SAMSON, professeur ordinaire à la section de médecine dentaire, autorise l'impression de la présente thèse, sans prétendre par là émettre d'opinion sur les propositions qui y sont énoncées.

Genève, le 29 avril 2009

Thèse n° **672**

Jean-Louis CARPENTIER
Doyen

N.B. - La thèse doit porter la déclaration précédente et remplir les conditions énumérées dans les "Informations relatives à la présentation des thèses de doctorat à l'Université de Genève".

I want to dedicate this research and all my education for the two most important people in my life, Mama and Mama Fog. They have been a part of my education from the time I learnt how to write until now. The warmth, courage and support they offered me on a daily basis were irreproachable. I also want to thank them for keeping me in their prayers, for being pillars of strength during arduous times. I am everything I am because of you. Mama and Mama Fog,

I love you

ACKNOWLEDGEMENTS

With appreciation and gratitude I would like to thank everyone who offered guidance and support during this research project and my post-graduate education.

I would like to sincerely thank my supervisor and director of this doctoral thesis, Dr Rabah Nedir for his help and support. Dr Nedir has been an immense encouragement for me in his determination, and overwhelming power to combine clinical perfection and research aptitude. I was honored to work under his supervision and to have an instantaneous and elaborate feedback on the topic. Working with a skilled researcher and clinician like him was an enriching experience.

It is with great regard and ardent admiration that I express my gratitude to Professor Samson. His prospective and philosophy in stomatology and oral surgery were stimulating. They gave me great ambition to seek more knowledge and contribute to the field. His humanity and humor with his patients and residents left an indelible print on my mind. I had my best years, professionally and academically, at his department.

Professor Belser was and will always be a great inspiration for me. His professionalism and meticulousness makes him unique in his field. Being his student was a privilege and a great honor. I would like to thank him for his generosity with his time and vast knowledge. Being a pioneer in his field, Professor Belser urges one never to stop to seek perfection.

Many thanks to Professor Bernard for teaching me his elegant and simplified approach to implant surgery. It enhanced my clinical acumen and honed my skills. I appreciate his confidence in imparting to his residents, his outstanding clinical experience. His commitment and dedication to advancement of implantology is motivating.

I would like to thank my dear friend and colleague Dr Semaan Abi Najm for his laborious efforts in the measurements. Special thanks

to Dr Mark Bischof for his precise and helpful observations that improved the quality of the research.

I am indebted to Dr. Natalie Nurdin PhD and Dr Serge Szmukler-Moncler PhD for their tremendous help and input. I look forward to working with them in the future in further research projects.

Sincere thanks to Manuela Longo for her time and strenuous efforts in the editing and organization of the thesis. Her efficiency is astonishing. Thanks to Silvana Paruzzolo for her correspondences.

I would like to acknowledge Dr Jean-Marie Briaux, Dr Stefan Beyer, Françoise Porchet, Monica Dubath as well as all the colleagues, dental assistants, dental hygienists and secretaries in all of Ardentis dental clinics, for their tremendous help with screening patients for the study. I would not have been able to complete the work without them, and without being in such a warm, helpful environment.

Genuine thanks to my friend Dr Alexandre Dudic. His help with performing the statistical analysis was invaluable.

Special thanks are due to Damien Rufi and Dr Florian Combremont for enhancing the manuscript with their vivid and beautiful images.

I would like to sincerely thank Dr Priyank Taneja, Dr Natalie Leow, Professor Swadesh Taneja, Dr Parul Taneja for refining the manuscript.

Last but not least, I am very fortunate to have loving friends. Their support and encouragement is never ending. It had enabled me to accept and enjoy any challenges that have come my way. I feel very grateful to have you in my life Asma, Francesca, Imen, Ines, Linda, Odyssia, Stella.

Evaluation radiologique à 5-6 ans des implants Straumann® à surface TPS/SLA : résultats obtenus en pratique privée.

1. Introduction

La réhabilitation implantaire est maintenant considérée comme un excellent traitement, avec peu de complications biologiques et prothétiques. Depuis les études initiales de Bränemark et al. (1985), les implants dentaires sont devenus le traitement de choix pour réhabiliter les espaces édentés. Les études longitudinales faites par Adell et al. (1981, 1985) ont confirmé la fiabilité de cette technique de réhabilitation prothétique.

Des critères pour évaluer le taux de succès ont été progressivement adoptés afin de pouvoir comparer les résultats fournis par les différentes études. La perte osseuse autour des implants mis en charge est en moyenne inférieure à 1mm lors de la première année et à 0,2mm par an pour les années suivantes. D'autres paramètres comme le degré d'inflammation, l'absence de mobilité, le retrait gingival, la profondeur de la poche et l'absence de radio-transparence péri-implantaire représentent également des critères pour évaluer le taux de succès. Puis, la définition de ces critères a été simplifiée par Buser et al. et elle a été résumée ainsi :

1. Absence de symptomatologie persistante (douleurs dysesthésie...),
2. Absence d'infection péri-implantaire récurrente avec suppuration,
3. Absence de mobilité.

1.1. Remodelage osseux péri-implantaire

La formation d'un espace biologique péri-implantaire peut mener à la formation d'un cratère autour du col de l'implant. Les études d'Herman et al. (2000 et 2002) ont montré que ce cratère s'établit précocement et se maintient au fil des années. Deux autres phénomènes peuvent participer au remodelage osseux péri-implantaire. Le premier dépend de la localisation du micro-gap (connexion implant-moignon) dans la technique chirurgicale en 2 temps. Le second est le rôle joué par l'interface entre la surface lisse et la surface rugueuse de l'implant dans le remodelage osseux.

La perte osseuse dépend principalement de facteurs biomécaniques et la profondeur de l'implant détermine le niveau où l'os péri-implantaire se stabilise. L'os reste rarement au contact de la surface lisse de l'implant. Sur les implants Straumann®, la longueur de la surface lisse (1.8mm pour la gamme esthétique et 2.8mm pour la gamme standard) prend déjà en considération ce remodelage osseux. Dans cette étude, toute perte osseuse au-delà de la limite surface lisse/surface rugueuse, est a donc été considérée comme une perte osseuse non-physiologique, c'est-à-dire pathologique.

1.2. Evaluation radiologique

La modification radiologique du niveau osseux péri-implantaire survient principalement au cours de la première année ; la perte ultérieure est faible.
Les radiographies intra-buccales sont considérées comme le procédé de choix pour l'évaluation de la radiotransparence osseuse proximale péri-implantaire. Plusieurs études longitudinales confirment que l'évaluation radiologique du niveau osseux proximal péri-implantaire constitue une voie non-invasive relativement précise. En conclusion de ses travaux, l'Atelier européen de parodontologie (1999) a précisé qu'une perte maximale de

2mm dans l'année qui suit la mise en charge de l'implant était acceptable. Le comité scientifique a cherché à établir les paramètres qui permettraient d'identifier les implants à risque de complications ou d'échecs afin de prévoir le développement d'une péri-implantite et une perte éventuelle de l'implant.

Toute déviation de l'axe de projection peut conduire à des erreurs lors de la mesure du niveau osseux crestal. C'est pourquoi la technique de long cône qui respecte le principe du parallélisme est considérée comme la méthode de référence pour l'évaluation du niveau osseux crestal proximal. La forte inclinaison du palais dans la région maxillaire postérieure et l'élévation du niveau du plancher buccal dans la région mandibulaire antérieure ne permettent pas le positionnement correct du film ; ceci peut conduire à des erreurs dans les mesures.

1.3. Facteurs conditionnant la perte osseuse péri-implantaire et le succès implantaire

Plusieurs facteurs peuvent favoriser la perte osseuse:

- le traumatisme chirurgical lors du décollement du périoste,
- la surchauffe mécanique,
- une force excessive exercée sur l'os crestal lors de l'insertion de l'implant,
- une surcharge occlusale, une relation inter-arcade défavorable et une prothèse comportant une extension,
- la résorption crestale physiologique,
- l'inflammation chronique du tissu conjonctif péri-implantaire,
- une péri-implantite.

D'autres facteurs – développés ci-dessus – ont aussi été étudiés dans la littérature pour leurs effets sur le remodelage osseux au-delà du niveau physiologique.

Après un bref rappel de ces différents éléments, il semblait logique de prendre la limite entre la surface lisse et la surface rugueuse de l'implant comme référence pour l'évaluation radiologique. Ainsi les mesures ont pu être effectuées sans avoir à réaliser une radiographie post-opératoire. En conséquence, en direction apicale on a mesuré la perte osseuse, en direction coronaire le « gain » osseux – c'est-à-dire la distance entre l'os et la limite surface lisse - surface rugueuse – afin de ne pas l'assimiler à un gain réel.

2. But de l'étude

Le but était :

1. de déterminer les taux de succès et de survie à 5-6 ans pour un échantillon de 528 implants,
2. d'évaluer la perte osseuse proximale moyenne péri-implantaire,
3. d'établir les facteurs pouvant influencer la perte osseuse péri-implantaire.

Les facteurs qui peuvent influencer le niveau osseux ont été investigués : ce sont la localisation de l'implant, son diamètre, sa longueur, la longueur de son col, la texture de sa surface, le type de la supra-structure implantaire, la largeur de la lamelle osseuse vestibulaire lors de son insertion , la distance entre l'implant et la dent ou l'implant adjacent, le type de la dentition opposée et le statut fumeur du patient.

La valeur de l'étude se résume dans le grand nombre d'implants inclus dans cette étude et l'absence de critères d'exclusion. De plus, l'absence d'un suivi strict pour l'hygiène bucco-dentaire comme cela est fait dans les institutions académiques, rendent les résultats plus réalistes : ils correspondent à la pratique de tous les jours.

3. Matériels et méthodes

L'échantillon étudié comprend 528 implants ITI (Straumann® AG, Waldenburg, Suisse) posés chez 236 patients entre 1995 et 2000 ; 50% de ces implants avaient une surface TPS et 50% une surface SLA.
Tous les patients ont été traités en pratique privée (Ardentis, Clinique Dentaire SA, Vevey, Suisse). Tous les implants ont été placés en respectant les conditions d'hygiène conseillées pour la chirurgie buccale en cabinet dentaire, c'est-à-dire de façon non stérile comme l'ont préconisé Scharf & Tarnow (1993).

Pour cette étude, tous les patients qui avaient des implants posés depuis plus de 5 ans (moyenne 5-6 ans) ont été convoqués pour réaliser une radiographie apicale avec la technique parallèle. Quelques radiographies de type bitewings ont été également utilisées pour les mesures.

Toutes les radiographies ont été ensuite introduites dans un système d'analyse d'images (Digora®, Soredex, Helsinki, Finlande) pour être calibrées et effectuer les mesures. Deux observateurs ont réalisé les mesures pour chaque cas. Après identification de la limite surface lisse-surface rugueuse de l'implant, on a calculé la moyenne des deux valeurs obtenues ; les niveaux osseux mésial et distal par rapport à cette limite ont été mesurés. Tous les implants qui présentaient un niveau osseux supérieur à cette limite en direction coronaire ont été identifiés.

Pour être sélectionnées pour l'étude, les radiographies devaient avoir les caractéristiques suivantes :

1. une distance uniforme (1,25mm pour les implants Straumann®) entre chaque spire de l'implant,
2. le même diamètre entre deux points pris au hasard sur l'implant et correspondant à celui donné par le fabriquant,
3. la limite entre surface lisse-surface rugueuse devait être au même point si on la calculait depuis le col de l'implant (1.8mm et 2.8mm respectivement pour l'implant Esthétique Plus® ou l'implant Standard®), ou si on le calculait depuis l'apex de l'implant, ce qui correspondrait à la longueur de l'implant, donné par le fabriquant.

3.1. Evaluation du taux de succès et du taux de survie

La survie des implants est basée sur le fait que l'implant est en place et en fonction ; l'évaluation du succès sur les critères de succès présentés précédemment.

3.2. Analyse statistique

Le coefficient de fiabilité, le Student t-test, l'analyse de régression ANOVA ainsi que le Pearson Chi-Square test ont été utilisés pour l'analyse des résultats.

Résultats et conclusions

L'échantillon final soumis à l'analyse radiologique comportait 411 implants (77,8% de la population initiale) ; 117 implants ont du être exclus pour des raisons liés aux patients (décès, perdu de vue du patient, arrêt de traitement pour des raisons financières ou refus d'une irradiation supplémentaire pour certains patients) ou du fait que les radiographies présentaient une déformation ne permettant pas d'effectuer correctement les mesures.

Certaines conclusions de cette étude étaient déjà connues, d'autres ont pu être mieux précisées, en particulier certaines associations à risque ont été mises en évidence :

- Le taux de survie sur une période de 5-6 ans est de 99,2% et le taux de succès de 93%. Le pourcentage de complications – ce qui correspond à la population à haut risque – s'élève à 7%.
- La valeur moyenne de la perte osseuse (moyenne entre les pertes mésiale et distale) est de 1.16mm (écart 0-5.41, DS ± 1.03mm). La différence entre les valeurs obtenues par les deux observateurs était non significative, comme cela avait déjà été noté dans des études précédentes. Ceci confirme la fiabilité de la méthode d'évaluation radiographique utilisée dans cette étude.
- Une différence significative de la perte osseuse moyenne a été constatée dans les cas suivants :
  - implants ayant une surface TPS,
  - implants ayant une localisation antérieure dans l'arcade dentaire,
  - chez les patients fumeurs,
  - une corticale vestibulaire inférieure à 1mm.

  De plus, l'association entre ces différents facteurs conduit à une perte osseuse plus grande, statistiquement significative.

Au terme de cette étude, on constate que :

- Les implants ayant un « os dépassant la limite surface lisse-surface rugueuse » (7.8%), les implants ayant une surface SLA, une localisation postérieure sur l'arcade dentaire, une corticale vestibulaire supérieure à 1mm, et les sujets non-fumeurs, constituent un groupe d'implants à « bas risque ». Ils présentaient une perte osseuse assez faible et les résultats étaient également statistiquement significatifs.
- Les implants placés dans la mandibule, les implants en rapport avec une denture antagoniste fixe ou mixte, ou une supra-structure amovible avaient une perte osseuse plus élevée que la moyenne mais les résultats ne sont pas statistiquement significatifs.
- Les implants courts ne présentaient pas une perte osseuse plus grande que les implants longs. Cette observation a des conséquences importantes car elle permet d'envisager une diminution substantielle du coût du traitement, du délai pour l'implantation et la mise en charge, et d'éliminer le recours à des procédures supplémentaires préalables à

la mise en place des implants (greffes, comblement de sinus...) comme greffes ou autres.

- Une réévaluation clinique et radiologique, ainsi que des contrôles réguliers et l'application rigoureuse de mesures d'hygiène bucco-dentaire sont conseillées d'une manière systématique chez tous les patients ayant des implants dentaires ; toutes ces mesures devraient être envisagées d'une manière plus rapprochée pour les sujets appartenant aux groupes à risque.

1. Introduction

Implant therapy has long been proven to be a safe and reliable mode of treatment with a limited number of biological and prosthetic postoperative complications [1]. Since the early studies of Brånemark et al.[2], osseointegrated implants have become the therapy of choice to rehabilitate edentulous ridges. Success rates are very high, as proven by the longitudinal studies of Adell et al.[3, 4]

Concise success criteria were established in earlier studies. They stated that the vertical bone loss at the implant crestal sites should, on average, be less than 1.0 mm following the first year of implants in function, and should not exceed 0.2 mm in subsequent years [5, 6]. Other parameters such as the absence of continuous radiolucency around the implants, lack of mobility, assessment of the degree of inflammation, gingival recession and pocket probing depths were also included in the classification of success criteria [5]. Later on, the definition of success was simplified by Buser et al. (1990) [7] as the following:

1. Absence of persistent subjective complaints, such as pain, foreign body sensation and/or dysthesia,
2. Absence of recurrent peri-implant infection with suppuration,
3. Absence of mobility.

These criteria were used in the present study for the determination of success and survival rates for a population of 528 Straumann® implants, over a period of 5-6 years. A radiological bone level evaluation was also performed at the end of the study period, and was included in the determination of the success criteria. The following sections explain and justify the methods and principles of this evaluation. The introduction concludes with an overview of the external factors that might influence the peri-implant bone level, which was considered in the current study.

1.1. Crestal bone remodeling

Comprehension of the physiological principles governing crestal bone remodeling around implants facilitates the distinction between an expected physiologic crestal bone remodeling, and a pathologic condition resulting in bone loss [8]. Hermann et al. 2001[9,10] suggested that this bone remodeling was a consequence of biologic width formation around implants, which was physiologically determined, stable and dimensionally similar to that around teeth.

The formation of a biologic width can lead to a circumferential crater around the implant shoulder [4, 8, 9]. In areas of thin bone, the development of a crater may result in the loss of crestal bone height and gingival recession. This physiologic dimension, that was established early and maintained over time, appears to exist between the bone and the implant-crown interface around one-piece implants. It is consistent with the formation of a biologic width similar to that found around the natural dentition [10, 11] (Fig. 1). However, this biologic width is vulnerable to change. Bone loss may be observed in order to maintain the biologic width, particularly, as a response to various external factors.

Two other phenomena may participate in expected bone remodeling [11]. The first phenomenon determining bone loss is the location of the microgap (implant-abutment

connection), in 2-stage implant surgeries. This also explains the 1.5 mm bone loss observed around submerged implants (when a microgap is created after abutment connection at the second-stage surgery) in the first year of function.

Secondly, the interface between the smooth and rough surface on an implant, is thought to play a major role. Bone loss is an adaptation to biomechanical influences, and implant placement depth determines the level at which it stabilizes [8, 10, 11]. Bone loss occurs up to that interface, and bone rarely stays on the machined surface. Thus, height of the smooth collar (e.g. 1.8 mm on Straumann® Esthetic implants) takes into consideration the notion of the biological width, in one-staged implant procedures. Having that in mind, any bone loss occurring further than that height (which happens to correspond to the smooth collar), could be considered as non-physiological bone loss. Based on these observations, this initial bone loss was considered as physiological remodeling; bone loss occurring beyond that point was hence regarded as pathological bone loss [8, 11].

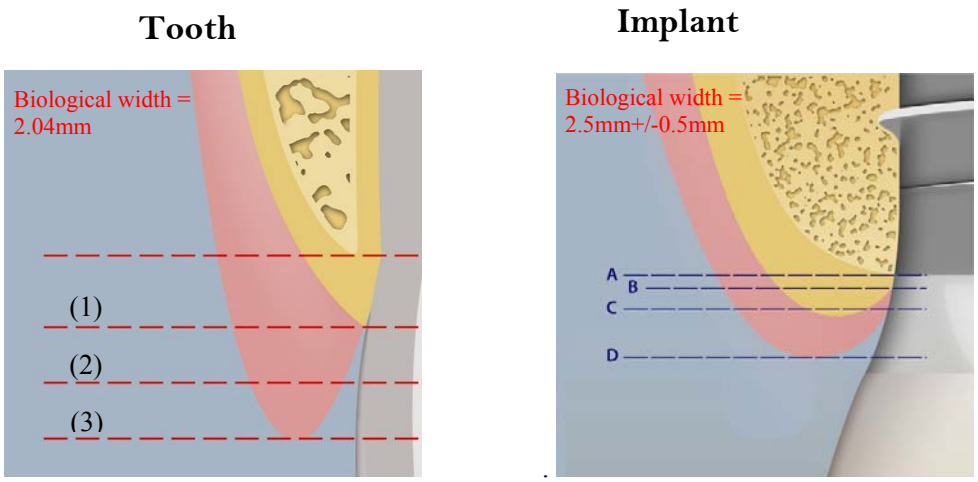


Fig 1. The biological width of a tooth compared to that of an implant.

(1) Connective tissue attachment: 1.07 mm
(2) Junctional epithelium: 0.97 mm
(3) Sulcus: 0.69 mm

A-B: Connective tissue attachment: 1.5+/- 0.5 mm
B-C: Junctional epithelium: 1.5+/-0.5 mm
C-D: Sulcus: 0.5-1 mm

This finding has been incorporated in the current study in an original way that enabled the investigators to consider the smooth-rough interface as the baseline bone level, up to which bone loss was considered as physiological.
In addition, external factors may participate in further bone remodeling, and hence bone loss. These will be detailed later.

1.2. Radiographic methodology

According to the literature, the majority of the radiographically measured bone loss occurred during the healing and remodeling periods, or within the first year of loading; very little bone loss occurred thereafter [3, 4, 6, 12]. Radiographs are currently considered the gold standard in measuring bone level changes at interproximal implant sites (Fig. 2) and in evaluating the presence or absence of peri-implant radiolucencies[13-17].

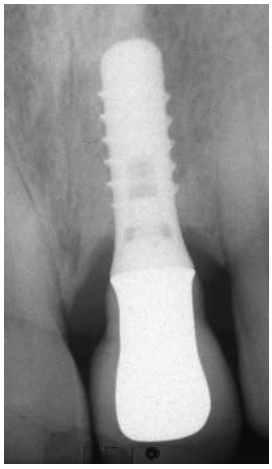


Fig 2. Interproximal estimation of the bone levels on a peri-apical radiograph.

Intra-oral radiography using the paralleling technique was recommended to evaluate minute bone changes [6]. The effects of the projection and the beam angle on the interpretation of non standardized films were reported by many authors [13-15].

1.3. Annual peri-implant bone loss

Several longitudinal studies consider that radiographic monitoring of bone level changes provides valuable insight into the longevity of oral implants [13-17] (Fig. 3). This indirect assessment is less invasive than the direct visualization of the inter-proximal bone through surgical access [15].

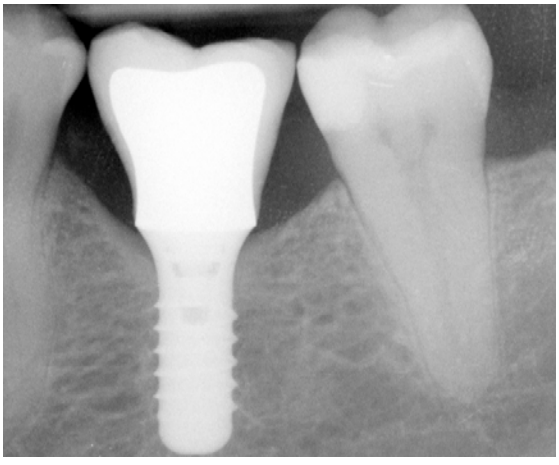


Fig 3. A radiographic image ensures the visualization of the interproximal bone level.

Numerous long-term dental implant studies have utilized intraoral radiographs to assess marginal bone loss over time as a critical examination variable [15, 17, 18]. The consensus report of the 3rd European Workshop on Periodontolgy [19] assessed that a maximal bone loss of 2 mm between baseline (prosthesis in place) and the 5-year examination is acceptable. The risk of developing peri-implantitis and eventual implant loss has led the scientific community to search for accurate and reliable prognostic parameters.

The early longitudinal studies of Adell et al. in the 1980s [3, 4] established that the majority of bone loss occurred during the healing and remodeling periods or within the first year of loading; very little bone loss occurs thereafter. Published data described a mean marginal bone loss of 0.4-0.5 mm during the first year post-implantation and 0.05-0.1mm annually thereafter [7, 14]. Similar observations were noted later by other research groups [16, 21, 22], who defined the following measurements for the one stage ITI implants: 0.75 mm after the first year and less than 0.1 mm the following years. Another study determined that a mean crestal bone loss ranging from 0.9-1.6 mm in the first year after functional loading was acceptable [17]. A mean annual loss of 0.05-0.13 mm was reported in various studies with screw-type titanium implants [11, 14, 21].

In their 5-year prospective study using standardized radiographs, Weber et al. [16] showed that the mean crestal bone loss for Straumann implants during the first year was approximately 0.6 mm, followed by a yearly loss of 0.05 mm. This study considered bone levels on the day of surgery as the baseline, which is uncommon in the dental implant literature to date. Most of the previous studies on machined surfaces measured bone loss in considering the point at which abutment connection was made as baseline (in the 2-stage technique). Hence they did not take into account bone remodeling that might have occurred previously. In contrast to the two- stage procedure implant system where osseointegration and marginal soft tissue adaptation occurs separately, theses healing events occur concomitantly usually within the first 3-4 months in 1-stage procedures, thus establishing a stabilized situation [11].

Certain studies suggest that implants with bone loss higher than 4 mm often showed a progressive loss of osseointegration, and possible implant loss in the subsequent years [18, 22]. Probing depths of 5 mm are usually associated to a chronic inflammatory state. Thus, one major objective has been to develop therapies that aim to improve these critical peri-implant situations, to eliminate soft tissue pockets, and /or to regenerate bone [23].

Different values presented in the different studies were related to the variability in analysis methods and data selection. For instance, the Brånemark group excluded bone loss occurring during the first year; their results were expressed as mean values, and concerned a population with large inter-individual deviation [24]. For Adell and coworkers, the reported bone loss was 0.1 mm with high standard deviations [4]. Measurement errors were reported to be responsible for incorrect judgment of peri-implant bone level [6, 15, 25]. The level at which implants were placed, implant surface textures (machined, different rough surfaces), implant design, and one versus 2-step surgical techniques were other factors that may explain the varying degrees of bone loss measured in the different studies [26-29]. Further studies should focus on the questions: does marginal bone height really decrease at a constant rate? What factors may affect such a decrease?

1.4. Limitations of the radiological method

Based on previously mentioned reports, radiographs with intraoral rectangular films were considered to ensure unbiased and reproducible results. The paralleling technique allows an optimum and reproducible quality of periapical radiographs [30-33]. However, any deviation from the correct vertical angle leads to errors in the assessments of the marginal bone height. According to the longitudinal study of Sewerin [34] on peri-implant bone loss, the distance between a reference point and the marginal bone level around implants could be assessed with a great accuracy by means of the long-cone paralleling technique, conventional or digitalised. The author measured, by evaluating bone height around both threaded and cylindrical implants on intra-oral radiographs, a mean inter-examiner difference of 0.09 ± 0.16 mm. Digital radiographs led to the same mean absolute difference (0.18 mm) as conventional intra-oral radiographic films [6, 35].

Differences in measurements may also be caused by the difficulty of placing the film intraorally. This occurs most often in the posterior maxilla because of the steep inclination of the palate, and in the anterior mandibular region. In the anterior mandible (especially in edentulous patients), many authors mentioned that the atrophy related elevation of the floor of the mouth, the pain and discomfort to the patient, all yield to difficulties in establishing good radiographs. Superimposition of the calcified structures of the jaw itself may also interfere with the measurement of the crestal bone level [34-36].

Spiekermann et al. [37] pointed out that with long observation periods; data taken from radiographs could be liable to a wide range of measurement errors that might hide the true bone level heights and resulting pocket depths.

The evaluation of periodontal or peri-implant marginal bone loss on dental radiographs implies the obvious disadvantage that only the mesial and distal bone levels could be distinguished [38-40]. However, this should not be of importance in crater-shaped peri-implant bone loss. The accurate value of bone loss tended to be underestimated on radiographs [39]. Moreover, variations in implant angulations in relation to the film plan as well as the direction of the radiographic beam influenced the image on the film. Small deviations from strict parallelism between implant and film plane were also able to significantly change bone height measurements [38, 41].

1.5. Reliability of the radiological method

As previously mentioned, a paralleling technique should be applied to minimize measurement errors. By using this technique, the film has to be positioned parallel to the axis of the implants and the film holder connected to the tube of a dental radiograph (Fig. 4). Correct vertical angle of projection is achieved when the threads on both sides are clearly identified [30].

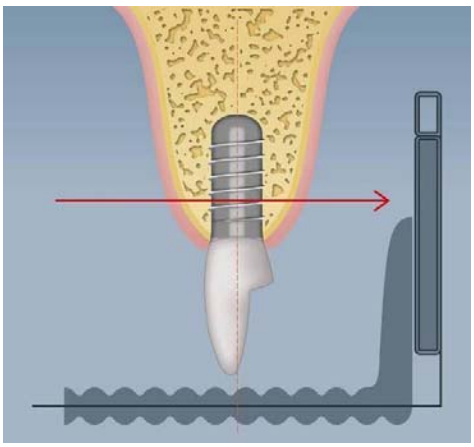


Fig 4. The radiographic paralleling technique ensures correct estimation of the peri-implant bone level.

Few studies dealt with accurate clinical and radiographic methods for detecting changes in the bone level. Radiographic assessment was compared to the histological method by Isidor [39]. In this study, clinical probing as well as radiographical and histological bone levels were assessed on machined surface implants placed in monkeys according to a 2-stage procedure. The author recommended the use of known hallmarks on the implant (smooth surface and threads) and showed a high correlation between the radiographic measurements and the histological evaluation.

The relationship between probing level and radiographic bone level for screw-type implants was also assessed by Papelessi and Diamanti-Kipioti [30]. Furthermore, correlations between clinical probing and histological levels were also evaluated by an experimental study in the dog [40]. Hence, both radiographic interpretations of changes over time and measurements of attachment level changes are reliable in assessing the treatment outcome of inter-proximal intra-bony defects [24].

The evaluation of bone level changes over time requires high precision methods. This means that the obtained results should be similar when repeated by the same or different observers [25]. Variations within observers can be substantial when alveolar bone loss around teeth is assessed. However, when determining bone loss over time, several observers making several and independent readings are more precise than several readings by the same observer [25]. This principle was followed in the present study.

1.6. Comparison of panoramic and periapical radiographs

Panoramic radiography has been proposed to be an alternative method to measure bone loss [41]. Because of its standardized projection in the vertical plane, it suits well for vertical bone measurement. In addition, panoramic radiographs might be more appropriate in some cases than periapical radiographs because they offer an image of both jaws. They could also be used in patients with limited mouth opening [41]. Panoramic radiographs proved to be comparable to regular intraoral radiographs in detection of bone loss around implants in the anterior mandible, where periapical films were difficult to place [34].

However, the bidimensional view obtained with panoramic radiographs is blurred by the superimposition of the cervical column on the anterior region; therefore, the images seem

magnified and distorted [33]. Some authors complained about its limited benefit owing to inferior image resolution and the inability to modify the radiographical beam angle. It was reported that the imaging accuracy of intraoral periapical radiography was 10 line pairs/mm (resolution 0.1 mm), versus 5 line pairs/mm (resolution 0.2 mm) for panoramic radiographs [41]. Accordingly, an error of approximately 0.2 mm with a limited interobserver variation was reported for both intraoral periapical radiography and scanographic X-ray using the film technique, for in vitro peri-implant bone level evaluation [6, 42].

Nevertheless, the use of periapical radiographs to measure peri-implant bone levels has been well established. Peri-apical radiographs demonstrated to be an accurate method for crestal bone level evaluation around implants (within 0.2 mm) [30, 32].

In conclusion, periapical radiography was reported to be more successful than the panoramic one in the detection of small osseous destruction (4.7 x) [30]. Panoramic radiography underestimated the osseous destruction, whereas periapical radiography was relatively accurate for this assessment [33]. This was the case regardless of the location of the dental surfaces (jaw, tooth group, mesial or distal) and of the degree of osseous destruction. The two radiographic methods were more concordant in the assessment of osseous destruction in advanced periodontitis than in initial periodontitis [32].

Bone loss is thought to be underestimated in the range of 13 to 32% in orthopantomograms, 11-23% in bitewings, and 9-20% in periapical radiographs [33]. Taking into account such observations, patients with only panoramic follow-up radiographs for bone level analysis in the present study were not enrolled.

Digital radiographic images proved to offer higher image quality [35]. In specific cases, even panoramic digital images might therefore offer some specific potential for bone level evaluation. As digital intra-oral images showed the smallest absolute differences in intra- and inter-observer reproducibility, and since image resolution was somewhat higher when compared to conventional intra-oral radiography, they may be recommended for marginal bone level assessment around oral endosseous implants [42].

1.7. Other predictors of bone loss and implant success

Long cone periapical radiographs are used in most longitudinal studies to evaluate peri-implant radiolucencies [6, 7, 13, 15, 16, 17, 18, 31, 44-51].

Several clinical studies indicated a maximum probe penetration of 3 mm for successful implants [15, 46, 48, 51]. The two year longitudinal study of Brägger et al. [13] confirmed that the measurements of probing attachment level (PAT) along with radiographic parameters were good predictors of peri-implant bone level. The use of modified periodontal indices was suggested later [23, 32]. The modified plaque and bleeding indices suggested by Mombelli and Lang [23] allowed a good evaluation of the state of the mucosa and oral hygiene. Additionally, several attempts to evaluate bone quality and density were investigated. For example, a radiographic index was created to measure bone apposition around implants after loading [6]. Dual photo absorptiometry was also used to quantify bone changes around implants [52]. Brägger et al. [53] established a sensitive method for periodontal and peri-implant bone assessment, using digital subtraction radiography and computer associated densitometric analysis. Low degrees of implant mobility could also be assessed using an

electronic device (Periotest, Siemens, Bensheim, Germany). Mobility tests were not considered a valuable predictive method [54,55]. None of these methods were investigated in the current study.

1.8. Factors influencing bone loss and implant failure

Bone loss and biological failures were extensively studied on machined surface implants placed according to a 1-stage and 2-stage procedures [1, 3-5, 54, 55]. Bone loss could be caused by any of the following reasons:

1. Surgical trauma due to elevation of the periosteum,
2. Mechanical overheating,
3. Excessive force exerted on the crestal bone at implant insertion,
4. Overloading due to traumatic occlusion, unfavorable jaw relationship and cantilever extensions,
5. Physiological residual ridge resorption,
6. Chronic connective tissue inflammation,
7. Peri-implantitis.

Bone loss within the first year of loading was also attributed to the biologic width formation [54], a process previously described. Implant failure was studied on machined implants as early as 1989 [55]. Two biological concepts have been proposed to explain pathological bone loss. The first is that peri-implant bone loss, peri-implant radiolucency, mobility and eventually infection might be due to the loss of biomechanical equilibrium by excessive load. The authors hypothesized that a fibrous capsule, unable to contribute to functional loading of the bone-implant interface, replaces the highly specialized bone. The second is related to infection, it implies bacterial colonization and inflammation-related crestal bone resorption, and represents the most important etiological factor of pathological bone loss [23,56].

1.9. External factors that may further affect crestal bone level

A literature search of possible parameters leading to crestal bone loss (CBL) showed that this may be affected by the following parameters: implant location, height of the smooth collar, implant diameter and length, implant surface texture, opposing occlusion, crown-to-implant ratio, type of suprastructure, as well as patient related factors such as periodontal disease, smoking, bruxism, and hygiene control [1,18 19, ,22, 55-65].

1.10. Aim of the study

The aim of this study was three fold:

1. To determine the five to six years success and survival rates of a population of 528 implants,
2. To evaluate radiographic bone changes around the implants,
3. To establish which factors may influence the degree of peri-implant bone change.

Unlike life-table analysis studies, all implants were evaluated at a minimum period of five years. All patients were treated and controlled in a private practice.

An original method was used to assess the pathological crestal bone loss (CBL) occurring during this period: the baseline bone level was considered to be located at the smooth-rough implant interface, thus avoiding the need of reference radiographs. Bone loss was evaluated by only analyzing the radiographs taken at the 5- to 6-years control.

Different statistical tests were used to investigate the influence of various clinical parameters on CBL. Analyzed parameters were the following: implant location, implant diameter, implant length, implant collar height, implant surface texture type, implant prosthetic suprastructure type, implant vestibular bone lamella width (VBL) at surgery, implant distance to adjacent tooth/implant, opposing dentition type, patient smoking status.

The relevance of this study lies in the large number of implants and in the wide range of inclusive criteria for the patient selection. Furthermore, the absence of strict routine hygiene recalls as carried on in academic institutions can lead to realistic results that would apply in an every day dental practice

2. Material and methods

2.1. Surgical and prosthetic procedures

Between January 1995 and December 2000, 528 ITI dental implants (Straumann AG, Waldenburg, Switzerland) were inserted in 236 consecutive patients. These patients were treated in a private practice environment (Ardentis Clinique Dentaire SA, Vevey, Switzerland). They belonged to the same pool of patients investigated in previous studies [64, 66]. Implants were placed by two surgeons (RN, MB) under clean but not sterile conditions as defined by Scharf & Tarnow [67]. The patient population consisted of 145 females (61.4%) and 91 males (38.6%). Age at implant placement ranged from 18 to 89 years old; patients younger than 50 years old received 176 (33.3%) implants, patients aged between 50 and 70 years received 278 (52.6%) implants, while 74 (14.0%) implants were placed in the elder patients. Before June 1999, 264 (50%) titanium plasma sprayed (TPS) implants were inserted. After this date, 264 (50.0%) sandblasted and acid-etched (SLA) implants were placed.

In the mandible, implant length was assessed considering a 2-mm security margin above the mandibular canal; therefore, standard insertion was performed when 10 mm of bone was available. In the maxilla, sinus perforation was not avoided; implant penetration in the sinus of 1 to 2 mm was tolerated. Standard insertion was performed when 5 mm of bone height was available. Esthetic Plus® implants (providing one additional millimetre for bone anchorage) were used when the esthetic situation required a deeper placement of the implant–crown junction in the sulcus [68] but not an enhanced anchoring length. Implant tilting to place a longer implant was not considered; 6 mm long implants were used only in conjunction with longer implants. Implant length (8, 10 or 12 mm) was not taken into consideration to determine the number of implants, the type of prosthetic rehabilitation or its dimensions. Surgeons paid attention to place all rough-smooth junctions at the level of

the mesial and distal crestal bone level or deeper. No implant was placed with the rough-machined limit above the crest at any proximal site.

The mean healing time for the TPS implants was 3.9 months in the mandible and 4.5 months in the maxilla. For the SLA implants, it was respectively 2.3 and 2.5 months. Prior to implantation, general health evaluation was performed and local clinical examinations were performed. No complementary biologic tests were requested. When required, implant treatment was decided after a benefit/risk analysis with the patient. A specific oral hygiene protocol was not followed, but the patients were given instructions about the importance of oral hygiene and the reduction/cessation of smoking habit, which was reinforced at every visit. A specific time period between tooth extraction and implant placement was not introduced: very few (2.3%) implants were placed consecutively to tooth extraction, 34.9% after 3–6 months, 15.9% after 6–12 months and 47.0% after 1 year.

The patients' pool included bruxing patients (21.3%), smokers (26.3%) and medically compromised patients (20.1 %) like HIV+, controlled diabetes, malignant pathology other than in the cervico-facial area, heart disease or coagulation deficiency. Light or heavy smokers were included without distinction; smoking cessation was not requested either before or after surgery. Bruxers received one implant per rehabilitated unit; in case of multiple implant rehabilitation, these patients were encouraged to wear night-guards to avoid prosthetic complications. All surgical procedures were performed under antibiotic prophylaxis (Amoxi-basan®, Schönenberger Pharma, Schönenwerd, Switzerland, 750 mg, 3x/d during 6 days or Dalacin C ®, Pfizer, Zürich, Switzerland, 300 mg, 3x/d during 5 days, in case of penicillin allergy) – The difference in the duration of the antibiotic treatment is related to the packaging system, in order to avoid for the patients to buy an extra pack in the case of Dalacin C®.

Treatment plans systematically included periodontal and carious status evaluations and, when necessary, disease management and maintenance prior to implant placement. All patients were instructed to attend at least a yearly routine hygienist session [69]. However, patients were not enrolled in this maintenance program.

No exclusion criteria were applied in selecting this patient pool and hence all available patients were re-called for a five to six year postoperative x-ray of their implants.

2.2. Patients enrolment

All patients were contacted by phone or mail, in order to achieve the five-six year control including a periapical radiograph with the long cone paralleling technique. Those which had recent bitewing radiographs of the included implants already present in their charts were not required for further periapical ones.

2.3. Data collection

Of all examined intraoral radiographs, 65% were conventional (non-digital) images. After November 2005, a digital system was installed in the clinic, and 35% were digital images using the DBSWIN system® (Dürr Dental, Baden-Württemberg, Germany). The phosphorus plates this system has to offer allow it to be comparable to the conventional

radiographic system (with silver halide grains) used earlier in the study. The DBSWIN system comprises an intraoral X-ray sensor VistaRay and the image plate systems VistaScan. It is a logistic system with extensive image processing and measurement tools.
Both methods used the paralleling long cone technique for the periapical radiographs. Conventional (non digital) films were then scanned in a digital format by a flatbed scanner (Epson Expression 1680 Pro, Wadenswil, Switzerland) with at least 600-1200 dpi resolution. All radiographs were then analyzed using image analysis software (Digora, Soredex, Helsinki, Finland), allowing a measurement precision of 0.01 mm. To determine the magnification factor, an internal calibration was performed for each radiograph (Fig. 5). In order to improve the image analysis, image enhancement operations including sharpness, brightness, contrast and gamma adjustments were done when necessary.

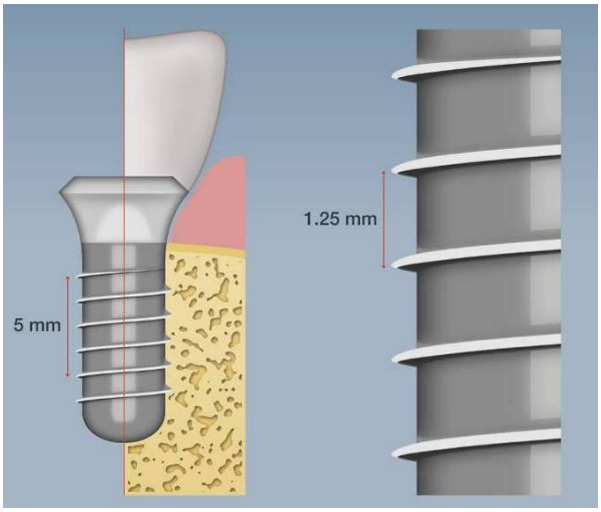


Fig 5. Calibration was done knowing that the inter-thread distance is 1.25 mm. The maximum number of threads visible on the X-ray (5 in this example) was measured.

2.4. Measurement method

Radiographic studies usually compare the bone loss reading between a reference radiograph taken after surgery or at prosthesis installation and at a given milestone [44-49]. In this study, the initial bone level was set according to histological studies carried out by Hermann et al. [8,-10]. The authors implied that a physiologic bone loss occurs up to the level of the rough-smooth boundary of the implant. Having identified rough-smooth interface of the implant on the post-operative 5-years radiographs, the need for a baseline radiograph was discarded.

When the bone level was found apical to that line, it was considered as a pathological bone loss. Bone appearing coronal to that line was considered as "supra-boundary bone" (for the definition see page 14). This does not necessarily mean new bone formation but simply identifies bone existing above the interface. The likely reason of the possible presence of bone above the interface is discussed later. Different factors were investigated for their effects on such bone changes.

It was therefore decided that the reference line R corresponding to the smooth-rough implant interface, is level with this physiological remodeling. This was dependent on smooth collar implant height (standard or esthetic implant) (Fig. 6).

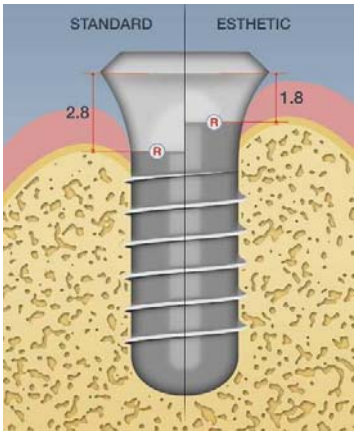


Fig 6. Standard and esthetic implant collars; note the differences in the location of the R line.

Two different observers (HG and SA) were then subsequently asked to measure the distance parallel to the long implant axis between the L line on the implant and the most apical part of the proximal marginal bone level. This measurement was carried out on both mesial and distal implant sides [15-17], on the 5-year postoperative radiographs. When unclear, the most apical bone-to-implant contact, corresponding to the worst case scenario was taken into account.

The R line was determined by two different methods, depending on whether the apical part of the implant was visible (periapical radiographs) - method A, or missing (bitewing radiographs) - method B:

1. Method A- Measures the implant length (given by the manufacturer) starting from the implant apex on the calibrated radiographic image taken with periapical radiographs (Fig. 7).

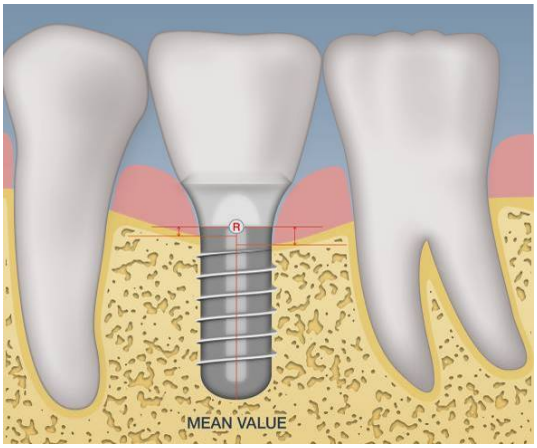


Fig 7. Measurement method A.

2. Method B- Measures the distance apical of the smooth implant collar, being 2.8 mm (standard implants) or 1.8 mm (for esthetic implants) as identified on the calibrated bitewing radiographs (Fig. 8).

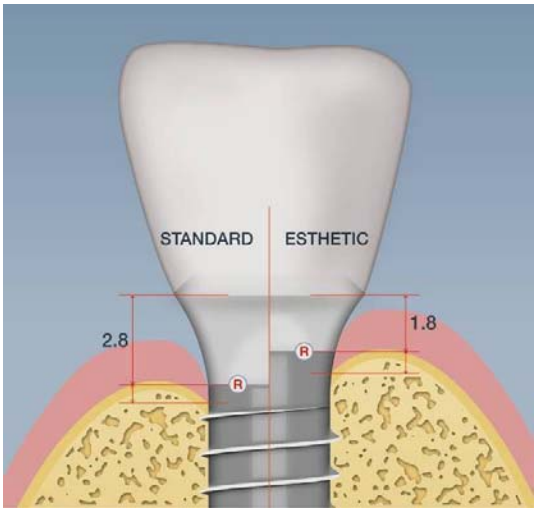


Fig 8. Measurement method B.

Bone level was calculated for mesial and distal sites, and the mean was calculated. Sometimes, when only the mesial or distal side could be measured, the obtained value was considered combined. Crestal bone loss was abbreviated CBL.

Patients with only panoramic postoperative radiographs and who could not be contacted for intraoral periapical radiographs were not included in the radiographic analysis. Panoramic radiographs showed limited resolution, enlargement and distortion [33]. Radiographs were selected according to criteria established by both examiners (the two observers). This selection included unbent films, in addition to with a non distorted image, as well as films with correct orientation, contrast and brightness permitting mesial and/or distal identification of the most apical bone-to-implant contact

2.5. "Supra-boundary bone"

Unchanged bone level and bone above the smooth-rough interface on the radiographs was named "Supra-boundary bone" in the present study, this was considered as a "non bone loss" situation. Just because bone appears on the smooth surface radiographically, it is not an indication of actual bone formation, since it would primarily depend on the depth at which the implant was placed; in other words if bone had been on that surface at baseline.

"Supra-boundary bone" was observed in some studies at approximately 30% of the Brånemark fixture surfaces between 1 and 3 years of follow-up [4, 29]. This was interpreted as a physiological remodeling process in response to functional loading and adaptation, as well as a lack of standardization of the measurement technique.

2.6. Investigated parameters

The investigated parameters were selected due to their potential clinical influence on peri-implant bone remodeling. They are as follows:

1. Implant jaw location (maxilla/mandible),

2. Height of the implant smooth collar (standard/esthetic),
3. Implant surface topography (TPS/SLA),
4. Opposing dentition,
5. Smoking status,
6. Location of implant (anterior/posterior),
7. Implant length,
8. Implant diameter,
9. Implant prosthetic suprastructure,
10. Implant vestibular bone lamella width (VBL) at surgery: VBL < 1 mm or VBL ≥ 1 mm,
11. Implant distance to adjacent tooth/implant. This was measured by drawing a straight line from the ® line to the adjacent tooth or implant (Fig. 9).

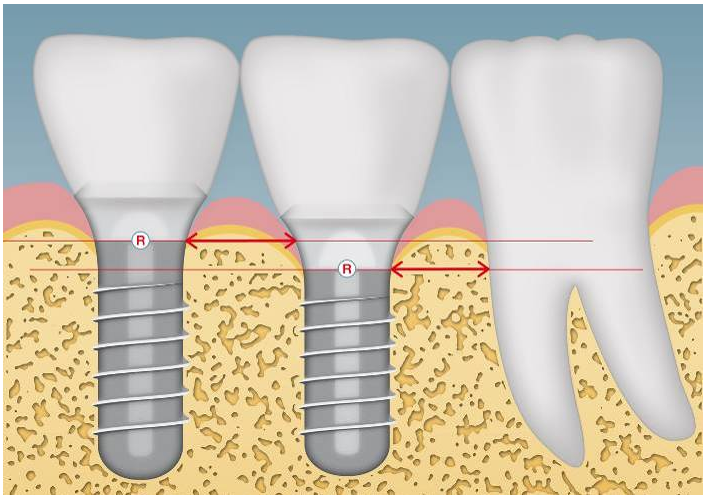


Fig 9. Implant-tooth and implant-implant distance measurement.

2.7. Criteria for determining interpretable radiographs

Strict inclusion criteria were used to determine the bone level changes for the obtained radiographs. All bent and unclear radiographs were excluded from the analysis; however, they were included for success and survival rate evaluations. Radiographs had to fulfill the following criteria to be considered -after calibration- for peri-implant bone level measurements:

1. An equal distance (1.25 mm) between all the threads of the implant along the entire implant surface,
2. An equal distance of the diameter of the implant (thread to thread) at two different random spots along the implant body,
3. The diameter of the collar and the implant length corresponded to the values given by the manufacturer; i.e. the R line had to present the same location when determined from the collar (at a distance of 2.8 or 1.8mm) or from the tip of the implant (corresponding to the value of the implant length).

If the second trial of X-ray capture didn't also yield the required quality, the radiographs were eliminated from the study. When an observer could not confidently identify the

implant collar and the most apical bone-to-implant contact, radiographic measurements were not included. Bitewing radiographs were also considered for bone level evaluation, since bone level changes in the follow-up period always began around the neck of the implant [34].

2.8. Survival and success rates' evaluation

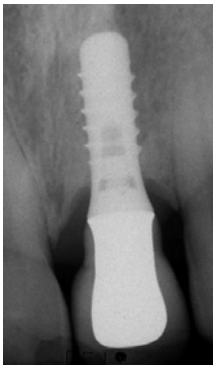
Survival rate was defined as the proportion of implants in place and in function [3, 7, 13, 18, 65, 70] at the 5-6 years re-evaluation. Success rate was considered as the proportion of implants showing no mobility, no peri-implant radiolucency, no active or recurrent peri-implantitis [5, 55, 65] and no radiological CBL > 3 mm.

2.9. Statistical analysis

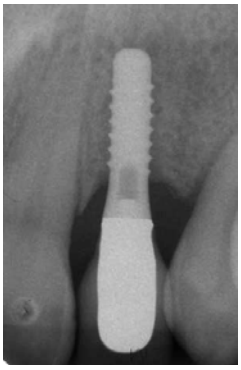
The coefficient of reliability was calculated in order to determine the accuracy of measurements between the two observers. Descriptive tables were used to calculate the mean CBL according to the different parameters. The difference between two similar variables i.e. TPS versus SLA or smokers versus non-smokers was evaluated using the Student T-Test ($p<0.001$).

ANOVA regression analysis was used to analyze the influence of the variables on CBL or "supra-boundary bone". These variables were classified in groups depending on values of CBL and presence of "supra-boundary bone" 1) CBL > 3 mm, 2) 2mm < CBL ≤ 3mm, 3) 1mm < CBL ≤ 2mm, 4) CBL ≤ 1 mm, 5) "supra-boundary bone" ($p < 0.05$) (Fig.10).

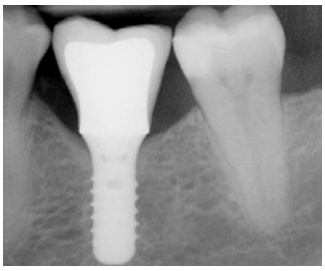
Fig. 10 : Radiographs from the study population illustrating the principal situations.



CBL: 0-1mm



CBL > 3mm



Supra-boundary bone level

The Pearson Chi-Square Test was also used to evaluate the correlation between the different parameters and bone change.

Finally, the influence of various combined factors was evaluated in regard to their influence on CBL. This was investigated with the ANOVA Univariate Analysis Test, ($p < 0.05$).

3. Results

3.1. Drop-outs and final patients population

Sixty-two participants (26.3%) dropped out of this study, corresponding to 117 (22.2%) implants. The reasons for drop-outs included deceased 7 patients (15 implants), 51 patients out of reach (92 implants), 1 patient delaying implant loading because of financial problems (2 implants), 2 patients refusing irradiation (6 implants), 1 patient unwilling to attend (2 implants). This is summarized in Table 1.

At the end of the 5-6 year study period, three implants in two patients failed, bringing the survival rate down to 99.2%.

The radiographs of 15 patients (22 implants) did not correspond to the above established criteria for bone level evaluation: 57% of the 22 implants were located in the posterior maxilla and 43% in the anterior mandible (from canine to canine). Nevertheless, these radiographs were included in the determination of the success and survival rates. The final implant population sample reached 411 implants (77.8% of the initial population) in 174 patients for survival rate evaluation, and 386 implants (73.1% of the initial population) for bone level and hence success evaluations (Table 1).

Reasons for drop-outs	Patients	Implants
Deceased	7	15
Out of reach	51	92
Financial problems	1	2
Refusing irradiation	2	6
Unwilling to attend	1	2
Total	62	117
Included initial population	236	528
Included final population	174 (73,7%)	411 (77,8%)

Table 1. Reasons for drop-outs and included final population.

The final population included 49.7% TPS-surfaced implants and 50.3% SLA-surfaced implants. Of these, 27.5% were placed in the anterior segment and 72.5% in the posterior region. Implants placed in the maxilla comprised 39.9% of the total implants, while 60.1% were placed in the mandible. The majority of the population had a natural/fixed opposing dentition (76.4%), 17.6% had a removable opposing dentition and 4.4% had a mixed

opposing dentition. Most implants (93.5%) were solid screws (2.0% with a 3.3 mm diameter collar, 92.0% with a 4.8 mm and 6% with a 6.5 mm) and 6.5% were hollow screws. 17% presented an esthetic collar and 83.0% a standard collar. Restorations were fixed (79.0%) and removable (21.0%). 12.4% of the removable suprastructure had a clip attachment design and 7.5% a bar attachment. 19.2% of the implants were placed in smoking patients and 80.8% in non-smokers. Rough-surface implants length distribution was the following: 1.0%: 6 mm, 21.5%:8 mm, 1.6%: 9 mm (Esthetic Plus 8 mm), 39.1%: 10 mm, 10.9%: 11 mm (Esthetic Plus 10 mm), 24.4%: 12 mm, 1.6%: 13 mm (Esthetic Plus 12 mm). At surgery, by the end of the drilling sequence and prior to implant placement, 72.8% of the implants presented a VBL higher than 1 mm and 27.2% less than 1 mm. Of the implants that displayed a VBL less than 1 mm, 27.6% were placed with a simultaneous lateral augmentation technique: xenograft (Bio-Oss®, Geistlich, Switzerland) and a resorbable membrane (Bio-Gide®, Geistlich, Switzerland). 72.4% of those with VBL less than 1mm had no augmentation technique.

3.2. Examined radiographs

91.3% of the final radiographs were obtained from periapical radiographs and the rest (8.7%) were obtained from bitewings. Both types presented high sensitivities for peri-implant bone loss measurements [30]. As mentioned previously, the bitewing radiographs that were in the patient chart before as part of a routine control imaging were used in the study in order to prevent further irradiation. This explains the small percentage of this type of radiographs.

3.3. Survival and success rates

Three failures in two patients were recorded. They were divided into early failure (1 implant, 0.2%) before loading and late failures (2 implants, 0.4%) after loading. The early failure was related to infection whereas late failures were related to implant overloading and mobility. Interestingly, all failures occurred during the first year.

The overall survival rate at the 5-6 year control was 99.2%. However, 7% of the implants showed radiological bone loss greater than 3 mm, decreasing the success rate to 93%.

Peri-implantitis, utilizing both clinical and radiological evaluation, was observed on six implants (1.6%) in four patients. Five occurred in the mandible whereas four in the posterior area. Surgical procedures were not undertaken to treat peri-implantitis. They were treated locally according to the Cumulative Interceptive Supportive Therapy (CIST) protocol [23]. In addition, a strict hygiene protocol was recommended and more frequent recall appointments (every 4 months instead of the recommended annual recall). The treated implants were followed up over subsequent years, and showed no signs of recurrent peri-implantitis. No implants manifested signs of mobility, and subjects did not complain of persistent pain, foreign body sensation and/or dysthesia.

3.4. Statistical analysis

Several tests were included in the statistical analysis using the data analysis program (SPSS).

The coefficient of reliability showed no significant difference ($p>0.05$) when comparing the measurements taken by the two observers (Table 2). Therefore, a combined mean value of the two measurements was used.

Bone Loss	n	Observer 1		Observer 2		95% confidence interval of the difference			Coefficient of reliability
		mean value (mm)	standard deviation (mm)	mean value (mm)	standard deviation (mm)	lower bound (mm)	upper bound (mm)	p-value	
Mesial	385	1.09	0.00	1.09	0.54	-0.06	0.06	0.93	0.87
Distal	386	1.20	0.04	1.17	0.57	-0.02	0.09	0.20	0.88

Table 2. Inter-observer coefficient of reliability.

3.4.1. Mean bone loss

Mean bone loss (mean mesial and distal heights) measured by both observers was 1.16 mm (range 0 - 5.41 mm, SD ± 1.03 mm).

3.4.2. Effect of different factors on mean CBL

Student t-test showed the following mean CBLs for the different factors investigated (Tables 3-14).

Surface	Mean CBL (mm) *	Standard deviation (mm)	n
SLA	0.86	0.83	192
TPS	1.24	1.17	194

Table 3. Surface topography effect on mean CBL. SLA: sand blasted large grit acid etched surface, TPS: titanium plasma-sprayed surface. *Statistically significant difference between SLA and TPS surfaces and mean CBL *($p < 0.001$).*

Design	Mean CBL (mm)*	Standard deviation (mm)	n
HS	1.22	1.31	24
SS	1.58	1.20	9
S	1.04	1.00	246
SE	1.19	1.13	65
WN	0.59	0.63	25
NN	0.89	0.76	8
L	1.05	0.96	9

Table 4. The effect of different implant designs on mean CBL. HS: hollow screw implant. SS: small screw implant, S: standard implant, SE: standard implant with esthetic collar, WN: wide neck implant, NN: narrow neck implant, L: large body implants.
* No statistically significant difference found between various implant designs on mean CBL *(p = 0.946).*

Arch location*	Mean CBL (mm)	n
Posterior	0.95	280
Anterior	1.31	106

Table 5. The effect of arch location on mean CBL. The difference was significant with $P < 0.001$.
*Statistically significant difference between anterior or posterior position and mean CBL (*p < 0.001).*

Implant diameter (mm) *	Mean CBL (mm)	Standard deviation (mm)	n
4.1	1.09	1.05	356
3.3	0.89	0.76	7
4.8	0.52	0.55	23

Table 6. The effect of implant diameter on mean CBL.
* No statistically significant difference found between implant diameter and mean CBL *(p = 0.138).*

Height of the smooth collar	Mean CBL (mm) *	Standard deviation (mm)	n
Esthetic (1.8mm)	1.15	1.13	77
Standard (2.8mm)	1.03	1.00	319

Table 7. The effect of height of the smooth collar on mean CBL. *No statistically significant difference found between height of smooth collar and mean CBL *(p = 0.435).*

Jaw location	Mean CBL (mm) *	Standard deviation (mm)	n
Maxilla	1.08	0.99	155
Mandible	1.03	1.06	231

Table 8. The effect of jaw location on mean CBL.
* No statistically significant difference found between jaw location and mean CBL *(p = 0.170).*

Opposing dentition	Mean CBL (mm) *	Standard deviation (mm)	n
Natural/Fix	1.00	1.03	296
Removable	1.06	0.96	69
Mixed	1.56	1.11	21

Table 9. The effect of opposing dentition on mean CBL.
* No statistically significant difference found between opposing dentition type and mean CBL *(p = 0.931).*

Suprastructure	Mean CBL (mm) *	Standard deviation (mm)	n
Fixed	0.99	1.01	305
Removable	1.28	1.03	81

Table 10. The effect of suprastructure on mean CBL.
*No statistically significant difference between suprastructure type and mean CBL *(p = 0.7).*

Smoking status	Mean CBL (mm) *	Standard deviation (mm)	n
Non-smoker	0.97	0.95	309
Smoker	1.36	1.27	77

Table 11. The effect of smoking status on mean CBL.
* A statistically significant difference was found between smoking status and mean CBL *(p < 0.001)*. Smokers demonstrated significantly more mean CBL.

Implant length	Mean CBL (mm) *	Standard deviation (mm)	n
6 mm	1.33	0.76	4
8 mm	0.88	0.92	83
9 mm	0.86	0.96	6
10 mm	1.14	1.17	151
11 mm	1.09	1.00	42
12 mm	1.03	0.91	94
13 mm	1.30	0.83	6

Table 12. The effect of implant length on mean CBL.
* No statistically significant difference was found when evaluating implant length in regard to mean CBL *(p = 0.901)*.

VBL	Mean CBL (mm) *	Standard deviation (mm)	n
> 1 mm	0.96	0.91	281
< 1 mm	1.29	1.28	105

Table 13. The effect of VBL width on mean CBL.
* A statistically significant difference was found when evaluating VBL effect on mean CBL *(p < 0.001)*. Increased mean CBL was observed when <1mm VBL remained.

Distance to adjacent tooth/implant	Mean CBL (mm) *	Standard deviation (mm)	n
1-2 mm	1.02	0.94	33
2-3 mm	1.11	1.15	151
3-4 mm	1.05	1.25	66
>4 mm	1.04	0.93	136

Table 14. The effect of adjacent tooth/ implant distance on mean CBL.
* No statistically significant difference found when evaluating distance between adjacent tooth implant and mean CBL *(p = 0.435)*.

3.4.3. ANOVA regression analysis

According to the ANOVA regression analysis, and in accordance with the Student t-test done previously, four factors showed statistically significant results when investigating their influence on peri-implant bone change ($p < 0.05$) (Tables 15-26). These factors were:

1. Implant surface topography (TPS>SLA),
2. Smoking status (smoking >non-smoking),
3. Anterior versus posterior location (anterior > posterior),
4. Width of the vestibular bone lamella (VBL<1 mm showed greater bone loss than VBL >1 mm).

Multiple regression analysis used to evaluate the significance of the influence on the mean bone loss of the following factors: implant surface, smoking status, anterior-posterior location and vestibular bone lamella width.

(a) Dependent variable (*Y*): mean bone loss.

$Y = -0.358 + b_1$ surface $+ b_2$ tobacco $+ b_3$ antpost $+ b_4$ vestibular bone

Variables	Coefficient *b*	Standard error	Significance
surface	0.465	0.100	$p < 0.001$
smoking status	0.529	0.128	$p < 0.001$
arch location	0.403	0.173	$p < 0.001$
vestibular bone lamella	0.317	0.138	$p = 0.005$

Significance of the model: $R = 0.360$, $R^2 = 13\%$, adjusted $R^2 = 12\%$, $p < 0.001$

Multiple regression analysis of mean bone loss in relation to: (a) implant surface, (b) smoking status, (c) anterior-posterior location and (d) vestibular bone width.

Independent variables: surface (SLA, TPS) + smoking status (non-smoking, smoking) + arch location + vestibular bone.
b_0 = constant, b_1, b_2, b_3, b_4 = regression coefficients, R = correlation coefficient, R^2 = percentage of explained variance.

Multiple regression analysis
$Y = -35.762 + b_1$ surface texture+ b_2 tobacco + b_3 arch location + b_4 vestibular bone width.
Independent variables: surface texture, tobacco, arch location, and vestibular bone width on bone loss
b_0 = constant, b_1, b_2, b_3 = regression coefficients, R = correlation coefficient, R^2 = percentage of explained variance.

Pearson Chi square test confirmed the significance ($p < 0.05$) of each investigated factor (mentioned above). All the other factors were not found to be statistically significant.

3.4.4. Effect of combined factors on mean CBL

Implants with different lengths and widths, different heights of the smooth collar, different jaw locations, having a removable or fixed suprastructure, having fixed, removable or mixed opposing dentitions, and at different distances from the adjacent teeth/implants did not show a significant influence on mean bone levels, even when combined with other factors in the current study.

An ANOVA univariate analysis test was used to evaluate the effect of a combination of different factors on mean CBL. Interesting correlations were noted when combining factors that had already individually shown to have a statistically significant impact on mean CBL For example, the combination of a smoking subject and TPS-surfaced implant resulted in a higher bone loss than each parameter independently (Tables 15- 21).

Surface *	Arch location*	Mean bone loss (mm)	Standard error (mm)	Lower bound (mm)	95% Confidence interval Upper bound (mm)	p-value	n
SLA	posterior	1.00	0.10	0.79	1.21	NS	133
	anterior	1.43	0.26	0.92	1.95	NS	59
TPS	posterior	1.58	0.13	1.32	1.84	NS	149
	anterior	1.63	0.20	1.24	2.03	< 0.05	47

Table 15. Evaluation of implant surface (TPS versus SLA) and arch location (anterior versus posterior) in relation to mean crestal bone loss
* A statistically significant mean bone loss occurred for TPS surfaced implants located in the anterior arch ($p < 0.05$).

Surface *	Smoking status*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		p-value	n
				lower bound (mm)	upper bound (mm)		
SLA	non-smoking	0.82	0.09	0.63	1.02	NS	146
	smoking	1.40	0.28	1.06	2.15	NS	46
TPS	non-smoking	1.40	0.09	1.22	1.59	NS	163
	smoking	1.61	0.21	1.41	2.21	< 0.05	31

Table 16. Combination of implant surface (TPS versus SLA) and smoking status in assessing mean bone loss. Highest bone loss occurred for TPS-surfaced implants placed in smoking subjects.
* A statistically significant mean bone loss occurred in smoker subjects on TPS surfaced implants located in the anterior arch ($p < 0.05$).

Smoking status*	Arch location *	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		p-value	n
				lower bound (mm)	upper bound (mm)		
Non-smoking	posterior	1.03	0.24	0.54	1.52	NS	229
	anterior	1.25	0.18	0.90	1.59	NS	80
Smoking	posterior	1.19	0.65	-0.10	2.48	NS	51
	anterior	1.68	0.56	0.57	2.79	< 0.05	26

Table 17. Evaluation of arch location (anterior versus posterior) and smoking status in relation to mean bone loss.
* A statistically significant mean bone loss occurred for implants located in the anterior arch and placed in smoking subjects ($p < 0.05$).

Surface *	Arch location*	Smoking status *	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		p-value	n
					lower bound (mm)	upper bound (mm)		
SLA	posterior	Non-smoking	0.69	0.11	0.48	0.89	NS	102
		Smoking	1.31	0.19	0.94	1.69	NS	31
	anterior	Non-smoking	0.96	0.17	0.63	1.29	NS	44
		Smoking	1.17	0.36	1.59	3.02	NS	15
TPS	posterior	Non-smoking	1.11	0.09	0.92	1.30	NS	127
		Smoking	2.04	0.25	1.55	2.53	NS	20
	anterior	Non-smoking	1.69	0.16	1.38	2.01	NS	36
		Smoking	2.31	0.50	0.19	2.16	< 0.05	11

Table 18. Evaluation of arch location (anterior versus posterior), smoking status and implant surface (TPS versus SLA) in relation to mean bone loss
* A statistically significant mean bone loss occurred when a combination TPS-surfaced implants were placed in a smoking patient in the anterior arch ($p < 0.05$)

Surface*	VBL*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		p-value	n
				lower bound (mm)	upper bound (mm)		
SLA	> 1 mm	0.89	0.09	0.69	1.07	NS	142
	< 1 mm	1.64	0.27	1.10	2.17	NS	50
TPS	> 1 mm	1.37	0.11	1.15	1.59	NS	139
	< 1 mm	1.75	0.21	1.35	2.16	< 0.05	55

Table 19. Evaluation of implant surface (TPS versus SLA) and width of vestibular bone lamella (VBL<1 mm or VBL> 1 mm) in relation to mean bone loss.
* A statistically significant association occurred for TPS-surfaced implants with a VBL less than 1mm ($p < 0.05$).

Arch location*	Vestibular bone lamella*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		p-value	n
				lower bound (mm)	upper bound (mm)		
Posterior	> 1 mm	0.98	0.09	0.80	1.15	NS	202
	< 1 mm	1.60	0.15	1.31	1.89	NS	75
Anterior	> 1 mm	1.28	0.12	1.04	1.51	NS	72
	< 1 mm	1.79	0.31	1.19	2.39	< 0.05	30

Table 20. Combination of implant location (anterior versus posterior arch) and width of vestibular bone lamella (VBL < 1 mm or VBL > 1 mm) in relation to mean bone loss.
* A statistically significant association occurred for anterior implants with a VBL less than 1mm ($p < 0.05$).

Smoking status*	Vestibular bone lamella*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		p-value	n
				lower bound (mm)	upper bound (mm)		
Non-smoking	> 1 mm	1.08	0.08	0.93	1.24	NS	219
	< 1 mm	1.14	0.11	0.92	1.36	NS	88
Smoking	> 1 mm	1.17	0.13	0.92	1.42	NS	55
	< 1 mm	2.25	0.32	1.61	2.88	< 0.05	17

Table 21. Combination of width of vestibular bone lamella (VBL> 1 mm or VBL<1 mm) and smoking status in relation to mean bone loss
* A statistically significant association occurred in smoker patients with a VBL less than 1mm ($P < 0.05$).

Moreover, the combination of not statistically significant factors with statistically significant ones was performed. Some interesting correlations were noted, but results were not significant (Tables 22-26)

Smoking status*	Height of the smooth collar*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		n
				lower bound (mm)	upper bound (mm)	
Non-smoking	esthetic	0.51	0.38	-0.25	1.27	52
	standard	0.87	0.16	0.55	1.19	250
Smoking	esthetic	1.04	0.27	0.52	1.56	14
	standard	1.77	0.21	1.36	2.18	60

Table 22. Combination of smoking status and height of the smooth collar (esthetic versus standard) in assessing mean bone loss. Although considered alone, the height of the smooth collar did not influence bone loss, the combination of a standard collar with smoking increased bone loss. Values were not significant.
* No statistically significant difference found when evaluating the smoking status and the height of the smooth collar. $p = 0.868$.

Smoking status*	Opposing dentition*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		n
				lower bound (mm)	upper bound (mm)	
Non-smoking	N/F	0.82	0.15	0.52	1.12	227
	removable	0.58	0.41	-0.22	1.38	60
	mixed	0.86	0.32	0.23	1.49	14
Smoking	N/F	1.24	0.13	0.98	1.49	64
	removable	1.01	0.35	0.31	1.70	8
	mixed	3.39	0.70	2.02	4.77	3

Table 23. Combination of smoking status and opposing occlusion (natural/fixed or N/F, removable or mixed) in assessing mean bone loss. The opposing occlusion seemed to induce higher bone loss in a smoker than in a non-smoker. A natural/fixed or mixed opposing occlusion caused higher mean bone loss than a removable one.
* No statistically significant difference found when evaluating the smoking status and the opposing dentition. p = 0.928.

Height of the smooth collar*	Opposing dentition*	Mean bone loss (mm)	Standard error (mm)	95% confidence Interval		n
				lower bound (mm)	upper bound (mm)	
Esthetic	N/F	0.86	0.22	0.43	1.28	64
	removable	0.016	0.99	-1.95	1.95	2
	mixed	NA	NA.	NA.	NA.	0
Standard	N/F	1.11	0.08	0.95	1.27	227
	removable	0.91	0.26	0.39	1.43	67
	mixed	1.71	0.32	1.08	2.33	16

Table 24. Combination of height of the smooth collar (esthetic versus standard) and opposing occlusion (natural/fixed (N/F), removable or mixed) in assessing mean bone loss. The standard height of the smooth collar caused generally higher bone loss and this bone loss was higher when the occlusion is natural/fixed or mixed.
* No statistically significant difference found when evaluating the height of the smooth collar and the opposing dentition. p = 0.452.

Smoking status*	Jaw*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		n
				lower bound (mm)	upper bound (mm)	
Non-smoking	maxilla	0.74	0.23	0.28	1.19	118
	mandible	0.75	0.24	0.29	1.23	187
Smoking	maxilla	1.06	0.17	0.71	1.39	34
	mandible	2.01	0.27	1.48	2.53	47

Table 25. Combination of smoking status and implant location (maxilla versus mandible) in assessing mean bone loss. An implant located in the mandible and placed in a smoker caused higher bone loss.
* No statistically significant difference found when evaluating the smoking status and the implant location. p = 0.652.

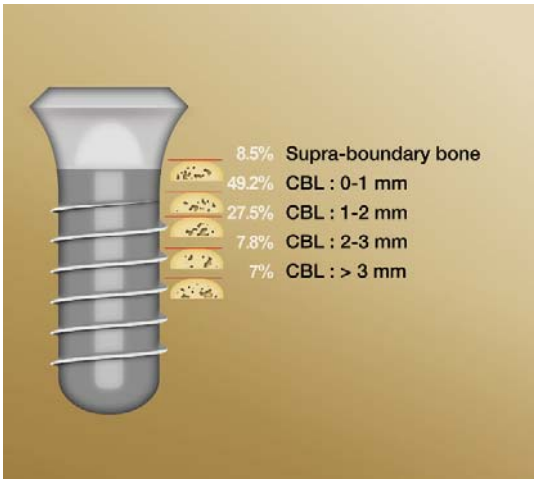
Smoking status*	Length*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		n
				lower bound (mm)	upper bound (mm)	
Non-smoking	6 mm	1.22	0.67	-.105	2.54	4
	8 mm	1.01	0.23	0.57	1.45	61
	9 mm	0.48	0.55	-0.60	1.56	=6
	10 mm	1.37	0.16	1.05	1.69	81
	11 mm	1.39	0.33	0.73	2.05	25
	12 mm	1.08	0.27	0.56	1.61	69
	13 mm	0.98	0.52	-0.05	2.00	=6

Smoking status*	Length*	Mean bone loss (mm)	Standard error (mm)	95% confidence interval		n
				lower bound (mm)	upper bound (mm)	
Smoking	6 mm	1.46	0.67	0.14	2.78	5
	8 mm	1.63	0.39	0.87	2.39	11
	9 mm	1.16	0.67	-0.17	2.48	8
	10 mm	1.85	0.24	1.39	2.31	30
	11 mm	0.98	0.41	0.17	1.79	6
	12 mm	1.07	0.28	0.50	1.63	14
	13 mm	0.99	0.53	-0.03	2.32	60

Table 26. Combination of different implant lengths (mm) and smoking status in assessing mean bone loss. No correlation was observed.
* No statistically significant difference found when evaluating the smoking status and the implant length. $p = 0.945$.

3.4.5. The influence of the statistically significant parameters on 5 subgroups of bone change

Parameters with significant influence on peri-implant bone change according to ANOVA were then distributed into 5 subgroups (Tables 27- 32). These groups were also divided according to implant length, although this was not a statistically significant factor. These groups were as follows (Fig. 10):



1- CBL > 3 mm
2- CBL : 2-3 mm
3- CBL: 1-2 mm
4- CBL : 0-1 mm
5- "Supra-boundary bone"

Mean CBL (mm) and "supra-boundary bone"	Surface			
	SLA (%)	n	TPS (%)	n
>3	2.0	4	11.9	23
2-3	6.2	12	9.3	18
1-2	27.2	52	27.8	54
0-1	56.7	109	41.7	81
"supra-boundary bone"	7.8	15	9.3	18
TOTAL	100	192	100	194

Table 27. Percentage distribution of TPS/SLA-surfaced implants in relation to crestal bone loss and "supra-boundary bone" groups. The Pearson Square test p-value indicates the significance of the correlation of this factor to CBL or "supra-boundary bone" ($p < 0.05$).

Mean CBL (mm) and "supra-boundary bone"	Arch location			
	anterior (%)	n	posterior (%)	n
>3	11.3	15	5.4	12
2-3	12.4	17	6.1	13
1-2	26.5	28	27.9	78
0-1	48.0	51	49.7	139
"supra-boundary bone"	1.8	2	5.3	31
TOTAL	100	106	100	280

Table 28. Percentage distribution of anterior/posterior implants in relation to crestal bone loss and "supra-boundary bone" groups. The Pearson Square test p-value indicates the significance of the correlation of this factor to CBL or "supra-boundary bone" ($p < 0.05$).

Mean CBL (mm) and "supra-boundary bone"	Smoking status			
	smoking (%)	n	non-smoking (%)	n
>3	9	9	11.6	18
2-3	9	9	11.6	21
1-2	21	21	27.1	85
0-1	37	37	48.2	153
"supra-boundary bone"	1	1	10.4	32
TOTAL	77	77	100	309

Table 29. Percentage distribution of the implants placed in smoker/non-smoker patients in relation to crestal bone loss and "supra-boundary bone" groups. The Pearson Square test p-value indicated the significance of the correlation of this factor to CBL or "supra-boundary bone" ($p < 0.05$).

Mean CBL (mm) and "supra-boundary bone"	Vestibular bone lamella			
	> 1 mm (%)	n	< 1 mm (%)	n
>3	3.6	10	16.2	17
2-3	7.8	22	7.7	8
1-2	29.2	82	22.8	24
0-1	48.8	137	50.4	53
"supra-boundary bone"	10.7	30	2.9	3
TOTAL	100	281	100	105

Table 30. Percentage distribution of the percentage of implants with a vestibular bone lamella either less than or greater than 1 mm in relation to crestal bone loss and "supra-boundary bone" groups. The Pearson Square test p-value indicates the significance of the correlation of this factor to CBL or "supra-boundary bone" ($p < 0.05$).

Mean CBL and "supra-boundary bone" (mm)	Length							n total
	6 mm (%)	8 mm (%)	9 mm (%)	10 mm (%)	11 mm (%)	12 mm (%)	13 mm (%)	
>3	0.0 (n=0)	16 (n=5)	0.0 (n=0)	7.9 (n=12)	9.2 (n=4)	6.6 (n=6)	0.0 (n=0)	27
2-3	30 (n=1)	16 (n=5)	18.8 (n=1)	6.6 (n=10)	9.2 (n=4)	7.4 (n=7)	34.5 (n=2)	30
1-2	30 (n=1)	36.5 (n=22)	31.3 (n=2)	29.2 (n=44)	21.1 (n=9)	29.9 (n=28)	0.0 (n=0)	106
0-1	30 (n=4)	11.4 (n=39)	31.3 (n=2)	48.3 (n=73)	59.6 (n=25)	48.8 (n=46)	65.5 (n=4)	190
"supra-boundary bone"	40 (n=4)	21.4 (n=12)	18.8 (n=1)	7.9 (n=12)	0.0 (n=0)	7.4 (n=7)	0.0 (n=0)	33
TOTAL	100 (n=4)	100 (n=83)	100 (n=6)	100 (n=151)	100 (n=42)	100 (n=94)	100 (n=6)	386

Table 31. Percentage distribution of implants according to different lengths (6, 8, 9, 10, 11, 12 and 13 mm) in relation to crestal bone loss and "supra-boundary bone" groups. The Pearson Square test p-value indicates the non-significant correlation of this factor to CBL or "supra-boundary bone" ($p = 0.458$).

Mean CBL and "supra-boundary bone" (mm)	1-2 mm (%)	2-3mm (%)	3-4mm (%)	>4 mm (%)	Total
>3	5.8 (n=7)	8.6 (n=10)	9.1 (n=4)	6.2 (n=5)	27
2-3	8.9 (n=3)	8.6 (n=25)	14.5 (n=9)	3.9 (n=18)	30
1-2	30.5 (n=8)	23.7 (n=36)	14.5 (n=6)	32.6 (n=41)	106
0-1	46.3 (n=9)	49.4 (n=56)	47.3 (n=37)	47.3 (n=47)	183
"supra-boundary bone"	8.2 (n=6)	9.8 (n=24)	14.5 (n=10)	10.1 (n=25)	33
TOTAL	100 (n=33)	100 (n=151)	100 (n=66)	100 (n=136)	379

Table 32. Percentage distribution of implant-implant or implant-tooth distances in relation to bone loss and 'supra-boundary bone` groups. The Pearson Square test p-value indicates a non-significant association between this factor and CBL or 'supra-boundary bone` ($p = 0.951$).

4. Discussion

Long term preservation of crestal bone height around osseointegrated implants is often used as a measure of primary success [5, 12, 22]. Prospective long-term studies exhibited survival and success rates largely exceeding 95% after 5 and 10 years of follow-up for the Straumann® implant system [3, 5, 18, 22, 45, 57]. A mean crestal bone loss ≤1.5 mm during the first year and ≤ 0.2 mm per year thereafter is proposed as one of the major success criteria. If we apply these strict success criteria then the CBL in 5 years should not exceed 2.3mm [1.5 + (0.2x4)].

In the current study, 8.5% of the implants exhibited "supra-boundary bone". In addition to 84.5% of the implants showing bone loss within the physiological range (0-3 mm), giving an overall successful pool of implants up to 93%. This represents a high success rate considering the private practice setting and the absence of exclusion criteria in the initial enrolment of the patients.

Patients with implants exhibiting a bone loss of 2-3 mm (7.8%) would require careful monitoring, with closer hygiene recalls and increased education in regard to patient awareness for dental hygiene and maintenance.

Bone loss greater than 3mm was observed in 7 % of the included implants. At the 5-6 year control, they were still well integrated in the jaw bone and the subjects did not manifest any symptoms that previously identified them as unsuccessful [7]. Moreover, the status and prognosis of such implants have to be carefully interpreted because other factors, mainly clinical parameters such as bleeding on probing and pocket depths, were not available, in

contrary to previous studies [5,12, 31,38, 39, 45-47, 51]. Considering such arguments, and although these implants were put by the study group in the unsuccessful implants category, one could argue the contrary. This group deserves careful monitoring, with closer hygiene recalls, more follow-up radiographs, and extended patient awareness to dental hygiene.

For the Straumann® implants, the distance from the implant shoulder to the first bone–implant contact was called DIB (distance implant-bone) and was used in previous studies [16, 21]. These studies followed the changes in peri-implant bone levels over time by taking measurement between two time points. A baseline and a post-operative radiograph were usually taken to identify initial and final bone levels, and therefore to calculate the difference: Δ DIB.

In the present study, an original method was used to calculate the bone change: the interface of the smooth-roughened surface (identified as the R interface) was considered as the baseline level. It was assumed to be the level up to which bone loss was considered as physiological, i.e. not affected by external factors. Bone loss occurring further from this point, in an apical implant direction, was thus identified as crestal bone loss (CBL). Bone localized coronally to this interface was defined as "supra-boundary bone". When the bone level was stabilized at the interface, it was then considered that no bone change occurred (CBL and "supra-boundary bone" were equal to 0 mm).

From that point, it was interesting to identify factors that might enhance bone loss or favor bone maintenance when single-staged Straumann® implants with treated TPS/SLA surfaces were used. It could be argued that the mean CBL was even lower than the 1.2 mm obtained in this study, as this value was compensated with implants that had what was called "supra-boundary bone". The present study did not quantify this "supra-boundary bone", as was described in a recently published study [51].

A paralleling radiographical technique may sometimes be difficult to perform because of the implant inclination and patient anatomy. For example, in the case of an extremely resorbed mandible, the intra-oral placement of the film was impossible because of the interference of the mouth floor [33]. In the maxilla, where the palate is the most inclined, it was difficult to position the film without bending [34]. This explained the large number of un-interpretable radiographs in these two regions.

When observing the comparative tables for the statistically significant results, namely surface texture, smoking status, anterior/posterior location and VBL, it is worth noticing that they strongly influenced both extremes of bone change groups, i.e. bone loss higher than 3 mm and bone occurring above the rough-smooth surface ("supra-boundary bone"). For example, a TPS-surfaced implant, an implant placed in a smoker, an implant localized in an anterior arch, and an implant with VBL < 1 mm showed higher differences than their counterparts in zones of bone loss > 3 mm (higher bone loss) or in zones of "supra-boundary bone" (least "supra-boundary bone"). Their influence became low in zones of physiological bone loss (0-3 mm).

4.1. Statistically significant factors affecting bone loss:

4.1.1. Surface texture effect

In the past 15 years, the topography of titanium surfaces has been investigated for dental implant applications [7, 16, 21, 37, 56]. The main goal of these experimental studies was to determine whether bone apposition could be enhanced by new microrough titanium surfaces as compared with the original implant surfaces utilized in implant dentistry, such as machined or titanium-plasma-sprayed (TPS) surfaces. Various techniques have been used to produce microrough titanium surfaces, including sandblasting, acid etching, or combinations of those, to modify surface topography. SLA surfaces were shown to have greater success and survival rates than TPS surfaces in several animal (miniature pigs) studies and human studies [70-73].

Among these new surfaces, the sandblasted and acid-etched (SLA) surface demonstrated enhanced bone apposition in histomorphometric studies and higher removal torque values in biomechanical testing [71-74]. Based on these experimental results, clinical studies were initiated to load SLA implants after a reduced healing period of only 6 weeks. In the study of Cochran et al. [71] comparing TPS with SLA surfaces in the canine mandible, linear measurements on standardized radiographs from the implant shoulder to first bone-to-implant contact (DIB) were done and bone density was evaluated by computer-assisted densitometric image analysis (CADIA). DIB measurements indicated that SLA implants significantly showed less bone height loss (0.52 mm) than TPS implants (0.69 mm). Histometric findings by the same groups later confirmed these results. The SLA implants exhibited significantly higher percentage of bone-to-implant contact than did the TPS implants [72]. The clinical examination up to 3 years demonstrated favorable results, with success rates around 99% [71]. A more recent study revealed very high success rates for SLA surfaced implants loaded at 6 weeks and placed in the posterior maxilla [74].

To date, this study is the first to have equally large numbers of each surface. The present study also clearly yielded significant higher bone loss on the TPS implants than on the SLA surface implants. Moreover, the TPS group had a greater proportion of implants having bone loss > 3mm. The TPS surface became more significant in terms of degrees of bone loss when combined with other factors such as smoking, anterior location and VBL prior to implant placement smaller than 1 mm. The proportion of bone above the rough-machined interface (named `supra-boundary bone` in the current study) was also significantly higher on the SLA surface. Therefore, it may be prudent to establish a more intense oral hygiene follow-up for patients with TPS-surfaced implants, especially if other aggravating factors, such as tobacco use, are present.

Of note, however, is that TPS surfaced implants still osseointegrated well and have contributed to the high survival rate of the study. Hence, although they have greater crestal bones loss (lower success rates), TPS surfaced implants still represent a valid treatment option for implants in function.

4.1.2. Tobacco effect

The effect of tobacco on dental implants is well documented in the literature and many authors have shown that heavy smokers show a greater degree of crestal bone loss when compared to non-smokers [49, 59, 65, 75]. However, the underlying mechanisms are not yet completely understood. Smoking is thought to interfere with early healing events in the process of osseointegration and hence the consequences are usually recognized in the first year following implant placement. Lindquist et al. [59] reported that smokers demonstrated worse oral hygiene and displayed approximately 3 times greater bone loss after 10 years than non-smokers. Moreover, factors including heavy or unfavorable occlusal loading previously associated with increased peri-implant loss became more relevant with smoking [49].

Smoking and poor oral hygiene were found to be of greater influence on peri-implant bone loss than overload in long-term studies of patients treated with fixed partial dentures [24, 59]. Other studies showed that smoking and implant location in the maxilla were associated with an increased peri-implant marginal bone resorption [75].

It was however argued that smoking should not be an absolute contra-indication for implant therapy. Long-term heavy smokers would rather be informed of the increased risk of marginal bone loss at the implant site over the long-term, and eventually a higher risk of late implant failure [75]. In the10-year follow-up study of Carlsson et al. [77], smoking was the most important factor affecting peri-implant bone loss in the mandible. A number of reviews of the literature emphasize smoking as a significant risk factor for a compromised prognosis of dental implants.

In agreement with that, the current study showed that smokers manifest a statistically significant higher degree of crestal bone loss when compared with non-smokers. Additionally, this effect was significantly enhanced when considered with other factors (TPS surface, anterior location and VBL<1 mm). Interestingly, smoking even provoked other non-statistically significant factors to increase bone loss; these include opposing fixed or mixed occlusion, mandibular location, and standard implant collar heights (tables 22, 23 and 25). These combinations were however still not statistically significant.

Despite that tobacco significantly influenced the implant success rates; it did not significantly lower the survival rate. Based on this result, one could argue that it cannot be considered a contra-indication for implant placement.

4.1.3. Oral hygiene and periodontal status effect

Oral hygiene and periodontal status are also of importance in regard to peri-implant bone loss and implant failure [55]. Isidor [39] found a progressive loss of radiographic bone and clinical probing depths at implants with enhanced plaque accumulation.

Although optimum dental hygiene was emphasized in the current study, patients were not enrolled in active and regular recall session. One might therefore assume that preliminary caries and pocket control – a procedure done systematically in the current study - is of a greater importance than strict post-treatment recall sessions. Consistency or frequency of recall and its effect on bone loss were not investigated in this study.

4.1.4. Implant location effect

Contradicting data in the literature have been reported on the effect of implant location (anterior versus posterior), on their success and survival rates. Weber et al. reported higher bone loss in the anterior region, although the size of the data was small [16]. Also, a 15-year prospective study demonstrated that implants placed in anterior segments showed higher bone loss than in the posterior segments [22]. Similarly, mesially placed implants showed more bone resorption than distally positioned implants, independently of implant surface roughness [14]. Lindquist et al. suggested that the more extensive bone loss around the anterior implants was a consequence of tensile forces, caused by loading of the posterior cantilever extensions and other biomechanical factors [24].

It is also debatable that implants placed in the posterior region show higher bone loss, considering that occlusal forces also increase because of the closeness of the temporo-mandibular joint. Therefore, all the posterior implants supporting partial prosthesis would experience more loading than those located in the anterior regions. Precisely, in a prospective 5-year study [20], the cumulative success rates for implants placed in molar sites were lower than mandibular and maxillary anterior regions. These differences reported for the anterior and posterior locations were attributed to bone quality and quantity (difficulty in achieving bicortical stabilization). Posterior regions were often characterized by unfavorable bone quality and reduced bone height, thus affecting bone loss and implant survival rate [78, 79]. Implants placed in the premolar or molar regions were generally shorter than those placed in the canine and incisor sites [64]. All of the above mentioned studies actually correspond to machined surfaced implants. With the introduction of roughened surfaces, research showed that posterior regions are no longer a risk factor.

Present results reported significant higher bone loss for implants placed in anterior regions. The combination of anterior region placement, tobacco use, and TPS-surfaced implant greatly increased bone loss. However, the results should be carefully interpreted as many of the anterior implants were usually placed deeper than those in the posterior region, to prevent exposure of the metal implant margin. Consequently, in addition to the crestal bone resorption which occurred for implants placed under standard conditions, bone adjacent to the polished implant surface was also lost. From a biological point of view, the subcrestal placement of the rough-smooth interface was consequently not recommended [27, 61].

Most of the posterior implants in the present study were short length. Due to the encouraging results in terms of CBL around posterior implants as opposed to anterior ones, short implant lengths could also be considered a valid treatment option and one with similar success rates to longer implants, especially in areas of reduced bone height.

4.1.5. Vestibular bone lamella width effect

The effect of VBL at implant placement on bone loss has not yet been reported in the literature. It is documented that a minimum width of 1 mm around implants, is required at placement to obtain optimum osseointegration and to prevent exposure of the implant threads following bone remodeling [5]. Primary stability was reported to be an even more significant factor for osseointegration [5, 56].

Bone that is less than 1 mm wide was thought to be more susceptible to resorption after surgery or following function. The rationale was that this minimal bone would fail to provide a sufficient matrix for the surrounding mesio-distal bone remodeling process, and would even enhance its resorption [12, 47, 77, 81]. Such findings should alarm clinicians while placing implants in anterior regions with a VBL less than 1 mm, since it may cause higher peri-implant bone loss and would therefore affect esthetic parameters, namely mesial and distal papillae.

There are reasons to suggest that over time this uneven outline of the marginal bone around dental implants was leveled out by a bone remodeling process and a reduction of the bone height at the proximal surfaces. Such an explanation is in agreement with findings reported by Carmagnola et al. [80] who, in a dog model, studied bone tissue reactions around implants placed in a compromised mandible. Following tooth extraction, the buccal bone plate was resected and a narrow ridge established. After 8 months of healing, implants were placed in the compromised site so that their lingual surfaces were invested in bone while about 4–5mm of their buccal portion remained exposed. During the process of healing and during 4 months of function marked modeling and remodeling of the bone tissue around the implants took place. At the buccal surfaces some regrowth of bone occurred while at the lingual surfaces there was a substantial resorption of bone. As a result, the marginal level of osseointegration tended to become similar at all four aspects of the implants. This finding could explain the greater proximal peri-implant bone loss around implants that have a buccal bone lamella that is smaller than 1mm [51].

The width of the VBL showed a higher influence on CBL when combined with tobacco use, anterior arch location or TPS surfaced implants. The high value of CBL around implants having a VBL < 1 mm might be due to their anterior location which often involved a deeper fixture placement, this parameter was discussed previously. Moreover, implants with a VBL that is greater than 1 mm had more bone coronal to the R interface ("supra-boundary bone"), than those with a VBL that is less than 1mm.

4.2. Statistically non- significant factors affecting bone loss

All other investigated factors (implant diameter, opposing arch occlusion, maxillary versus mandibular jaw location, smooth collar height, fixed versus removable suprastructure, implant-implant or implant-tooth distance, and implant length) did not show a significant influence on bone remodeling in the current study. This could be attributed to the small number of patients who were concerned by these factors, errors in the radiographic analysis, or the actual negligible influence on bone remodeling and bone loss in the included patient sample. Nevertheless, when combined with other factors, some of these factors might influence bone levels. This will be discussed in the following paragraphs.

4.2.1. Implant diameter effect

Implant diameter is the distance between the peak of the widest thread and the same point on the opposite side of the implant. In contrast, implant diameter is distinct from the implant platform diameter, the latter being a measure of the interface of the implant connected with the abutment. Because a variety of implant widths and platforms are available, a wide-platform is not always related to an increased diameter of the implant

thread. Implant diameter was not reported as a limiting factor in peri-implant bone loss [26, 82].

Reported advantages of using wide-diameter implants include: increased bone to implant contact, use as "rescue" implants in the case of site over-preparation during drilling, immediate placement in failure sites, reduction in abutment stresses and strain. The most obvious indication for wide-diameter implants (especially at the platform level) is for molar fixed rehabilitations [26].

Contrasting effects of implant diameter on success and survival rates were reported in the literature. Some studies report that 5 mm wide implants have higher failure rate than 3.75 or 4 mm wide implants because wider implants are often used in rescue procedures for failed implants [82]. Also, it has been reported that 5 mm wide implants developed for compromised situations had similar survival and success rates to standard-size Brånemark® implants.

Inversely, another study [83] showed that cumulative survival and success rates of small-diameter implants and standard-diameter implants were not statistically different ($p > 0.05$); although bone quality was a significant factor in failure, marginal bone loss was not influenced by the different implant diameters. The results suggested that small-diameter implants could be successfully used in the treatment of partially edentulous patients. Furthermore, no statistically significant relationship was observed between peri-implant bone loss and implant diameter [49, 84]. When considering wide neck ITI implants, a five-year life-table and radiographic analysis showed that these implants were highly predictable, with small prosthetic complications. The average bone loss measured at the two-year post-operative control was similar to standard implants [85].

No correlation between the different implant collar diameters on bone loss were noted in the present study. Wide neck implants did not show higher bone loss than smaller diameter implants. Moreover, combinations with other factors did not seem to have an effect.

4.2.2 . Effect of opposing dentition

Occlusal overloading has been reported to be associated with increased bone loss and implant failure. This report was based on anecdotal observations supported by theoretical biomechanical theories, but was never proven in controlled studies in humans. Studies in monkeys demonstrated that overload could cause increase bone loss in some included implants [63]. Isidor [39] showed that overloaded implants had a decreased bone-to-implant contact. These overloaded implants also presented a smaller area in contact with mineralized bone tissue than non-loaded implants. Furthermore, once peri-implantitis has progressed, the control of occlusion and inflammation was probably not sufficient to promote the healing mechanism [18, 46, 65]. Implants with surrounding tissue inflammation probably deserve a greater care in avoiding overload. Again, theses conclusions were drawn from studies done on machined surfaces.

Also, when reviewing the literature on the effect of the opposing dentition on bone loss, there was no conclusive answer to the question: did the prosthetic status in the opposing jaw influence the peri-implant bone loss and/or implant failure? Peri-implant bone loss may be enhanced in the jaw occluding with a fixed prosthesis in comparison with one occluding

with a complete denture [86]. On the contrary, Carlsson et al. [77] did not experience such differences in peri-implant bone loss and suggested that the prosthesis in the opposing arch did not influence peri-implant bone loss.

The opposing dentition alone did not seem to influence bone loss in the present study. The combination of smoking and implants with a fixed or mixed opposing occlusion increased bone loss, unlike removable opposing dentition. This parameter deserves further analysis, since our results were not statistically significant.

4.2.3. Jaw location effect

Implant survival was lower in the maxilla than the mandible; this was attributed partially to a different bone quality in the maxilla [2, 14, 59, 65]. In the study of Carlsson et al. [77], all the failing – maxillary – implants (placed with 2-stage implant procedures) were lost during the healing period and not after the connection of the prosthesis. However, the same study reported similar peri-implant bone loss in both jaws.

Other studies revealed different results. A comparison between bone loss in the mandible and in the maxilla around 2-stage implants at abutment connection showed that a steady state was achieved after the first year of loading. The bone loss was 0.05 mm in the maxilla and 0.2 mm in the mandible for completely edentulous individuals wearing dentures [86]. Very few studies have been carried out on rough-surfaced implants [75], and in theses no differences between maxilla and mandible were noted. A more recent study [87] showed that the implants located in the maxilla were associated with significantly higher bone loss.

No statistically significant differences in bone loss were noted around implants in the maxilla or in the mandible in the current study. However, the combination of smoking and mandibular location caused higher bone loss, unlike the combination of a maxillary location and a smoking subject. Further research on the influence of jaw location and bone conditions on oral implant outcomes are needed.

4.2.4. Effect of height of the smooth collar

It was shown that the height of the smooth implant collar has an effect on bone remodeling around the implant. Straumann® implants showed more marginal bone loss if the smooth part of the implant came into contact with the bone after a deeper placement [27]. This result led to the development of the "Esthetic" Plus line within the ITI Dental Implant System. The magnitude of initial bone remodeling around implants was dependant on the location of the rough-smooth border of the implant in an apico-coronal dimension [88]. The implant having the shortest smooth coronal collar showed no additional bone loss, while enabling deeper placement. Its use might reduce the risk of an exposed metal implant margin in areas of esthetic concern [81, 89].

The current study showed no significant difference between esthetic implants when compared with standard implants, in terms of crestal bone loss. This would be of interest as a deeper placement, especially in the anterior area, would jeopardize proximal bone.

4.2.5. Suprastructure effect

The systemic review of Berglundh et al. [12] has demonstrated that implants supporting overdentures exhibited higher frequencies of biological and technical complications than implants with fixed reconstructions. A seven-year study reported similar survival rate for implants supporting single-tooth prostheses (95.6%), cantilever fixed partial prostheses (94.4%), fixed partial prostheses (96.1%), fixed complete prostheses (100%), and implant/tooth-supported prostheses (90.6%) and overdentures (95.7%) [89]. Mericske-Stern [62] observed that patterns of force transmission onto the implants were similar with a fixed complete denture and an overdenture connected to maxillary implants. The influence of mechanical and anatomical-prosthetic variables on peri-implant parameters was studied by several authors [48, 61-63, 89]. The type of the implant to denture attachments was shown to have little or no influence on the peri-implant parameters [90, 91]. The bar design did not significantly influence the occlusal force distribution pattern. Wyatt and Zarb [17] observed that implants supporting distal extensions prosthesis significantly increased bone loss in the first year of loading when compared to implants supporting prosthesis bounded by natural teeth.

Excessive marginal bone loss was explained by the overloading due to the lack of anterior contact and the presence of parafunctional activity [77]. It was shown that 70% of the occlusal forces were borne by the distal cantilevers and 30% by the implant-supported segment of the prosthesis on "Toronto bridges" or "Branemark bridges" [60, 61]. Biomechanical calculations and such results suggested that the most distal implants presented higher risk of bone loss because they were exposed to the largest forces, bending movements and stress concentrations. Subsequently, Nedir et al. did not experience lower survival rates of rough surfaced implants having a single unit distal extension [66].

In the present study, a removable suprastructure did not manifest greater peri-implant bone loss, despite the advanced age and presumed reduced dexterity of older patients. Overdentures do not represent a higher risk for the development of peri-implant lesions. Elderly patients with overdentures supported by attachments or bars can reasonably maintain healthy peri-implant conditions. The small sample of patients with a removable prosthesis might also explain the non-significance of the results.

4.2.6. Implant-tooth/implant-implant distance effect

Few investigations which assess the influence of the distance between implants or between implants and teeth in regard to bone loss are reported in the literature. Effects on the interdental papilla were thoroughly studied by Tarnow et al. [92]. This group observed that increased crestal bone loss would result in an increase in the distance between the base of the contact point of the adjacent crowns and the crest of bone. It is a proposed way to determine whether the papilla will be present or absent between two implants, and was previously reported between natural teeth. When multiple implants had to be placed in the esthetic zone, the use of small diameter implants might preserve at least 3 mm of bone at the implant-abutment level between them. Differences between implant diameters did not however yield significant results when considering their effect on peri-implant bone remodeling, however, further research is needed.

No correlations between implant-implant or implant-tooth distances and mean bone level change were established in the present study.

4.2.7. Implant length effect

Reported studies on smooth-surfaced implants showed that short implants failed more frequently than longer ones [21, 60, 64, 95]. Historically, the use of short implant was not widely recommended because it was believed that occlusal forces might be dissipated over a large implant surface area to prevent excessive stresses at the interface [81]. However, finite element analysis (FEA) has shown that the occlusal forces are mainly distributed to the crestal bone, rather than evenly throughout the entire surface area of the implant interface [63]. Since masticatory forces were usually light and fleeting, they are normally well tolerated by the bone. This might explain why the implant length was not linearly related to biomechanical stability. Long term studies show a dramatic increase in failures for implants shorter than 7 mm in length, especially on machined surface implants, even more in type 4 bone [93].

Smoking, implant location and morphology, which were demonstrated to influence marginal bone loss, also associated with an increased failure rate with short implants [94]. Similarly, it was demonstrated that short implants, wide implants, implants supporting fixed prostheses, and implants placed in smokers were associated with a high CBL [49]. Implant length was the most significant factor in the maintenance of machined surfaced dental implants.

However, the introduction of rough surfaced implants has allowed a greater bone-to-implant contact; hence, higher success and survival rates were noted. Bernard et al. [94] suggested that the distinct magnitude of anchorage and the distinct loosening patterns registered for Brånemark® and Straumann® implant systems of different lengths might be related to the various surfaces. Greater torque forces were needed for rough implants of short length, unlike for implants with machined surfaces. Implants as short as 5 mm in length, with porous surface treatments, were introduced to replace possible sinus lift procedures [94]. Based on such observations of increased bone-to-implant contact on rough surfaces, private practitioners used short implants in various situations (e.g. in posterior maxilla with limited bone height or in posterior mandibular locations because of the proximity of the mandibular canal), they showed that short implants were as successful as long ones [64].

Renouard et al. [96] also demonstrated that the use of short implants could be considered for prosthetic rehabilitation of the severely resorbed maxilla as an alternative to more complicated surgical techniques; both implant failure rate and bone resorption over two years were not affected.

Mean marginal bone loss and gingival crevice probing depth associated with short or long implant lengths were statistically comparable [50]. Accordingly, when considering the long-term multicenter evaluation of 2359 non-submerged Straumann® implants [21], the five year survival and success rates of 8 mm long implants did not differ significantly from the longer implants, despite the posterior placement of the shorter implants.

Peri-implant bone loss was quite similar for long and short implants in the present study, even when combined with other factors. Moreover, implants placed in the posterior area – that tended to be shorter for anatomical reasons- exhibited less bone loss than those placed in anterior areas. That confirmed the previous observation that length of rough-surfaced implant did not influence bone loss and implant success. This was a significant finding which might not only simplify surgical and planning procedures, but also might drastically expand the applications of implant therapy.

4.3. Other factors worthy of investigation

Further analysis on the effect of other factors on peri-implant bone remodeling might include prosthesis-related factors: the type of fixed suprastructure (single crown or fixed partial denture), nature of the fixed partial denture (two splinted crowns, a bridge, and a cantilever), misfit of the suprastructure, and crown to implant ratio [97].

The effect of the level of implant submersion and the delay of placement or loading might be also of interest. Patient periodontal status and number of visits to the hygienist are also shown to affect bone remodeling around implants. Other studies have observed that crestal bone level changes were correlated with the presence of a microgap even when a two-part implant (i.e. implant plus an abutment) was placed with a non-submerged technique [10]. When the microgap was located above the bone crest, less bone remodeling occurred; whereas when the microgap was placed below the bone crest, greater amounts of bone were lost. The lack of data in the studied population prevented the inclusion of the factors described above.

5. Conclusions

The conclusions of this study can be summarized in eight points. Some of these were already known and were thus confirmed; others were identified, in particular some interesting associations identifying some groups at risk:

1) The survival rate (99.2%) presented hereby compared well with related previously published studies.

2) Specific peri-implant bone loss beyond the smooth-rough implant interface was on average 1.2 mm, throughout a period of 5-6 years. Such value was in agreement with those reported in the literature on rough surface implants to date.

The radiographic method used for the evaluation could be described as unique: the bone level change was evaluated from the smooth-rough implant interface considered as the baseline level; therefore, the measurements were done from 5-6 year post-operative radiographs only. The results confirm the reliability of the measurements.

3) The success rate (93%) was mainly based on the percentage of implants having CBL greater than 3mm. Theses were considered as a higher failure risk group. Different criteria for success rate evaluations were used in different studies.

4) Two sub-populations within this study, presented higher failure risk groups, and should be monitored more closely and attentively when considering hygiene control and while establishing the treatment planning process:

4.1 The first group represented 7% of the total population. It showed a CBL higher than 3 mm, which was considered as "alarming" by the study group.

4.2 The second group included a population with the following factors: TPS-surfaced implants, anterior arch location, smokers, and VBL thinner than 1 mm at surgery. These factors – considered separately or combined – were associated with higher peri-implant CBL.

5) "Supra-boundary bone"; which is bone appearing above the rough-smooth interface was observed on 7.8% of the included implants. It was quite noticeable with SLA-surfaced implants, non-smoking subjects, implants located in a posterior arch, and implants with a VBL higher than 1 mm at surgery. These can be considered as "low failure risk groups".

6) Implants placed in the mandible, implants with an opposing mixed/fixed occlusion and implants supporting a removable suprastructure tended to cause higher bone loss, although results were not statistically significant.

7) Short implants showed a very limited bone loss, the difference in bone loss between short and long implants was not statistically significant. This confirmed the reliability of the use of short implants.

8) Systemic and continuous monitoring of peri-implant bone conditions along with the identification and control of associated risk factors are highly recommended for the diagnosis of peri-implant disease.

6. Bibliography

1. Lang NP, Wilson TG, Corbet EF. Biological complications with dental implants: their prevention, diagnosis and treatment. Clin Oral Implants Res 2000; 11 Suppl 1:146-55.
2. Brånemark PI, Zarb GA, Albrektsson T. Tissue-integrated prostheses (pp 129-43). Quintessence, Chicago, 1985.
3. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981; 10:387-416.
4. Adell R, Lekholm U, Rockler B, Brånemark PI, Lindhe J, Eriksson B, Sbordone L. Marginal tissue reactions at osseointegrated titanium fixtures (I). A 3-year longitudinal prospective study. Int J Oral Maxillofacial Surg 1986; 15:39-52.
5. Alberktsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants 1986; 1:11-25.
6. De Smet E, Jacobs R, Gijbels F, Naert I. The accuracy and reliability of radiographic methods for the assessment of marginal bone level around oral implants. Dentomaxillofac Radiol 2002; 31: 176-81.
7. Buser D, Weber HP, Lang NP. Tissue integration of non-submerged implants. 1-year results of a prospective study with 100 ITI hollow-cylinder and hollow-screw implants. Clin Oral Implants Res 1990 1:33-40.
8. Hermann JS, Buser D, Schenk RK, Cochran DL. Crestal bone changes around titanium implants. A histometric evaluation of unloaded non-submerged and submerged implants in the canine mandible. J Periodentol 2000;71:1412-24.
9. Hermann JS, Schoolfield JD, Nummikoski PV, Buser D, Schenk RK, Cochran DL. Crestal bone changes around titanium implants: a methodological study comparing linear radiographic with histometric measurements. Int J Oral Maxillofac Implants 2001; 16:475-85.
10. Hermann JS, Schoolfield JD, Schenk RK, Buser D, Cochran DL. Influence of the size of the microgap on crestal bone changes around titanium implants. A histometric evaluation of unloaded non-submerged implants in the canine mandible. J Periodontol 2001; 72:1372-83.
11. Hermann JS, Cochran DL, Nummikoski PV, Buser D. Crestal bone changes around titanium implants. A radiographic evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. J Periodontol 1997; 68:1117-30.
12. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. J Clin Periodontal 2002; 29 Suppl 3:197-212. 232-3.
13. Brägger U, Hugel-Pisoni C, Burgin W, Buser D, Correlations between radiographic, clinical and mobility parameters after loading of oral implants with fixed partial dentures. A 2-year longitudinal study. Clin Oral Implant Res 1996; 7:230-9.
14. Zechner W, Trinkl N, Watzak G, Busenlechner D, Tepper G, Haas R, Watzek G. Radiologic follow-up of peri-implant bone loss around machine-surfaced and rough-surfaced interforaminal implants in the mandible functionally loaded for 3 to 7 years. Int J Oral Maxillofac Implants 2004; 19:216-21.

Mis en forme : Anglais (Royaume-Uni)
Mis en forme : Anglais (Royaume-Uni)
Mis en forme : Anglais (Royaume-Uni)
Code de champ modifié
Mis en forme : Anglais (Royaume-Uni)
Mis en forme : Anglais (Royaume-Uni)
Mis en forme : Anglais (Royaume-Uni)
Code de champ modifié
Mis en forme : Anglais (Royaume-Uni)
Mis en forme : Anglais (Royaume-Uni)
Code de champ modifié
Code de champ modifié
Mis en forme : Anglais (Royaume-Uni)

15. Zybutz M, Rapoport D, Laurell L, Persson GR. Comparisons of clinical and radiographic measurements of inter-proximal vertical defects before and 1 year after surgical treatments. J Clin Periodontol 2000; 27:179-86.
16. Weber HP, Crohin CC, Fiorellini JP. A 5-year prospective clinical and radiographic study of non-submerged dental implants. Clin Oral Implants Res 2000; 11:144-53.
17. Wyatt CC, Zarb GA. Bone level changes proximal to oral implants supporting fixed partial prostheses. Clin Oral Implants Res 2002; 13:162-8.
18. Fransson C, Lekholm U, Jemt T, Berglundh T. Prevalence of subjects with progressive bone loss at implants. Clin Oral Implants Res 2005; 16:440-6.
19. Wenntröm J, Palmer R. Consensus report of session 3: clinical trails (pp 255-9). Proceedings of the 3rd European workshop on Periodontolgy. Implant Dentistry. Lang N, Karring T, Lindhe J eds. Quintessence, Berlin, 1999.
20. Jemt T, Lekholm U. Oral implant treatment in posterior partially edentulous jaws: a 5-year follow-up report. Int J Oral Maxillofac Implants 1993; 8:635-40.
21. Buser D, Mericske-Stern R, Bernard JP, Behneke A, Behneke N, Hirt HP, Belser UC, Lang NP. Long-term evaluation of non-submerged. ITI implants. Part 1: 8-year life table analysis of a prospective multi-center study with 2359 implants. Clin Oral Implants Res 1997; 8: 161-172.
22. Snauwaert K, Duyck J, van Steenberghe D, Quirynen M, Naert I. Time dependent failure rate and marginal bone loss of implant supported prostheses: a 15-year follow-up study. Clin Oral Investig 2000; 4:13-20.
23. Mombelli A, Lang NP. The diagnosis and treatment of peri-implantitis. Periodontol 2000 1998; 17:63-76.
24. Lindquist LW, Carlsson GE, Jemt T. A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. Clin Oral Implants Res 1996; 7:329-36.
25. Grondahl K, Sunden S, Grondahl HG. Inter- and intraobserver variability in radiographic bone level assessment at Brånemark fixtures. Clin Oral Implants Res 1998; 4:243-50.
26. Lee JH, Frias V, Lee KW, Wright RF. Effect of implant size and shape on implant success rates: a literature review. Prosthet Dent 2005; 94:377-81.
27. Hämmerle CH, Brägger U, Burgin W, Lang NP. The effect of subcrestal placement of the polished surface of ITI implants on marginal soft and hard tissues. Clin Oral Implants Res 1996; 7: 111-9.
28. Hartmann GA, Cochran DL. Initial implant position determines the magnitude of crestal bone remodeling. J Periodontol 2004; 75:572-7.
29. Bernard JP, Belser UC, Martinet JP, Borgis SA. Osseointegration of Brånemark fixtures using a single-step operating technique. A preliminary prospective one-year study in the edentulous mandible. Clin Oral Implants Res 1995; 6:122-9.
30. Pepelassi EA, Diamanti-Kipioti A. Selection of the most accurate method of conventional radiography for the assessment of periodontal osseous destruction. J Clin Periodontol 2000; 27:179-86.
31. Romeo E, Lops D, Amorfini L, Chiapasco M, Ghisolfi M, Vogel G. Clinical and radiographic evaluation of small-diameter (3.3-mm) implants followed for 1-7 years: a longitudinal study. Clin Oral Implants Res 2006; 17:139-48.
32. Rosling B, Hollender L, Nyman S, Olsson G. A radiographic method for assessing changes in alveolar bone height following periodontal therapy. J Clin Periodontol 1975; 2:211-7.
33. Zechner W, Watzak G, Gahleitner A, Busenlechner D, Tepper G, Watzek G. Rotational panoramic versus intraoral rectangular radiographs for evaluation of peri-

implant bone loss in the anterior atrophic mandible. Int J Oral Maxillofac Implants 2003; 18:873-8.
34. Sewerin IP. Errors in radiographic assessment of marginal bone height around osseointegrated implants. Scand J Dent Res 1990; 98:428-33.
35. Benn DK. Limitations of the digital image subtraction technique in assessing alveolar bone crest changes due to misalignment errors during image capture. Dentomaxillofac Radiol 1990; 19:97-104.
36. Wahl G, Lang H. Deformation at the implant interface to prosthetic superstructure: an interferometric approach. Clin Oral Implants Res 2004; 15:233-8.
37. Spiekermann H, Jansen VK, Richter EJ. A 10-year follow-up study of IMZ and TPS implants in the edentulous mandible using bar-retained overdentures. Int J Oral Maxillofac Implants 1995; 10:231-43.
38. Quirynen M, van Steenberghe D, Jacobs R, Schotte A, Darius P. The reliability of pocket probing around screw-type implants. Clin Oral Implants Res 1991; 2:186-92.
39. Isidor F. Clinical probing and radiographic assessment in relation to the histologic bone level at oral implants in monkeys. Clin Oral Implants Res 1997; 8:255-64.
40. Ericsson I, Lindhe J. Probing depth at implants and teeth. An experimental study in the dog. J Clin Periodontol 1993; 20:623-7.
41. Akesson L, Hakansson J, Rohlin M. Comparison of panoramic and intraoral radiography and pocket probing for the measurement of the marginal bone level. J Clin Periodontol 1992; 19:326-32.
42. Lofthag-Hansen S, Lindh C, Petersson A. Radiographic assessment of the marginal bone level after implant treatment: a comparison of periapical and Scanora detailed narrow beam radiography. Dentomaxillofac Radiol 2003; 32:97-103.
43. Battenberg RH, Meijer HJ, Raghoebar GM, Van Port RP, Boering G. Mandibular overdentures supported by two Brånemark, IMZ or ITI implants. A prospective comparative preliminary study: one-year results. Clin Oral Implants Res 1998; 9:374-383.
44. Fiorellini JP, Buser D, Paquette DW, Williams RC, Haghighi D, Weber HP. A radiographic evaluation of bone healing around submerged and non-submerged dental implants in beagle dogs. J Periodontol 1999; 70:248-54.
45. Heydenrijk K, Raghoebar GM, Meijer HJ, Stegenga B. Clinical and radiologic evaluation of 2-stage IMZ implants placed in a single-stage procedure: 2-year results of a prospective comparative study. Int J Oral Maxillofac Implants 2003; 18:424-32.
46. Karoussis K, Muller S, Salvi G, Heitz-Mayfield L, Brägger U, Lang N. Association between periodontal and peri-implant conditions ; a 10 year prospective study. Clin Oral Impl Res 2004; 15:1-7.
47. Meijer HJ, Heijdenrijk K, Raghoebar GM. Mucosal and radiographic aspects during the healing period of implants placed in a one-stage procedure. Int J Prosthodont 2003; 16:397-402.
48. Mericske-Stern R, Oetterli M, Kiener P, Mericske E. A follow-up study of maxillary implants supporting overdentures. clinical and radiographic results. Int J Oral Maxillofac Implants 2002; 17:678-86.
49. Penarrocha M, Palomar M, Sanchis JM, Guarinos J, Balaguer J. Radiologic study of marginal bone loss around 108 dental implants and its relationship to smoking, implant location, and morphology. Int J Oral Maxillofac Implants 2004; 19:861-78.
50. Romeo E, Ghisolfi M, Rozza R, Chiapasco M, Lops D. Short (8mm) dental implants in the rehabilitation of partial and complete edentulism: a 3 to 14 year longitudinal study. Int J Prosthodont 2006; 19:586-92.

51. Blanes RJ, Bernard JP, Blanes ZM, Belser UC. A 10-year prospective study of ITI dental implants placed in the posterior region : I Clinical and radiographic results. Clin Oral Implants Res 2007; 18:699-706.
52. Von Wowern N. In vivo measurement of bone mineral content of mandibles by dual photon absoptiometry. Scand J Dent Res 1985; 93:162-8.
53. Brägger U, Pasquali L, Kornman KS. Remodeling of interdental alveolar bone after periodontal flap procedures assessed by means of computer-assisted densitometric image analysis (CADIA). J Clin Periodontol 1988; 15:558-4.
54. Cochran DL, Hermann JS, Schenk RK, Higginbottom FL, Buser D. Biologic width around titanium implants. A histometric analysis of the implanto-gingival junction around unloaded and loaded nonsubmerged implants in the canine mandible. J Periodontol 1997; 68:186-98.
55. Smith DE, Zarb GA. Criteria for success of osseointegrated endosseous implants. J Prosthet Dent 1989; 62:567-72.
56. Abrahamsson I, Zitzmann NU, Berglundh T, Wennerberg A, Lindhe J. Bone and soft tissue integration to titanium implants with different surface topography: an experimental study in the dog. Int J Oral Maxillofac Implants 2001; 16:323-33.
57. Merisc̈ke-Stern R, Venetz E, Fahrlander F, Burgin W. In vivo force measurements on maxillary implants supporting a fixed prosthesis or an overdenture: a pilot study. J Prosthet Dent 2000; 84:535-47.
58. Keller W, Brägger U, Mombelli A. Peri-implant microflora of implants with cemented and screw retained suprastructures. Clin Oral Implants Res 1998; 9:209-17.
59. Lindquist LW, Carlsson GE, Jemt T. Association between marginal bone loss around osseointegrated mandibular implants and smoking habits: a 10-year follow-up study. J Dent Res 1997; 76:1667-74.
60. Lum LB. A biomechanical rationale for the use of short implants. J Oral Implantol 1991; 17:126-31.
61. Mailath G, Stoiber B, Watzek G, Matejka M. Bone resorption at the entry of osseointegrated implants - a biomechanical phenomenon. Finite element study. Z Stomatol 1989; 86:207-16.
62. Merisc̈ke-Stern R. Force distribution on implants supporting overdentures: the effect of distal bar extensions. A 3-D in vivo study. Clin Oral Implants Res 1997; 8:142-51.
63. Miyata T, Kobayashi Y, Araki H, Ohto T, Shin K. The influence of controlled occlusal overload on peri-implant tissue. Part 4: a histologic study in monkeys. Int J Oral Maxillofac Implants 2002; 17:384-90.
64. Nedir R, Bischof M, Briaux JM, Beyer S, Szmukler-Moncler S, Bernard JP. A 7-year life table analysis from a prospective study on ITI implants with special emphasis on the use of short implants. Results from a private practice. Clin Oral Implants Res 2004; 15:150-7.
65. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (I) Success criteria and epidemiology. Eur J Oral Sci 1998; 106:527-51.
66. Nedir R, Bischof M, Szmukler-Moncler S, Belser UC, Samson J. Prosthetic complications with dental implants: from an up-to-8-year experience in private practice. Int J Oral Maxillofac Implants 2006; 21:919-28.
67. Scharf DR, Tarnow DP. Success rates of osseointegration for implants placed under sterile versus clean conditions. J Periodontol 1993; 64:954-6.
68. Buser D, von Arx T. Surgical procedures in partially edentulous patients with ITI implants. Clin Oral Implants Res 2000; 11 Suppl 1:83-100.

69. Hämmerle CH, Ingold HP, Lang NP. Evaluation of clinical and radiographic scoring methods before and after initial periodontal therapy. J Clin Periodontol 1990; 17:255-63.
70. Arlin ML. Survival and success of sandblasted, large-grit, acid-etched and titanium plasma-sprayed implants: a retrospective study. J Can Dent Assoc 2007; 73:821.
71. Cochran DL, Buser D, ten Bruggenkate CM, Weingart D, Taylor TM, Bernard JP, Peters F, Simpson JP. The use of reduced healing times on ITI implants with a sandblasted and acid-etched (SLA) surface: early results from clinical trials on ITI SLA implants.Clin Oral Implants Res 2002; 13:144-53.
72. Cochran DL, Schenk RK, Lussi A, Higginbottom FL, Buser D.Bone response to unloaded and loaded titanium implants with a sandblasted and acid-etched surface: a histometric study in the canine mandible. J Biomed Mater Res 1998; 40:1-11.
73. Bornstein MM, Schmid B, Belser UC, Lussi A, Buser D. Early loading of non-submerged titanium implants with a sandblasted and acid-etched surface. 5-year results of a prospective study in partially edentulous patients. Clin Oral Implants Res 2005; 16:631-8.
74. Roccuzzo M, Wilson TG. A prospective study evaluating a protocol for 6 weeks' loading of SLA implants in the posterior maxilla. Clin Oral Implants Res 2002: 13: 502–7.
75. DeLuca S, Zarb G. The effect of smoking on osseointegrated dental implants. Part II: Peri-implant bone loss. Int J Prosthodont 2006; 19:560-6.
76. Gruica B, Wang HY, Lang NP, Buser D. Impact of IL-1 genotype and smoking status on the prognosis of osseointegrated implants. Clin Oral Implants Res 2004; 15:393-400.
77. Carlsson GE, Lindquist LW, Jemt T. Long-term marginal peri-implant bone loss in edentulous patients. Int J Prosthodont 2000; 13:295-302.
78. Ozkan Y, Ozcan M, Akoglu B, Ucankale M, Kulak-Ozkan Y. Three-year treatment outcomes with three brands of implants placed in the posterior maxilla and mandible of partially edentulous patients. J Prosthet Dent 2007; 97:78-84.
79. Quirynen M, Naert I, van Steenberghe D, Nys L. A study of 589 consecutive implants supporting complete fixed prostheses. Part I: Periodontal aspects. J Prosthet Dent 1992; 68:655-63.
80. Carmagnola D, Araujo M, Berglundh T, Albrektsson T, Lindhe J. Bone tissue reaction around implants placed in a compromised jaw. J Clin Periodontol 1999; 26: 629-35.
81. Brägger U, Hafeli U, Huber B, Hammerle CH, Lang NP. Evaluation of postsurgical crestal bone levels adjacent to non-submerged dental implants. Clin Oral Implants Res 1998; 9:218-24.
82. Renouard F, Arnoux JP, Sarment DP. Five-mm-diameter implants without a smooth surface collar: report on 98 consecutive placements. Int J Oral Maxillofac Implants 1999; 14:101-7.
83. Ivanoff CJ, Grondahl K, Sennerby L, Bergstrom C, Lekholm U. Influence of variations in implant diameters: a 3- to 5-year retrospective clinical report. Int J Oral Maxillofac Implants 1999; 14:173-80.
84. Block MS, Delgado A, Fontenot MG. The effect of diameter and length of hydroxylapatite-coated dental implants on ultimate pullout force in dog alveolar bone. J Oral Maxillofac Surg 1990; 48:174-8.
85. Bischof M, Nedir R, Abi Najm S, Szmukler-Moncler S, Samson J. A five-year life-table analysis on wide neck ITI implants with prosthetic evaluation and radiographic analysis: results from a private practice. Clin Oral Implants Res 2006; 17:512-20.

86. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal study covering 25 years. J Prosthet Dent 1972; 27:120-32.
87. Penarrocha M, Guarinos J, Sanchis JM, Balaguer J. A retrospective study (1994-1999) of 441 ITI(r) implants in 114 patients followed-up during an average of 2.3 years. Med Oral 2002; 7:144-55.
88. Hanggi MP, Hanggi DC, Schoolfield JD, Meyer J, Cochran DL, Hermann JS. Crestal bone changes around titanium implants. Part I: A retrospective radiographic evaluation in humans comparing two non-submerged implant designs with different machined collar lengths. J Periodontol 2005; 76:791-802.
89. Romeo E, Lops D, Margutti E, Ghisolfi M, Chiapasco M, Vogel G. Long-term survival and success of oral implants in the treatment of full and partial arches: a 7-year prospective study with the ITI dental implant system. Int J Oral Maxillofac Implants 2004; 19:247-59.
90. Kiener P, Oetterli M, Mericske E, Mericske-Stern R. Effectiveness of maxillary overdentures supported by implants: maintenance and prosthetic complications. Int J Prosthodont 2001; 14:133-40.
91. Oetterli M, Kiener P, Mericske-Stern R. A longitudinal study on mandibular implants supporting an overdenture: the influence of retention mechanism and anatomic-prosthetic variables on peri-implant parameters. Int J Prosthodont 2001; 14:536-42.
92. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. J Periodontol 2000; 71:546-9.
93. Ivanoff CJ, Grondahl K, Bergstrom C, Lekholm U, Brånemark PI. Influence of bicortical or monocortical anchorage on maxillary implant stability: a 15-year retrospective study of Brånemark system implants. Int J Oral Maxillofac Implants 2000; 15:103-10.
94. Bernard JP, Szmukler-Moncler S, Pessotto S, Vazquez L, Belser UC. The anchorage of Brånemark and ITI implants of different lengths. I. An experimental study in the canine mandible. Clin Oral Implants Res 2003; 14:593-600.
95. Deporter D, Todescan R, Caudry S. Simplifying management of the posterior maxilla using short, porous-surfaced dental implants and simultaneous indirect sinus elevation. Int J Periodont Restorat Dent 2000; 20:476-85.
96. Renouard F, Nisand D. Short implants in the severely resorbed maxilla: a 2-year retrospective clinical study. Clin Implant Dent Relat Res 2005; 7 Suppl 1:104-10.
97. Rokni S, Todescan R, Watson P, Pharoah M, Adegbembo AO, Deporter D. An assessment of crown-to-root ratios with short sintered porous-surfaced implants supporting prostheses in partially edentulous patients. Int J Oral Maxillofac Implants 2005; 20:69-76.