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DISSERTATION

The clinical retrospective analysis of fixed and removable implant-supported prostheses in edentulous patients-a 10-year study

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1. Introduction

Health, fun and aesthetics are the modern concepts in our life, health includes good teeth which are essential for a good quality of life. Even though dental science has advanced and the rate of edentulism among the elderly is continually decreasing, edentulism is considered a major health problem, affecting millions of individuals throughout the world. According to World Health Organization criteria (WHO 2001), edentulism is considered a physical impairment since important body parts have been lost. Edentulism not only affects the self-confidence, but also has a dramatic impact on the quality of life. When teeth are removed, “Mother Nature” assumes there is no need for the bone that supported the teeth. Over time the bone slowly, but progressively diminishes, the upper and lower jaw bones resorb (Atwood, D. A. 1971; Atwood, D. A. 1979).

For decades the best solutions for the replacement of missing teeth were bridges, removable partial or full dentures. Dental rehabilitation with traditional removable prostheses in case of atrophic edentulous jaws may create functional problems, because of frequent instability and lack of retention of the prosthesis (Engquist, B. et al. 1988; Naert, I. et al. 1988).

Thanks to the groundbreaking research findings of Brånemark describing the direct contact between bone and titanium endosseous implants and the Swiss research group led by Schroeder (Branemark, P. I. et al. 1977; Schroeder, A. et al. 1981)，the development of various endosseous implant systems that could be used in the clinic has progressed.

The development of titanium dental implants has extended treatment alternatives for completely edentulous patients by retaining either fixed or removable prostheses.

The purpose of this clinical retrospective study was to evaluate the cumulative survival and success rates of 1652 implants that were inserted in the patients rehabilitated with fixed or removable implant-retained prostheses over a mean period of 10 years, and to analyze the proper treatment planning so as to establish general guidelines for selecting fixed or removable implant-retained dentures for dentists or patients.

1.1. Endosseous dental implants

A plethora of implant systems has evolved with preference being given to two-piece implants. Two-piece implants are composed of an anchorage component, termed the 'endosseous dental implant body', which is osseointegrated in the jawbone, and a retentive component, termed the dental implant abutment. The abutment is screw tightened to the implant body and retains the prosthetic component.
Various geometric forms of the dental implant body are used—such as a cylinder, screw, or blade (Binon, P. P. 2000).
Dental implants are root analogues that are surgically placed into the jaw bone and used to support crowns, bridges and dentures. The most common dental implant material is 'commercially pure titanium' which shows adequate strength, is resistant to corrosion and has a modulus of elasticity similar to that of bone (Steinemann, S. G. 1996). Osseointegrated implants as anchors for various prosthetic reconstructions therefore became a predictable treatment option (Lekholm, U. 1993; Zarb, G. A. and Schmitt, A. 1993; Zarb, G. A. and Schmitt, A. 1993).
Since the 1960s, a number of studies have examined the incorporation of threaded titanium implants in bone tissue (Branemark, P. I. et al. 1977; Buser, D. et al. 1994; Cook, S. D. et al. 1987; Ersanli, S. et al. 2005; Fartash, B. et al. 1990; Geesink, R. G. et al. 1987; Gotfredsen, K. et al. 1991; Naert, I. et al. 2002; Schroeder, A. et al. 1981; Shirakura, M. et al. 2003). Osseointegration can be defined as:

- Osseous integration, the apparent direct attachment or connection of osseous tissue to an inert alloplastic material without intervening connective tissue (Branemark, P. I. et al. 1977).
- The process and resultant apparent direct connection of the endogenous material surface and the host bone tissues without intervening connective tissue (Simons, A. M. et al. 1993).
- The interface between alloplastic material and bone (Davis, D. M. 1998).

In a more comprehensive way, osseointegration is characterized as "a direct structural and functional connection between ordered, living bone and the surface of a load-bearing implant" (Listgarten, M. A. et al. 1991).

Osseointegration can be compared with direct fracture healing, it clearly shows a process of direct or primary healing, in which the fragment ends become united by bone, without intermediate fibrous tissue or fibrocartilage formation (Abrahamsson, I. et al. 2004; Albrektsson, T. and Jacobsson, M. 1987; Branemark, P. I. et al. 1977; Schenk, R. K. and Buser, D. 1998; Schroeder, A. et al. 1981; Walter, J. B. 1976). A fundamental difference, however, exists: osseointegration unites bone not to bone, but to an implant surface.

1.1.1. Implant macro design

The macro design or shape of an implant has an important bearing on the bone response which has a great influence on initial stability and subsequent function (Friberg, B. et al. 1991; Jemt, T. et al. 1992; Narhi, T. O. et al. 2001; Palmqvist, S. et al. 1994; Smedberg, J. I. et al. 1993).
A wide variety of different implant shapes have been developed and clinically tested in the past 20 years. Macroscopically, there are two basic types of implants: Screws and cylinders, the most widely used in clinic. In general, a titanium implant of any shape can achieve osseointegration, if primary stability is obtained (Carlsson, G. E. 2000; Hansson, S. 1999; Ivanoff, C. J. et al. 1997). Today, screw-type threaded implants are highly preferred in implant dentistry, since threaded implants offer two major advantages compared to press-fit cylindrical implants (Albrektsson, T. et al. 1988; Zitter, H. and Plenk, H., Jr. 1987). First, the implant threads improve primary implant stability, which is important to avoid micromovements of the implant until osseointegration is achieved, and the threads seem to play an important role for the load transfer from the implant to the surrounding bone (Hutton, J. E. et al. 1995; Karoussis, I. K. et al. 2004; Quirynen, M. et al. 1992).

1.1.2. Implant surface

Since 1977, when Branemark first reported osseointegration of machined titanium (Ti), other studies on improving or enhancing implant-bone bonding or osseointegration by modifying orthopedic and dental implant surfaces have been ongoing (Schroeder, A. et al. 1981). In the past 10 years, surface modifications have received attention by several research teams (Buser, D. et al. 1991; Cochran, D. L. 1999; Martin, W. C. et al. 2001; Schwartz, Z. et al. 1997; Schwartz, Z. et al. 1999).

Implant surfaces can be divided into smooth (machined or turned) and rough on the basis of surface roughness. Surface modifications can be broadly classified into 3 categories:

- Addition of materials of desirable functions to the surface (category 1)
- Conversion of the existing surface into more desirable compositions and/or topographies (category 2)
- Removal of materials from the existing surface to create specific topographies (category 3)

Proper techniques are used to prepare the surface and the roughness ranging from 25-250 μm and are either “additive” or “subtractive” in character. Additive procedures involve coating the implants with titanium or hydroxyapatite using plasma spraying technique or sintering porous beads onto the surface of the implant. Subtraction techniques involve the use of sandblasting followed by an application of acid to etch the surface. Acids such as nitric acid and sulphuric acid are used with proper surface treatment protocols. One such surface is the “SLA” (sandblasted, large-grit, acid-etched) surface, such as Camlog implant system and Straumann implant system (Barewal, R. M. et al. 2003; Esposito, M. et al. 2007).

Branemark implant system and Steri-Oss implant system are with machined implant surface (Branemark, P. I. et al. 1977; Branemark, P. I. et al. 1995).

Surface modification can be achieved by the following physical or chemical techniques (Table 1):

	Physical techniques	Chemical techniques
Category 1	Plasma-spray coating Physical vapor deposition	Biomimetic deposition of calcium phosphate coatings Surface immobilization of functional molecules
Category 2	Ion implantation	Electrochemical oxidations
Category 3	Surface machining Grit-blasting	Acidic etchings

Table 1: Surface modification

The two best documented titanium surfaces in implant dentistry are the machined titanium surface and the SLA surface. Several attempts have been made to improve implant anchorage in bone by modifying the surface characteristics of titanium implants (Attard, N. J. and Zarb, G. A. 2004; Barewal, R. M. et al. 2003; Carlsson, G. E. 2000; Ersanli, S. et al. 2005; Jaffin, R. A. and Berman, C. L. 1991; Jemt, T. 1993; Jemt, T. et al. 1996; Quirynen, M. et al. 1992). Based on numerous studies in the past decade, there is overwhelming scientific evidence that rough titanium surfaces offer significantly better bone anchorage than do machined titanium surfaces. This was evaluated both by histomorphometric evaluation of the bone-implant interface, and by biomechanical studies measuring either pull-out, push-out or removal torque forces (Buser, D. et al. 1991; Carr, A. B. 1998; Gotfredsen, K. et al. 1992; Wennerberg, A. et al. 1995; Wennerberg, A. et al. 1996; Wennerberg, A. et al. 1997; Wong, M. et al. 1995). It is not surprising that rough titanium implants have become increasingly popular in implant dentistry in recent years and are now offered by most implant manufacturers as they have proven clinically successful (Adell, R. et al. 1981; Albrektsson, T. et al. 1986; Buser, D. et al. 2002; Jemt, T. et al. 1996; Naert, I. et al. 2002; Nelson, K. et al. 2006; Nelson, K. et al. 2007; Quirynen, M. et al. 1992; Zarb, G. A. and Schmitt, A. 1993).

1.1.3. Loading conditions

Branemark (Branemark, P. I. et al. 1977) established a protocol stating that the prime requirement for achieving osseointegration was to leave the implants load-free for 6 months in the maxilla and 3 months in the mandible. These waiting periods were said to be necessary to avoid the formation of fibrous tissue around the implant, which would prevent direct bone apposition and, therefore, osseointegration.

Recent scientific literatures show how the waiting periods for loading implants have changed and evolved (Babbush, C. A. et al. 1986; Gatti, C. et al. 2000; Jo, H. Y. et al. 2001; Meyer, U. et al. 2004; Randow, K. et al. 1999; Tarnow, D. P. et al. 1997; Thomas, K. A. et al. 1987; Zubery, Y. et al. 1999).

According to the timing of loading of dental implants, the procedure of loading could be classified into (Kawai, Y. and Taylor, J. A. 2007):

- Immediate loading: loading immediately after surgery. The implants are surgically placed and loaded immediately using a temporary prosthetic restoration (Aparicio, C. et al. 2003; Cochran, D. L. et al. 2004).

- Early loading: loading is initiated in a period up to 12 weeks in maxilla and 6 weeks in mandible post-surgery. Investigations have shown the successful outcome of early loaded implants (Ericsson, I. and Nilner, K. 2002; Nelson, K. et al. 2006).
- Conventional loading: loading is initiated after 12 weeks or more after surgery. The original healing periods as envisaged by different implant systems, typically after 12 weeks in mandible and 24 weeks in maxilla (Esposito, M. et al. 2007; Nelson, K. et al. 2007).

Currently there is no accurate method which precisely determines the optimum period of healing before loading can be commenced. In some circumstances, it has been shown that immediate loading is compatible with subsequent successful osseointegration, providing the bone quality is good and the functional forces can be adequately controlled (Balshi, T. J. and Wolfinger, G. J. 1997; Buser, D. et al. 2002; Buser, D. et al. 1997; Esposito, M. et al. 2007; Jo, H. Y. et al. 2001; Kan, J. Y. and Rungcharassaeng, K. 2000; Randow, K. et al. 1999; Tarnow, D. P. et al. 1997; Zubery, Y. et al. 1999). The ideal time to load implants might be influenced by the type and surface of the implant, the quality of the bone, the use of bone grafts and other yet unknown variables (Balshi, T. J. and Wolfinger, G. J. 1997; Buser, D. et al. 2002; Buser, D. et al. 1997; Esposito, M. et al. 2007; Jo, H. Y. et al. 2001; Kan, J. Y. and Rungcharassaeng, K. 2000; Randow, K. et al. 1999; Tarnow, D. P. et al. 1997; Zubery, Y. et al. 1999).

1.2. Prosthetic considerations for implant-supported prostheses

Two prosthetic designs can be considered when implant-retained prosthodontic treatment is indicated for the completely edentulous arch, which are based on their retention modus which is either fixed or removable (Adell, R. et al. 1981; Attard, N. J. and Zarb, G. A. 2004; Branemark, P. I. et al. 1995; Buser, D. et al. 2002; Lindquist, L. W. et al. 1996; Widbom, C. et al. 2005).

1.2.1. Removable implant-retained overdenture

The consensus meeting in Montreal, Canada, which was held in 2002 indicated that implant overdentures have become the standard options for the restoration of edentulous patients (Cochran, D. L. et al. 2004; Ekelund, J. A. et al. 2003). Several options are available for the retention of the prosthesis:

- Ball retainment

- Magnet retainment
- Telescope retainment
- Bar retainment

The numbers of implants utilized in overdentures are usually two to four for mandibular edentulous patients and four to six in the edentulous maxilla. Several reports have been published on the clinical advantages of implant-retained overdenture configurations over conventional complete dentures in terms of retention, stability, and patients' satisfaction (Meijer, H. J. et al. 2003; Mericske-Stern, R. and Zarb, G. A. 1993; Naert, I. et al. 2004).

1.2.1.1. Ball-retained overdenture

A ball-retained overdenture is a tissue supported conventional overdenture retained by the ball-shaped abutments which are threaded directly into the implants and fit into the female part (sockets) in the denture (Meijer, H. J. et al. 2001; Naert, I. et al. 2004). The indications of the ball-retained overdenture are limited and are shown as follows:

- Financially compromised patients
- Compromised patients with manual dexterity deficiency

Ball-retained overdentures have been described to require more maintenance than do bar-clip retained overdentures (MacEntee, M. I. et al. 2005).

1.2.1.2. Magnet-retained overdenture

A magnetic attachment can be defined as a retention magnetic unit consisting of two parts that attract each other by means of magnetic flux field for increasing retention and stabilisation of the overdentures. A magnetic attachment requires two elements where one of them would be fixed on an implant and the other in the denture. The indications for using magnetically retained overdentures on implants are formulated (Gonda, T. et al. 2004):

- Financially compromised patients
- Retention of complete overdentures in the maxilla or the mandible in patients with manual dexterity deficiency

1.2.1.3. Telescope-retained overdenture

Telescopic crowns were initially introduced as retainers for removable partial dentures (RPDs) at the beginning of the 20th century (Langer, A. 1973; Langer, A. 1980). They are also known as a double crowns, or crown and sleeve coping. These crowns consist of an inner or primary telescopic coping, permanently cemented to an abutment, and a congruent detachable outer or secondary telescopic crown, rigidly connected to a detachable overdenture. The secondary crown engages the primary coping to form a telescopic unit and serves as an anchor for the remainder of the denture. Telescopic-retained overdentures are functionally comparable with conventional fixed dentures and are considered to be a effective replacement for lost teeth and are well tolerated psychologically (Eitner, S. et al. 2008). Retention can be enhanced over a prolonged period by using galvano-telescopic copings, composed of pure 24K gold and deposited directly onto a duplicate or directly onto the abutment, electroformed copings are fairly thin (± 0.2 mm) with a marginal accuracy of 4.0 – 20 µM (Raigrodski, A. J. et al. 1998; Vence, B. S. 1997; Weigl, P. et al. 2000). The successful use of this technology in implant dentistry comprises removable dentures retained by a cone-shaped telescopic crown (Weigl, P. et al. 2000). The retention mechanism of conical double crowns based on electroformed copings is known to give desirable retentive force over a longer period of time (Heckmann, S. M. et al. 2004; Simon, H. and Marchack, C. B. 2004).

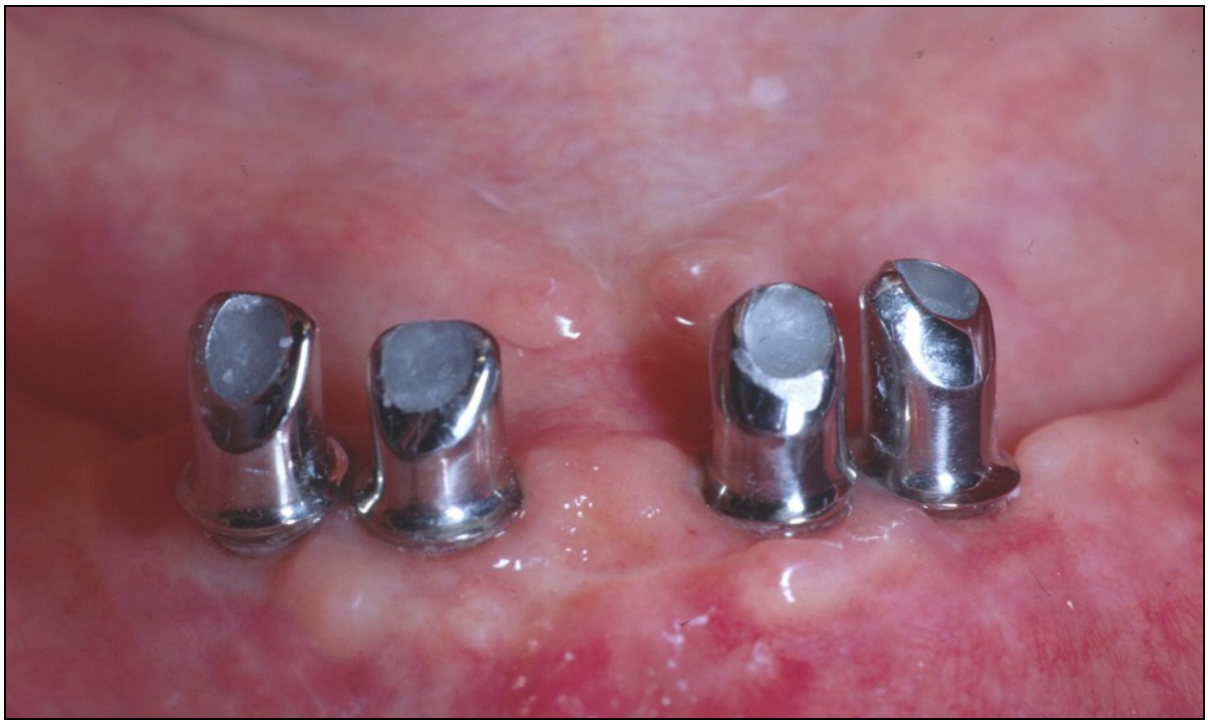

Figure 1: Telescopes for the retention of a mandibular prosthesis

In general, overdentures with less than 4 implants are not implant-supported but implant- retained (Attard, N. J. and Zarb, G. A. 2004; Awad, M. A. et al. 2003; Bakke, M. et al. 2002; Buser, D. et al. 2002; Ekelund, J. A. et al. 2003; Feine, J. S. et al. 2002; Naert, I. et al. 2004; Stellingsma, C. et al. 2004; Widbom, C. et al. 2005; Zitzmann, N. U. and Marinello, C. P. 1999).

1.2.1.4. Bar-retained overdenture

A bar-retained overdenture is a conventional acrylic denture retained by attachments to an implant-supported metal cast (bar). The denture can be either tissue supported or implant supported (Attard, N. J. and Zarb, G. A. 2004). A thin metal bar that follows the curve of the jaw is attached to at least two implants that have been placed in the jawbone. Clips or other types of attachments mate with the bar. The denture fits over the bar and is securely positioned by the attachments. Naert et al. (Naert, I. et al. 1999) found that the bar systems presented the highest retention capacity, when compared with the magnets or ball attachments.

The amount of implants used to support a bar depends on the amount of available bone and also how much financial resource a person is willing to use. Not always, but usually, the more implants, the more retentive the bar. Bars on the upper arch require more

implants than bars on the lower arch due to less bone density in the maxilla and altered stress distribution over the system (Romeo, E. et al. 2002).

Implant-tissue supported overdentures in the mandible were proposed as early as the early 1980s and the classic overdenture design is based on two implants placed in the mandibular canine regions and connected together by a bar which should be parallel to a line drawn between the mandibular condyles (Branemark, P. I. et al. 1977).

A bar and clip is one of the most popular retention aids for an implant-retained overdenture (Batenburg, R. H. et al. 1998; Bergendal, T. and Engquist, B. 1998; Buser, D. et al. 2002; Carlsson, G. E. et al. 2004; Krennmair, G. et al. 2006; Meijer, H. J. et al. 2003).

Different bar systems with corresponding retaining elements are available. They are based on two designs: either a Dolder-bar or an individually milled-bar (Branemark, P. I. et al. 1977; Carr, A. B. 1998; Eckert, S. E. and Carr, A. B. 2004; Ekelund, J. A. et al. 2003; Feine, J. S. et al. 2002; Jemt, T. et al. 1996; Mericske-Stern, R. and Zarb, G. A. 1993; Trakas, T. et al. 2006; Visser, A. et al. 2005). They differ in the design of the bar shape, to allow different degrees of rotational movements and altered distribution of load to the implants in a vertical direction (Romeo, E. et al. 2002).

Dolder-bar system: The oval shaped bar seats on 2 implants allowing rotation while a u-shaped bar sits on more than 2 implants allowing a minimized rotation (Batenburg, R. H. et al. 1998; Krennmair, G. et al. 2006).

Milled-bar system: Comprises an individual fabricated bar with an accurate fit between the mesostructure (carries retention element) and superstructure ensuring overall rigidity. The retention element can be a metal/plastic clip or an electroformed female part.

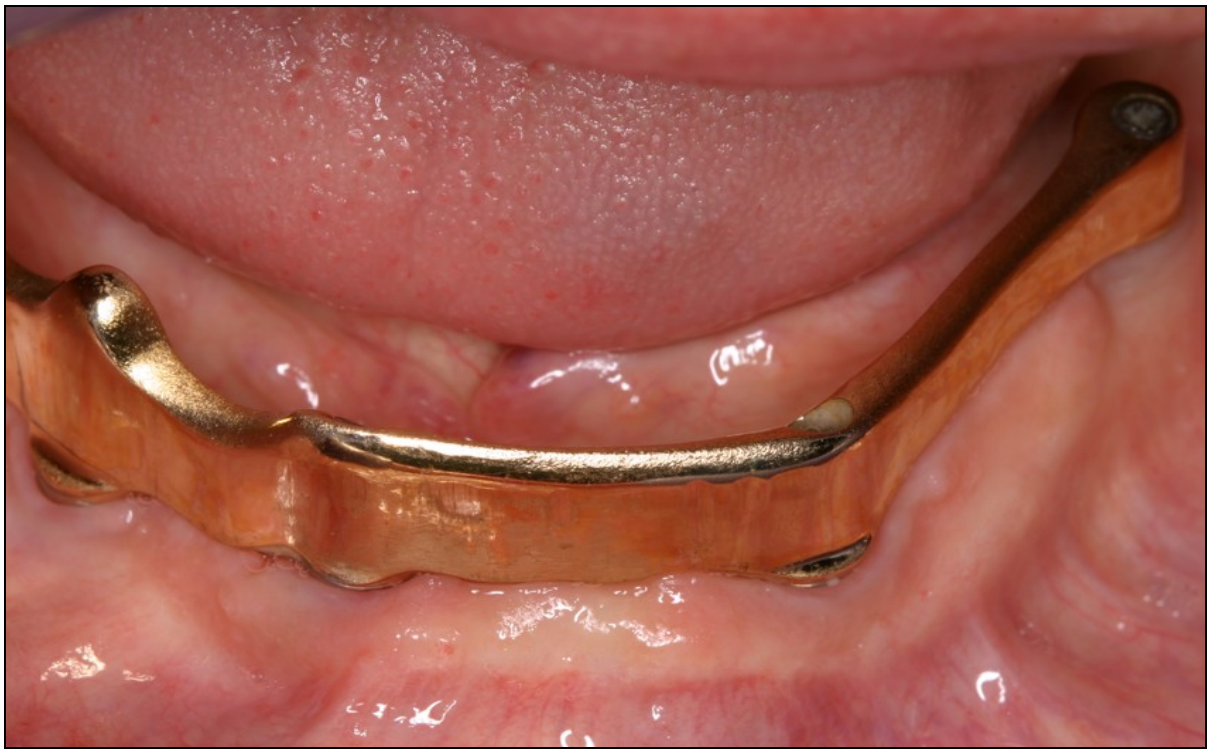

Figure 2: An individually fabricated bar in the edentulous mandible after 5 years of use

The indications of the bar-retained overdenture are as follow:

- Fully edentulous arch
- Extensive bone or soft tissue loss
- Implant-supported restoration (not tissue supported)

1.2.2. Fixed implant-retained prostheses

The fixed implant retained prostheses range from limited span bridges to complete arch restorations for the edentulous jaw. The rehabilitation of edentulous patients with fixed implant restorations has led to numerous implant restorative concepts which are based on two modes of retention: screw-retained and cement-retained prostheses. The screw-retained or cement-retained restorations have shown good results in edentulous patients in past years (Chee, W. et al. 1999; Chee, W. and Jivraj, S. 2006; Hebel, K. S. and Gajjar, R. C. 1997; Heckmann, S. M. et al. 2004; Michalakis, K. X. et al. 2003; Misch, C. E. 1995). Fixed implant-retained restorations require a minimum amount of 4 implants in the mandible and 6 implants in the maxilla (Attard, N. J. and Zarb, G. A. 2004; Branemark, P. I. et al. 1995).

1.2.2.1. Screw-retained implant-supported prostheses

The screw-retained implant-supported prostheses were validated in various studies (Adell, R. et al. 1990; Adell, R. et al. 1981; Zarb, G. A. and Schmitt, A. 1990). Screws may be used to attach prostheses to implants, which have the advantages of retrievability and simplicity of replacement for maintenance of both the restorations and the implants. These restorations were developed in response to the need, but the presence of the access screw hole interferes with good esthetics and structural integrity, and has proved to result in mechanical complications (Chee, W. et al. 1999; Chee, W. and Jivraj, S. 2006; Hebel, K. S. and Gajjar, R. C. 1997; Heckmann, S. M. et al. 2004; Michalakis, K. X. et al. 2003; Misch, C. E. 1995).

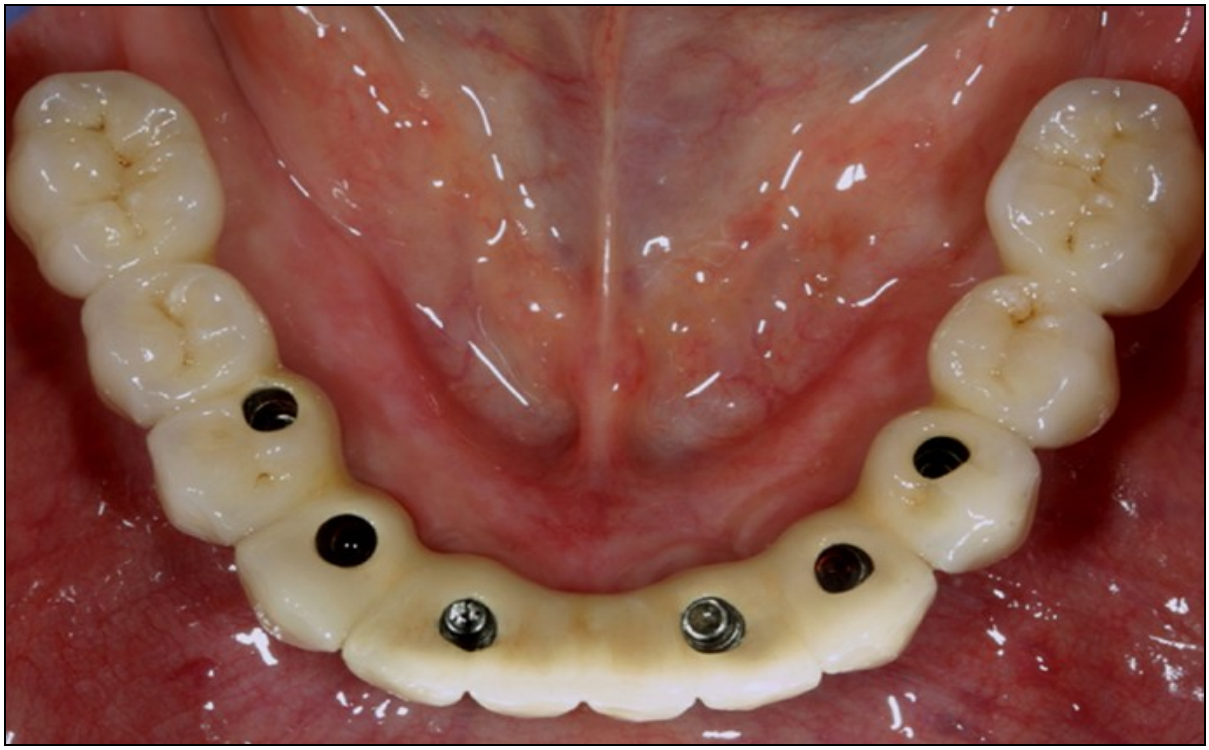

Figure 3: Screw-retained fixed prosthesis in use

1.2.2.2. Cement-retained implant-supported prostheses

Cement-retained prostheses are cemented onto the screw-tightened abutments displaying a higher degree of passive-fit, easier fabrication and good esthetics; but the main disadvantage is the difficulty of retrievability (Chee, W. et al. 1999; Chee, W. and Jivraj, S. 2006; Hebel, K. S. and Gajjar, R. C. 1997; Heckmann, S. M. et al. 2004; Michalakis, K. X. et al. 2003; Misch, C. E. 1995).

Their retrievability depends on the cement used and has been evaluated in in-vitro experiments (Breeding, L. C. et al. 1992; Dixon, D. L. et al. 1992; Michalakis, K. X. et al. 2003; Michalakis, K. X. et al. 2000).

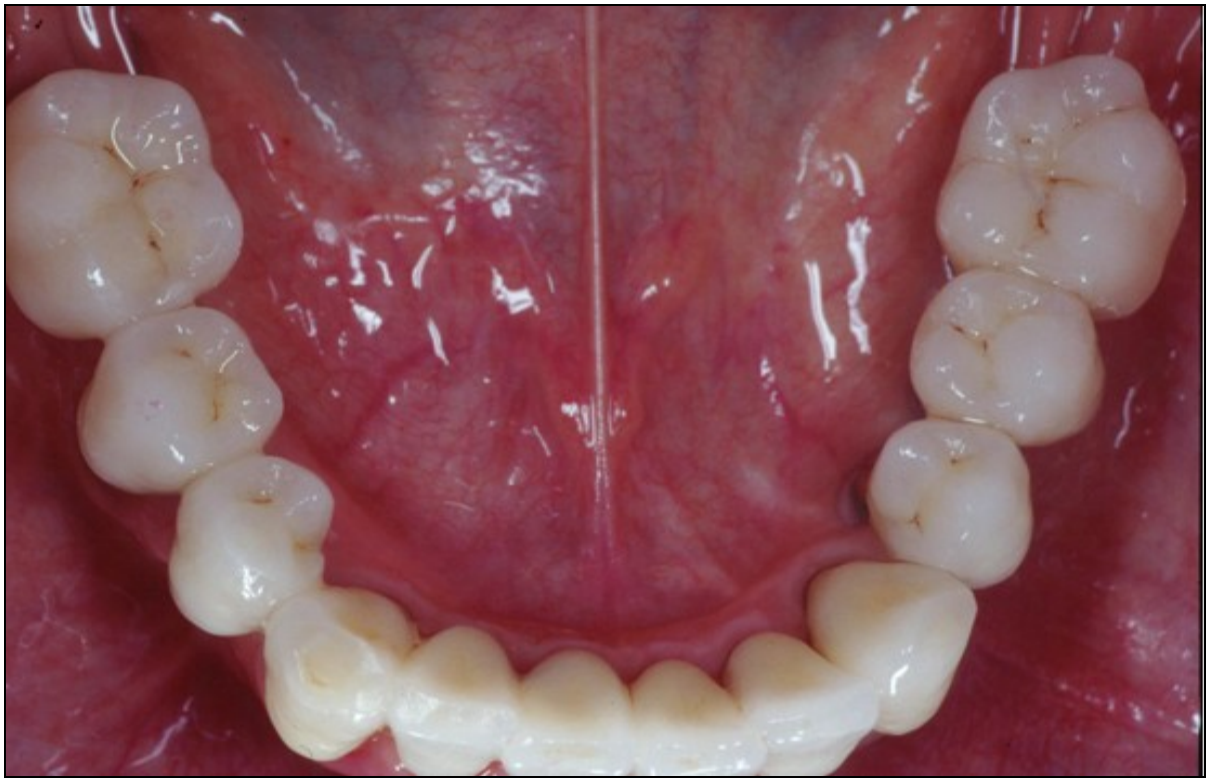

Figure 4: Mandibular cement-retained prosthesis

1.3. Success criteria of implants

Over the last three decades, several parameters and clinical tests have been combined to demonstrate a variety of surrogate endpoints for ‘the success’ of endosseous implants (Anderson, J. D. 1998; Saadoun, A. P. et al. 2004; Sennerby, L. and Roos, J. 1998; Smith, D. E. and Zarb, G. A. 1989). The following parameters are predominantly considered: mobility of the single implant, the peri-implant bone level, radiolucency, the peri-implant probing depth and tissue conditions (Anderson, J. D. 1998; Bakke, M. et al. 2002; Buser, D. et al. 2002; MacEntee, M. I. et al. 2005; Sennerby, L. and Roos, J. 1998; Smith, D. E. and Zarb, G. A. 1989).

The criteria originally delineating success of osseointegrated implants emphasized a condition of no mobility together with stable bone or minimal bone loss around individual implants with time (Albrektsson, T. et al. 1986). These criteria effectively separated osseointegrated implants conceptually from the previous generation of implants, where

less stringent criteria had been applied and a degree of mobility and peri-implant bone loss were accepted (Schnitman, P. A. et al. 1980). Later, amended criteria were advocated, emphasizing that a satisfactorily functioning implant should also meet esthetic requirements (Smith, D. E. and Zarb, G. A. 1989). But Buser's criteria are widely used by clinicians (Buser, D. et al. 2002).

2. Purpose

Variables of prosthetic design must be considered when implant prosthodontic treatment is indicated for the edentulous jaw. There remains little conclusive evidence to guide clinicians or patients as to the optimal type of prosthesis for rehabilitation of the fully edentulous maxilla or mandible.

The purpose of this retrospective, randomized study was to evaluate the cumulative survival and success rates of 1652 implants that were inserted over a period of 10 years so as to test the specific hypothesis that there is no difference in implant survival between fixed and removable implant-supported prostheses in edentulous jaws.

A thorough Chart review was performed to acquire the data used for statistical analysis. Clinical evaluation was performed using an established standard protocol and the success criteria proposed by Buser were applied. Life table analysis of Kaplan-Meier were used to calculate 10-year implant survival rate according to gender, implant location and the various implant types that were used in the study, and a comparison of the parameters was performed to identify a possible success factor. As most commonly reported in implant outcome studies, implant survival and success were assessed from the time of implant placement rather than from prosthesis loading.

3. Materials and Methods

3.1. Patient selection and implants

From January 1995 to January 2006, a total of 287 fully edentulous patients (male/female 116/161) were consecutively registered and treated with endosseous dental implants to be rehabilitated with fixed or removable implant-supported prostheses by three surgeons and two prosthodontists in the Department of Oral, Maxillofacial Surgery, Charite Campus Virchow, Berlin，Germany. A total of 2063 implants were placed in the fully edentulous maxilla, mandible or in both jaws. Special selection criteria for the patients treated with implants were not explicitly applied. Exclusion criteria used only for patients in this study were shown in Table 2:

- Alcoholism or drug abuse within the last five years
- Untreated periodontitis
- Uncontrolled diabetes
- History of leukocyte dysfunction or deficiency
- Metabolic bone disorders
- History of renal failure

Table 2: Exclusion criteria of patients

Patients were also included if they had prior bone augmentation procedure with iliac crest bone or receiving daily medication with coumarin derivates. During the time of Chart review, about 60 patients (male/female 34/26) with 411 implants were excluded because of lack of assessable or complete data, leaving 227 completely edentulous patients with 1652 implants to be evaluated. Of the 227 patients included, 92 were males and 135 females with a mean age of 63.74 years (range from 32.7 - 86.2 years). The monitoring of all patients after implant placement was based on an established standard protocol established for recall evaluation of implant patients in the department (Table 3).

- Visual and digital inspection of prosthetic restoration and/or implants
- Random torque control of implant is performed
- Random measurement of mPBI and mAPI
- Fulfilment of Buser criteria

Table 3: Criteria evaluated during follow-up

Seven different implant systems from four implant companies were used in the study: these were Camlog (Camlog Vertriebs GmbH, Wimsheim, Germany), Steri-Oss, Branemark MKII, Replace (Nobel BioCare AG, Goteberg, Sweden), IMZ (DENTSPLY Friadent, Frankfurt, Germany), Straumann ITI (Institut Straumann AG, Waldenburg, Switzerland) and Zygoma implants (Nobel BioCare AG, Goteberg, Sweden). All implants were with sandblasted, large-grit, acid-etched (SLA) surface or machined surface.

Data regarding age, gender, implant type, implant region, the date of implant placement and healing cap connection, the date of incorporation of prostheses, type of restoration and information on implant loss were evaluated. Clinical and radiologic evaluations were conducted as scheduled. At these review appointments, implant success was examined according to the Buser's criteria in Table 4.

- Absence of mobility of implant - Absence of persistent subjective complaints such as pain, foreign body sensation and/or dysaesthesia - Absence of a recurrent peri-implant infection with suppuration - Absence of a continuous radiolucency around the implant

Table 4: Buser's criteria on implant success

3.2. Surgical procedure

All implants were placed according to the manufacturers' instructions using low-speed drilling for preparation of the implant sites. Two or one-stage surgery was performed. All implants were placed after raising a full-thickness muco-periosteal flap. Stabilization of

the wound margins was performed with a recurrent suture technique. The sutures were removed after 7-10 days. The details of the implants placed were registered in a specific dental record and comprised: brand, diameter and length.

3.3. Prosthetic procedure

An open-tray impression of the implants for the fabrication of the master model was made in all cases using a polyether impression material (Impregum, Espe). Conventional prosthetic steps were followed including a bite-registration and a try-in of a wax-up before the fabrication of the metal-components of the restoration was started. The implant-retained superstructures were classified in two groups: removable or fixed. All abutment screws were tightened with a torque specified by the implant manufacturer.

3.3.1. Removable prostheses

The implant-retained restorations were considered removable when the prostheses, seated on a mesostructure that was tightly fastened to the abutments, were removable by the patient. Removable restorations were subdivided into bar-retained or telescope retained. The bars and telescopes were individually fabricated using a high-gold alloy (Orplid TKF, Hafner, Pforzheim, Germany). In all removable prostheses, acrylic resin artificial teeth (Creapearl; Amann Girrbach, Pforzheim, Germany) and SR-Vivodent or Orthotyp PE (Ivoclar Vivadent, Schaan, Liechtenstein) were used.

3.3.2. Fixed prostheses

The implant-retained fixed dentures were either vertically screwed directly onto the implant fixture or cemented on screw-tightened abutments using a provisional luting agent (ImProv, NobelBiocare, Sweden). A differentiation of the two subtypes (screwed or cemented) was not performed. The fabrication procedure of the cement-retained restoration has been described in detail (Nelson, K. et al. 2008).

3.4. Post-surgical phase

After implant placement and during the healing period, the patients were referred for a clinical and radiographic evaluation. During clinical evaluation, disturbed wound healing or signs of infection and inflammation were monitored. Orthopantomographic x-rays were taken using ORTHOPHOS XG (Siemens Dental System, Bensheim, Germany) or Oralix 9200 pan oral imaging system (Gendex Dental Systems, Chicago, USA). The timepoint of loading of the implants varied, with most of the implants being loaded after reduced healing times. Definitive prosthetic rehabilitation was initiated when the implants were successfully integrated and the torque value of the individual implant was ≥ 35 Ncm. The healing date and the rehabilitation date were recorded. The healing duration was defined as the period from the date implants were inserted into the jaw to the date when healing-caps were connected or the prosthetic phase was initiated.

3.5. Clinical evaluation

The patients were routinely seen for clinical examination at 4 weeks after prosthetic restoration, and every 3 months thereafter during the first year. In the second year the recall took place twice and further follow-ups were scheduled annually. The annual clinical evaluation included the assessment of several parameters as described in Table 4. Orthopantomographic x-rays were performed twice in the first year and once in the following years using ORTHOPHOS XG (Siemens Dental System, Bensheim, Germany) or Oralix 9200 pan oral imaging system (Gendex Dental Systems, Chicago, USA). Implants were considered successful if the Buser's criteria were met (Table 4), otherwise the implants were considered implant failure. All patients were enrolled in an oral-hygiene program.

3.6. Statistical analysis

Descriptive analysis was performed with all data available. All the restored implants had completed at least the 1-year examination. Chart review was conducted, and life-table analysis was performed using the Kaplan-Meier method. Statistical analysis was accomplished using SPSS 11.5 for Windows, Chi-square test was used for comparative

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

4. Results

4.1. Implant localization and gender

A total of 227 edentulous patients (92 males, 135 females) were treated with endosseous dental implants and rehabilitated with fixed or removable implant-retained prostheses.

The age of the patients in January 2006 was 32.7 to 86.2 year-old, the mean age was 63.7 years. The distribution of patients and their ages is shown in Figure 5.

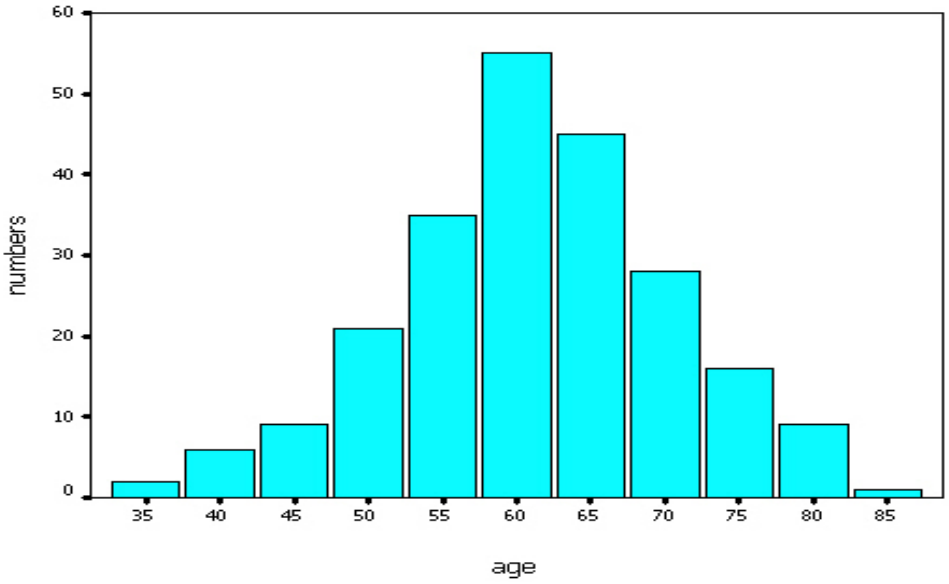

Figure 5: Age distribution of the patients

60 participating patients (22 males, 38 females) were completely edentulous in the maxilla and 86 patients (36 males, 50 females) were completely edentulous in the mandible, they had remaining teeth in the opposite jaw， whereas 81 patients of this study (36 males, 45 females) were completely edentulous in maxilla and mandible (Figure 6).

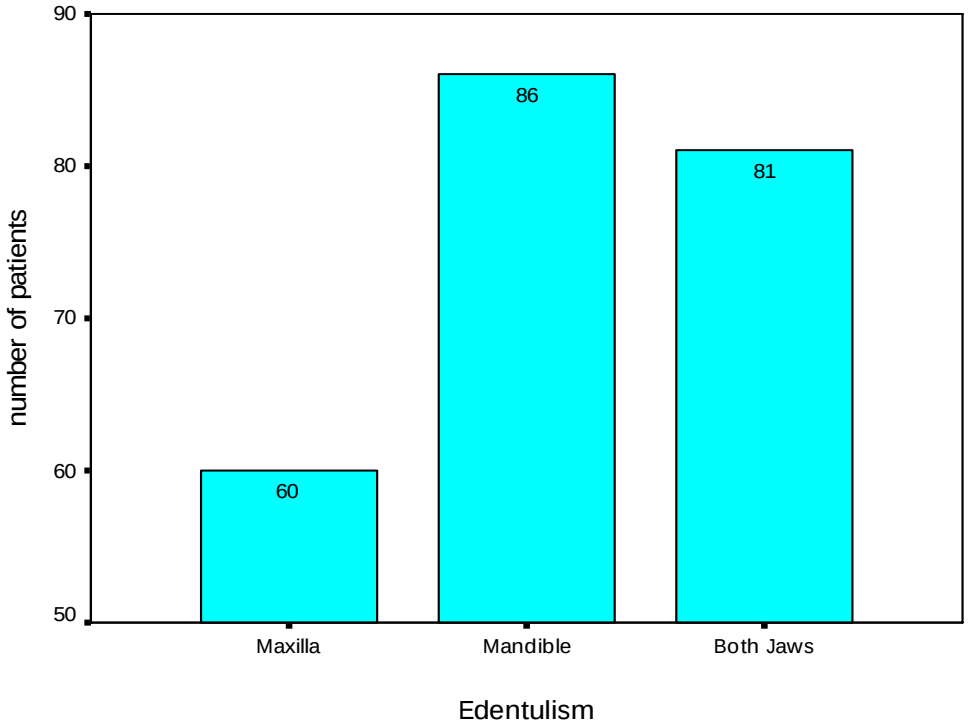

Figure 6: Distribution of edentulism in the jaw

A total of 1652 implants were monitored, 866 of them (52.42%) were located in the maxilla and 786 implants (47.58 %) in the mandible (Table 5). With regard to gender, 711 implants (43.04 %) were inserted in male and 941 implants (56.96%) were inserted in female (Table 5).

	Male	Female	Total(n)	Total (%)
Maxilla	365	501	866	52.42
Mandible	346	440	786	47.58
Total(n)	711	941	1652	
Total (%)	43.04	56.96		100

Table 5: Distribution of implants in gender

The detailed localization of 1652 implants is shown in Table 6. As to location of implants inserted, 942 (57.02%) and 710 implants (42.98%) were inserted in anterior and posterior region of jawbone, respectively (Table 7).

18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28	Total
2	**12**	**26**	**49**	**88**	**96**	**97**	**67**	**76**	**85**	**87**	**88**	**50**	**29**	**13**	**1**	**866**
48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38	
	9	**30**	**34**	**105**	**57**	**108**	**43**	**52**	**107**	**67**	**98**	**34**	**31**	**11**		**786**

Table 6: The localization of 1652 implants (WHO)

	Anterior	Posterior	Total(n)	Total (%)
Maxilla	508	358	866	52.42
Mandible	434	352	786	47.58
Total(n)	942	710	1652	(100)
Total (%)	57.02	42.98	(100)	

Table 7: Distribution of implants in region

In the maxilla, 684 implants (78.98%) were placed in regions 14 to 24 (Figure 7). In the mandible, 637 implants (81.04%) were placed in regions 34 to 44 with a predominance of lateral incisor and first premolar region (Figure 8).

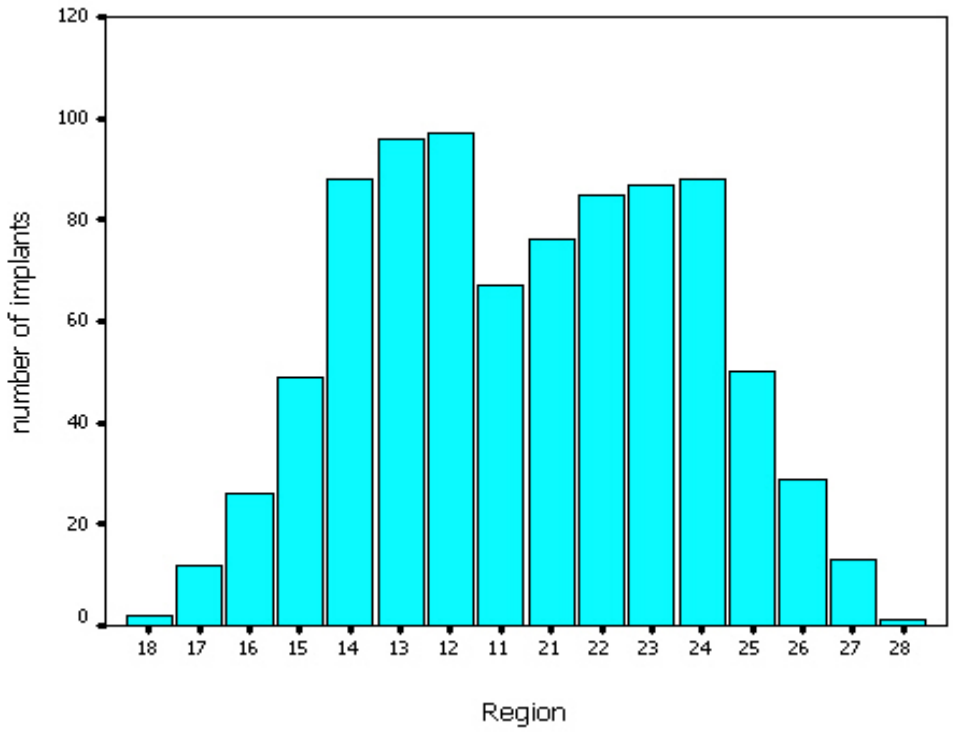

Figure 7: The localization of implants in maxilla

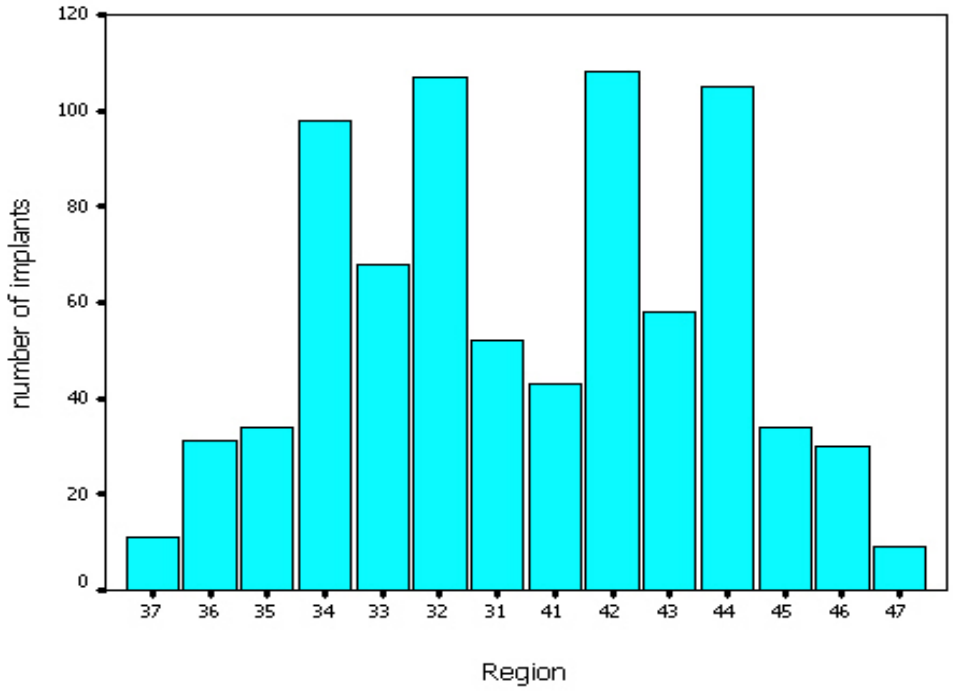

Figure 8: The localization of implants in mandible

4.2. Types of implants

Seven different implant systems were utilized, being: Camlog system; Sterio-Oss system; Branemark system; Straumann system; Replace system; IMZ system and Zygomaimplant system, the distribution of the different implant system is shown in Figure 9. Of the 1652 implants, four implant systems were mainly used with two surface modifications of implant, these were the Camlog implant system (55.08%) with rough surface, the Steri-Oss implant system (21.37%) with machined surface, the Branemark implant system (11.99%) with machined surface and the Straumann implant system (7.63%) with rough surface.

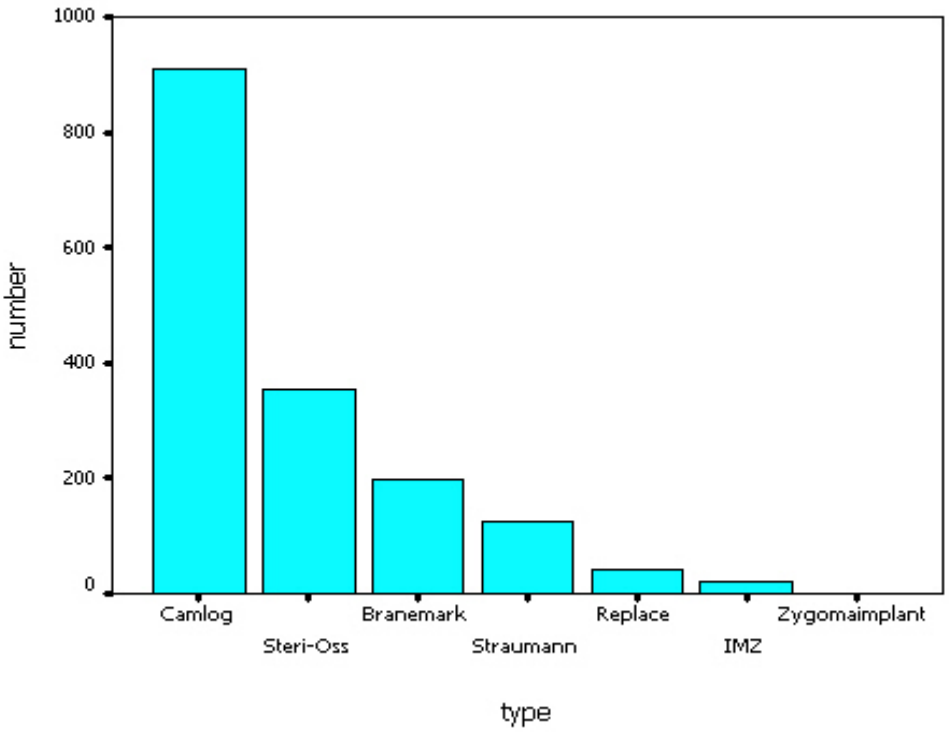

Figure 9: The distribution of implant systems

Usually one implant system was used in one patient, but still there were 34 patients (14.98%) who received two kinds of implant system. Of the 1652 inserted implants, the Camlog implant system accounted for 910 implants (55.08%), the Sterio-Oss system for 353 implants (21.37%), the Branemark system for 198 implants (11.99%), and the Straumann system for 126 implants (7.63%). The distribution of the different implant systems according to jaw and gender is listed in Table 8 and 9.

Type	Maxilla	Mandible	Total	Relative ratio (%)
Camlog	526	384	910	55.08
Steri-Oss	164	189	353	21.37
Branemark	72	126	198	11.99
Straumann	53	73	126	7.63
Replace	37	6	43	2.60
IMZ	13	8	21	1.27
Zygomaimplant	1	0	1	0.06
Total	866	786	1652	100

Table 8: Distribution of implant system in jaws

Type	Male(n)	Female(n)	Total(n)	Total (%)
Camlog	395(57)	515(85)	910(142)	55.08
Steri-Oss	120(22)	233(35)	353(57)	21.37
Branemark	84(11)	114(18)	198(29)	11.99
Straumann	68(10)	58(12)	126(22)	7.63
Replace	33(6)	10(2)	43(8)	2.60
IMZ	10(1)	11(1)	21(2)	1.27
Zygomaimplant	1(1)		1(1)	0.06
Total(n)	711(108)	941(153)	1652(261)	100

Table 9: Distribution of various implant systems in gender, n= number of patients

4.3. The number of implant-retaining prostheses

The number of implants used to retain prostheses differed in the jaws. In the maxilla and mandible, usually 6 to 8 implants and 4 to 6 implants were inserted, respectively (Figures 10, 11). At least 3 implants and 2 implants were placed to support prostheses in maxilla and mandible, respectively. The detailed data are listed in Tables 10 & 11 and the corresponding graph is shown in Figures 10 & 11.

No. of retained implants	No. of prostheses	No. of implants	Relative ratio of prostheses
3 implants	2	6	0.014184
4 implants	29	116	0.205674
5 implants	10	50	0.070922
6 implants	**59**	**354**	**0.41844**
7 implants	10	70	0.070922
8 implants	**21**	**168**	**0.148936**
9 implants	5	45	0.035461
10 implants	2	20	0.014184
11 implants	2	22	0.014184
15 implants	1	15	0.007092
Total	141	866	1

Table 10: Distribution of retained implants and prostheses in maxilla

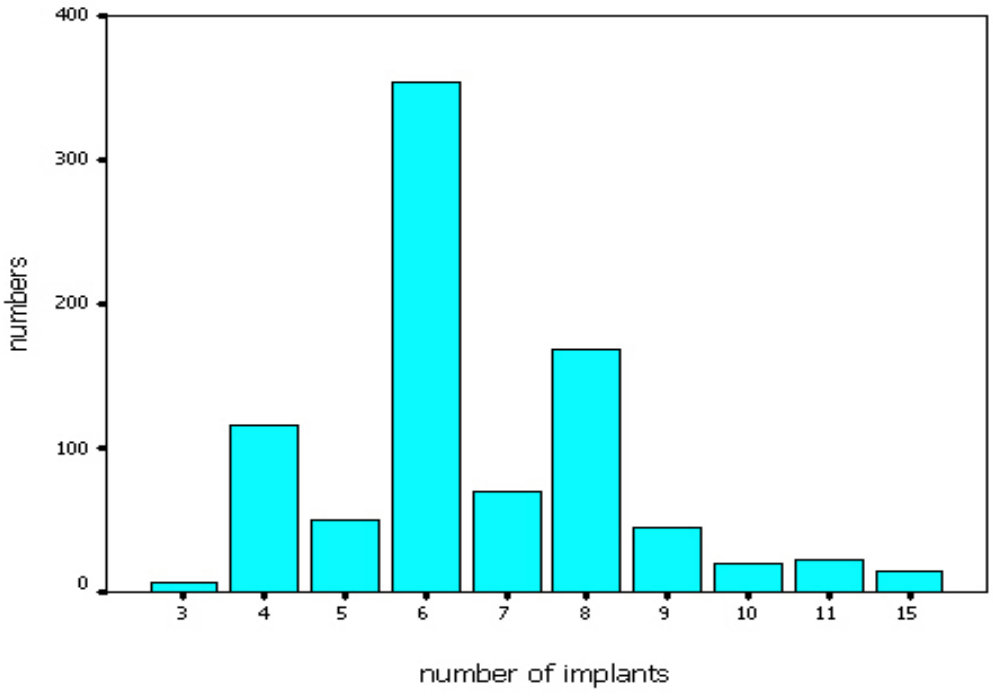

Figure 10: Distribution of retained implants in maxilla

No.of retained implants	No. of prostheses	No. of implants	Relative ratio of prostheses
2 implants	7	14	0.041916
3 implants	11	33	0.065868
4 implants	**77**	**308**	**0.461078**
5 implants	**30**	**150**	**0.179641**
6 implants	**26**	**156**	**0.155689**
7 implants	9	63	0.053892
8 implants	3	24	0.017964
9 implants	2	18	0.011976
10 implants	2	20	0.011976
Total	167	786	1

Table 11: Distribution of retained implants in mandible

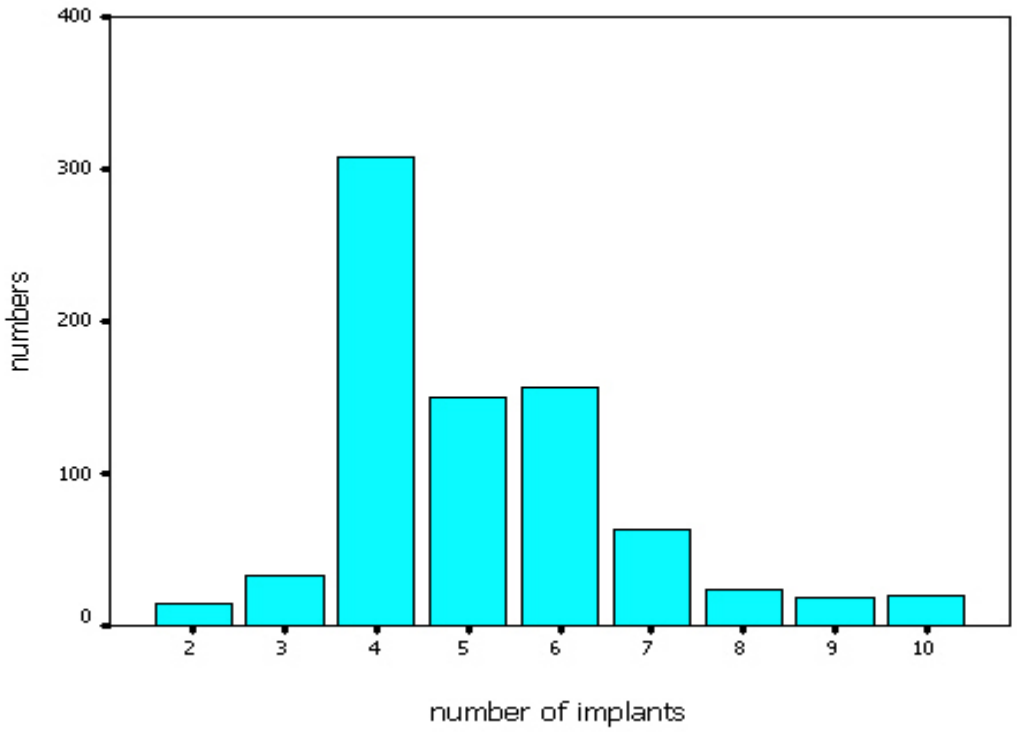

Figure 11: Distribution of retained implants in mandible

4.4. Prosthetic rehabilitation

A total of 308 prostheses were assembled in 227 patients with 76 fixed prostheses (24.68%) and 232 removable prostheses (75.32%), see Figure 12. 60 patients fully edentulous in the maxilla (male/female 22/38) were rehabilitated with 15 fixed (male/female 6/9) and 45 removable (male/female 16/29) implant-supported prostheses, 86 patients fully edentulous in the mandible (male/female 36/50) were rehabilitated with 7 fixed (male/female 6/1) and 79 removable (male/female 30/49) implant-retained prostheses, 81 patients fully edentulous in the maxilla and mandible (male/female 36/45) were rehabilitated in both jaws with 162 prostheses. Of 81 patients fully edentulous in both jaws, 21 patients (12 male, 9 female) were rehabilitated with fixed prostheses in the maxilla and mandible; 48 patients (19 male, 29 female) were rehabilitated with removable prostheses in both jaws; 12 patients (5 male, 7 female) received a fixed and a removable dentures. Of these 12 patients, 7 patients (male 4, female 3) were rehabilitated with fixed prostheses in the mandible and removable prostheses in the maxilla; 5 patients (1 male, 4 female) were rehabilitated with removable prostheses in the mandible and fixed prostheses in the maxilla, which made a total 54 fixed and 108 removable implant-retained prostheses in 81 patients with fully edentulous in both jaws. A detailed distribution of prosthetic projects and implants is listed in Tables 12 and 13.

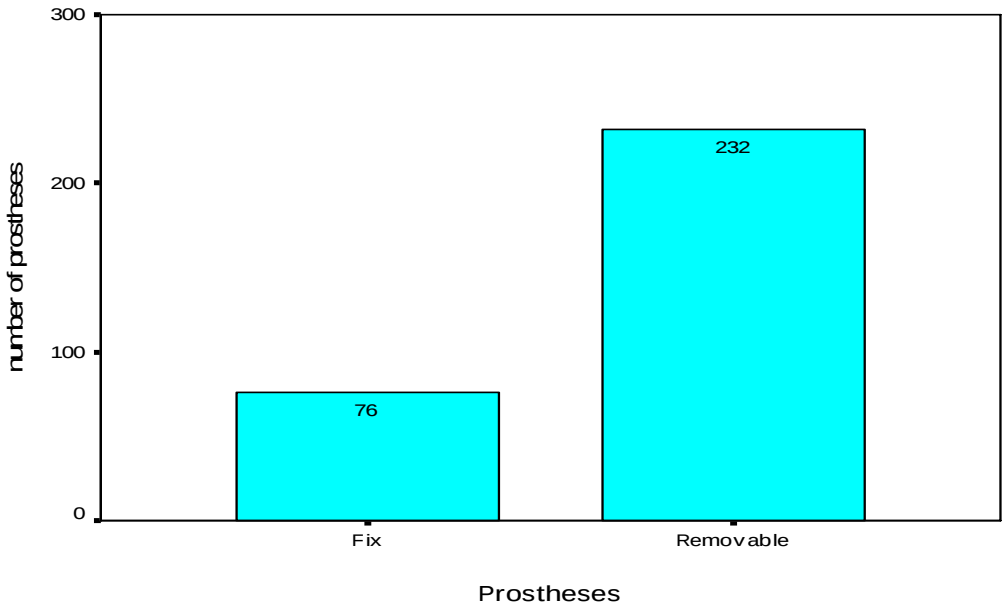

Figure 12: The distribution of prostheses

	No. of implants	No. of prostheses	Relative ratio of prostheses
Maxilla rem	564	100	0.324675
Maxilla fix	302	41	0.133117
Mandible rem	578	132	0.428571
Mandible fix	208	35	0.113636
Total	1652	308	1

Table 12: Implant distribution in different types of rehabilitation

Prosthetic project	Gender(M/F)	No. of patients	No. of prostheses	Ratio of prostheses (%)	No. of implants
Max fix	M	6	6	1.95	46
	F	9	9	2.92	61
Max rem	M	16	16	5.19	90
	F	29	29	9.42	172
Max/Man fix	M	12	24	7.79	168
	F	9	18	5.84	118
Max/Man rem	M	19	38	12.34	285
	F	29	58	18.83	200
Max fix/Man rem	M	1	2	0.65	14
	F	4	8	2.60	47
Max rem/Man fix	M	4	8	2.60	42
	F	3	6	1.95	31
Man fix	M	6	6	1.95	32
	F	1	1	0.32	6
Man rem	M	30	30	9.74	127
	F	49	49	15.91	213
Total(n)		227	308	100	1652

Table 13: Distribution of prosthetic rehabilitation of patients in jawbone
F=female, M=male, Max fix =maxilla fixed implant-retained prostheses, Max rem=maxilla removable implant-retained prostheses, Man fix=mandible fixed implant-retained prostheses, Man rem=mandible removable implant-retained prostheses.

4.4.1. Removable implant-supported prostheses

The 232 removable implant-retained overdentures (100 overdentures were in the maxilla and 132 overdentures in the mandible) were supported by 1142 implants (564 implants in maxilla and 578 implants in mandible). There were two types of retaining methods: bar-retained and telescope-retained. Most of the patients were rehabilitated by using bar-retained overdenture (98.70%), only three patients (two female patients and one male patient) were rehabilitated by using telescope-retained overdenture

(1.30%), two telescope-retained prostheses were in the maxilla and one telescope-retained prosthesis was in the mandible. The distribution of the bar-retained and telescope-retained removable prostheses with regard to the number of implants is listed in Tables 14 and 15.

	Gender	No. of Bar-retained overdentures	No. of telescope-retained overdentures	No. of overdentures
Max	M	38	1	39
rem	F	60	1	61
Man	M	50	0	50
rem	F	81	1	82
Total(n)		229	3	232
Ratio (%)		98.70	1.30	100

Table 14: The distribution of removable overdentures

	No. of implants (Bar-retained overdenture)	No. of Implants (Telescope-retained overdenture)	Total
Max rem	554	10	564
Man rem	574	4	578
Total	1128	14	1142

Table 15: Distribution of implants in removable overdentures

The implant-retained removable overdentures in the maxilla were usually supported by 6 implants, at least 3 implants in the maxilla were supported in each removable overdenture, whereas in the mandible the overdentures were mainly supported by 4 implants and at least 2 implants were retained in each removable overdenture (Figure 13, 14).

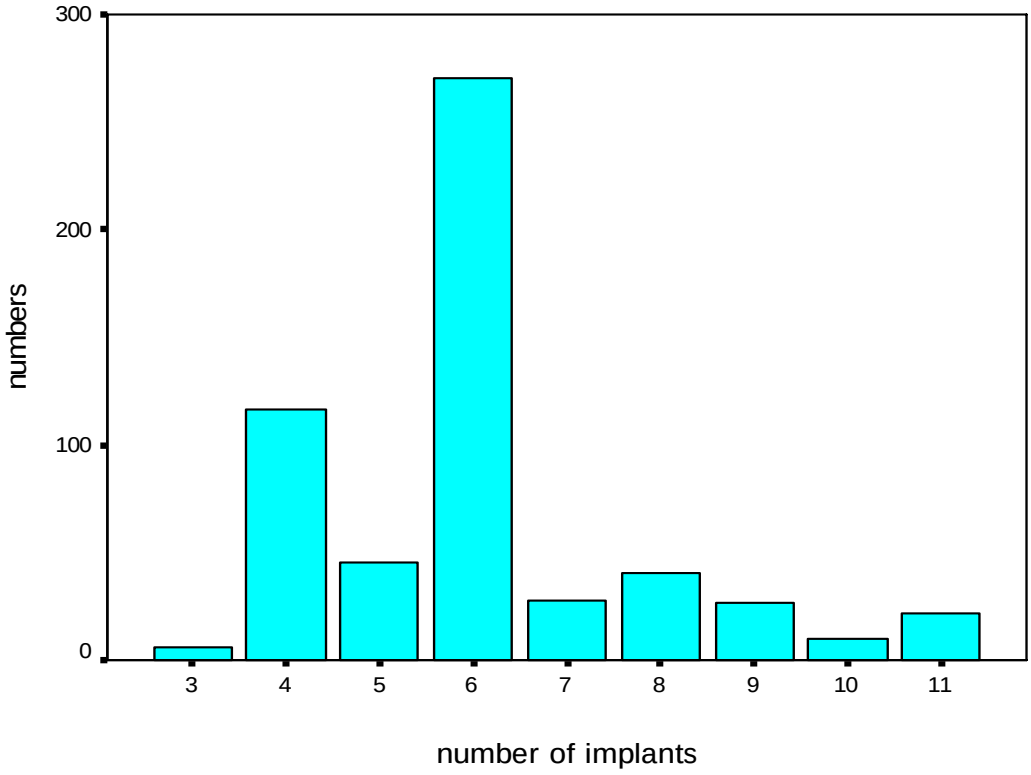

Figure 13: Distribution of implants and overdentures in maxilla

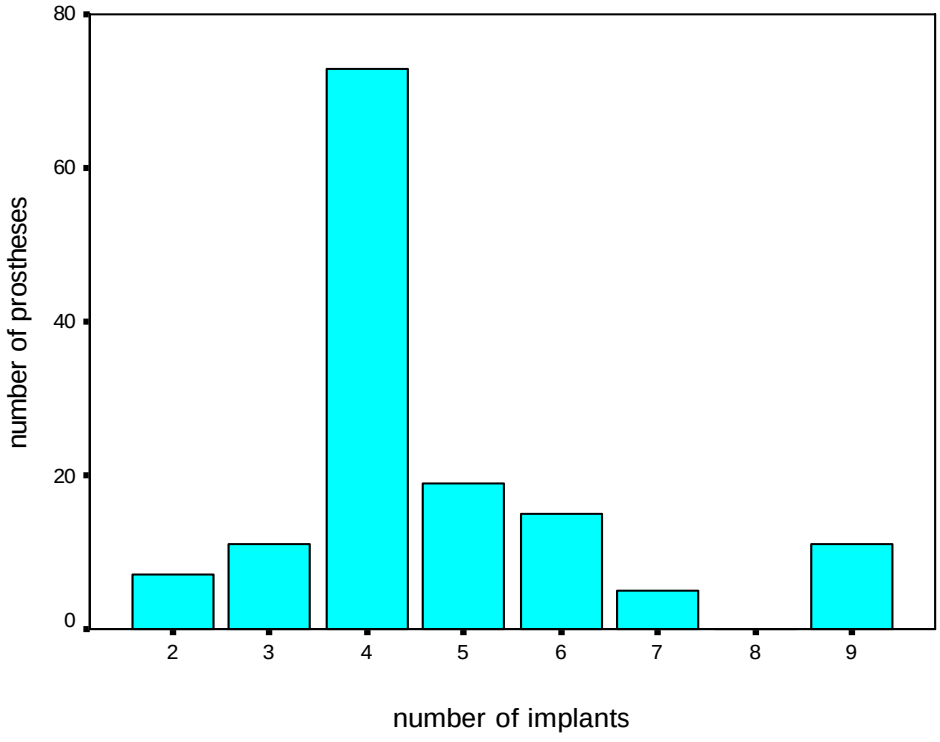

Figure 14: Distribution of implants and overdentures in mandible

4.4.2. Fixed implant-supported prostheses

Seventy-six fixed implant-supported prostheses (41 fixed prostheses in maxilla and 35 fixed prostheses in mandible) were supported by 510 implants (302 implants were placed in the maxilla and 208 implants in the mandible). In the maxilla, the fixed implant-retained prostheses were usually supported by 6-8 implants, a reduced implant number was used in one female patient who was treated with five implants for a fixed prosthesis with the introduction of the shortened dental arch concept (Table 16). In the mandible they were often supported by 5-6 implants, a reduced implant number was used in four female patients who were treated with four implants for a fixed prosthesis also with the introduction of the shortened dental arch concept (Table 17).

No. of retained implants	No. of fixed prostheses	Relative ratio of fixed prostheses	No. of implants
5 implants	1	0.02439	5
6 implants	**14**	**0.341463**	**84**
7 implants	**6**	**0.146341**	**42**
8 implants	**16**	**0.390244**	**128**
9 implants	2	0.04878	18
10 implants	1	0.02439	10
15 implants	1	0.02439	15
Total	41	1	302

Table 16: Distribution of retained-implants in fixed prostheses in maxilla

No. of retained implants	No. of fixed prostheses	Relative ratio of fixed Prostheses (%)	No.of implants
4 implants	4	0.114286	16
5 implants	**11**	**0.314286**	**55**
6 implants	**11**	**0.314286**	**66**
7 implants	4	0.114286	28
8 implants	3	0.085714	24
9 implants	1	0.028571	9
10 implants	1	0.028571	10
Total	35	1	208

Table 17: Distribution of retained-implants in fixed prostheses in mandible

Twenty-four fixed prostheses (31.58%) were cement-retained by using an electroforming crown supported by 159 implants, 52 screw-retained prostheses (68.42%) were supported by 351 implants. The detailed distribution is listed in Tables 18 and 19.

	Gender	No. of screw-retained prostheses	No. of cement-retained prostheses	Number of fixed prostheses
Max fix	M	9	10	19
	F	16	6	22
Man fix	M	18	4	22
	F	9	4	13
Total(n)		52	24	76
Ratio (%)		68.42	31.58	100

Table 18: Distribution of the fixed screw- / cement- retained prostheses

	No. of implants (screw-retained)	No. of implants (telescope-retained)	Total No.of implants
Max fix	202	100	302
Man fix	149	59	208
Total	351	159	510
Ratio (%)	68.82	21.18	100

Table 19: Distribution of implants in fixed prostheses

Seven different kinds of implant systems were used for fixed and removable implant-retained prostheses in this study, they were Camlog implant system, Steri-Oss implant system, Branemark implant system, Replace implant system Zygoma implant, Straumann and IMZ implant system. Camlog (55.08%), Steri-Oss (21.37%), Branemark (11.99%) and Straumann implant systems (7.63%) were used in most cases in this study (Table 20, 21).

Type	Max fix	Max rem	Man fix	Man rem	Total	Total (%)
Camlog	232	298	144	236	910	55.08
Steri-Oss	39	124	42	148	353	21.37
Branemark	23	50	8	117	198	11.99
Straumann	8	45	10	63	126	7.63
Replace		33	4	6	43	2.60
IMZ		13		8	21	1.27
Zygoma		1			1	0.06
Total	302	564	208	578	1652	
Total (%)	18.28	34.14	12.59	34.99		100

Table 20: Distribution of implant systems and prostheses

Max fix =maxilla fixed implant-retained prostheses, Max rem=maxilla removable implant-retained prostheses, Man fix=mandible fixed implant-retained prostheses, Man rem=mandible removable implant-retained prostheses

Type	Max fix	Max rem	Max/ Man fix	Max/ Man rem	Max fix/Man rem	Max rem/Man fix	Man fix	Man rem	Total	Total (%)
Camlog	100	163	229	225	16	28	22	127	910	55.08
Steri-Oss	7	47	33	125	19	24	11	87	353	21.37
Branemark		20	24	52	12			90	198	11.99
Straumann		21		39	14	11	5	36	126	7.63
Replace		10		23		10			43	2.60
IMZ				21					21	1.27
Zygoma		1							1	0.06
Total	107	262	286	485	61	73	38	340	1652	
Total (%)	6.48	15.86	17.31	29.36	3.69	4.42	2.30	20.58		100

Table 21: Distribution of implant systems in different prosthetic projects

4.5. Time periods

After the implants were inserted in the jaw, the healing duration, rehabilitation duration and the duration for prostheses in function were documented. The healing duration was defined as the interval from the date when implants were placed into jawbone to the date when healing caps were connected (or secondary surgery) in the jawbone**.** The observation duration was defined as the interval from the date when prostheses were assembled in function to the time-point date scheduled on 1st Jan 2006.

4.5.1. Healing duration (from implant placement to secondary surgery)

The healing duration showed a wide interval from immediate loading (0 days) to 230 days, the most frequent duration was from 80 days to 140 days, the mean healing duration in the jaw was 104.06 days, in the maxilla 110.07 days; in the mandible 97.45 days (Table 22). The healing duration in jawbone is shown in Figures 15, 16 and 17.

	Minimum duration(days)	Maximum duration(days)	Mean duration(days)	SD(day)
Maxilla	0	230	110.07	45.57
Mandible	0	230	97.45	44.71
Jawbone	0	230	104.06	45.59

Table 22: Descriptive statistics of healing duration in jawbone

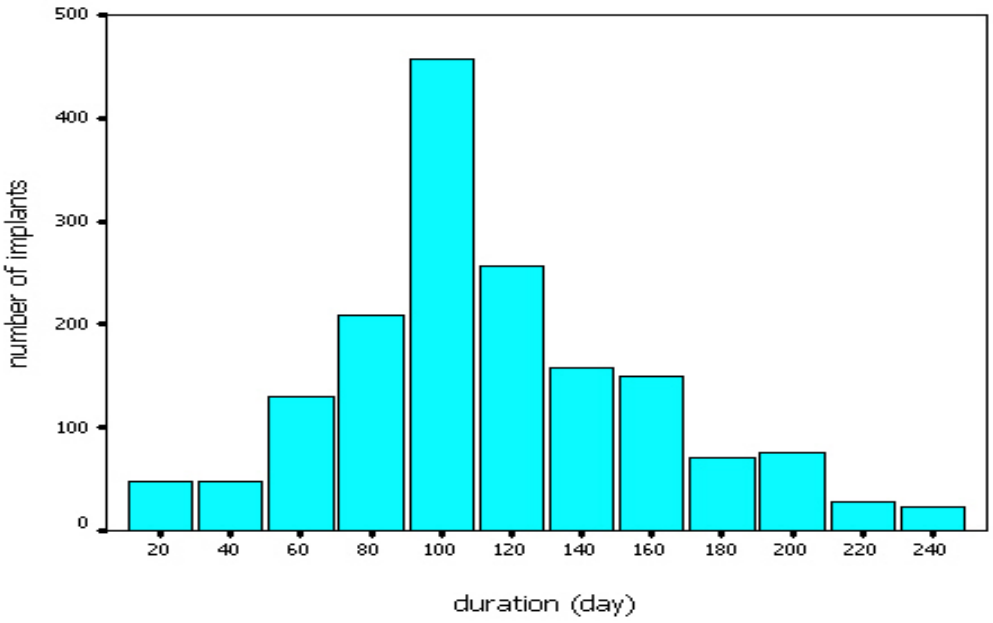

Figure 15: Healing duration in jawbone

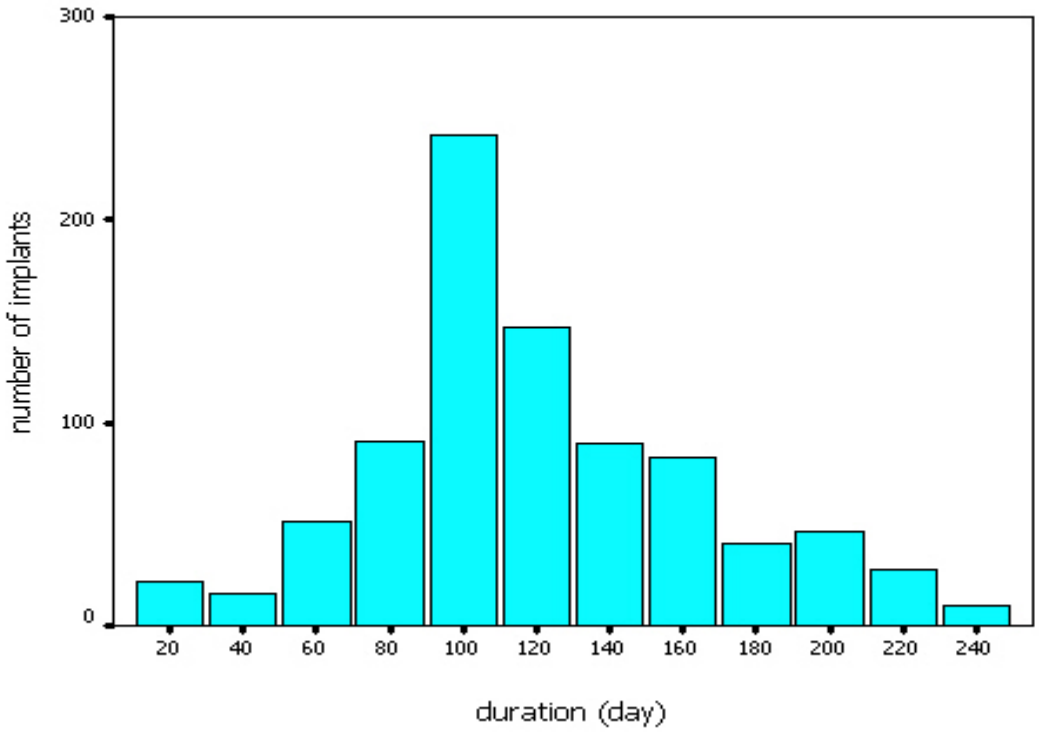

Figure 16: Healing duration in maxilla

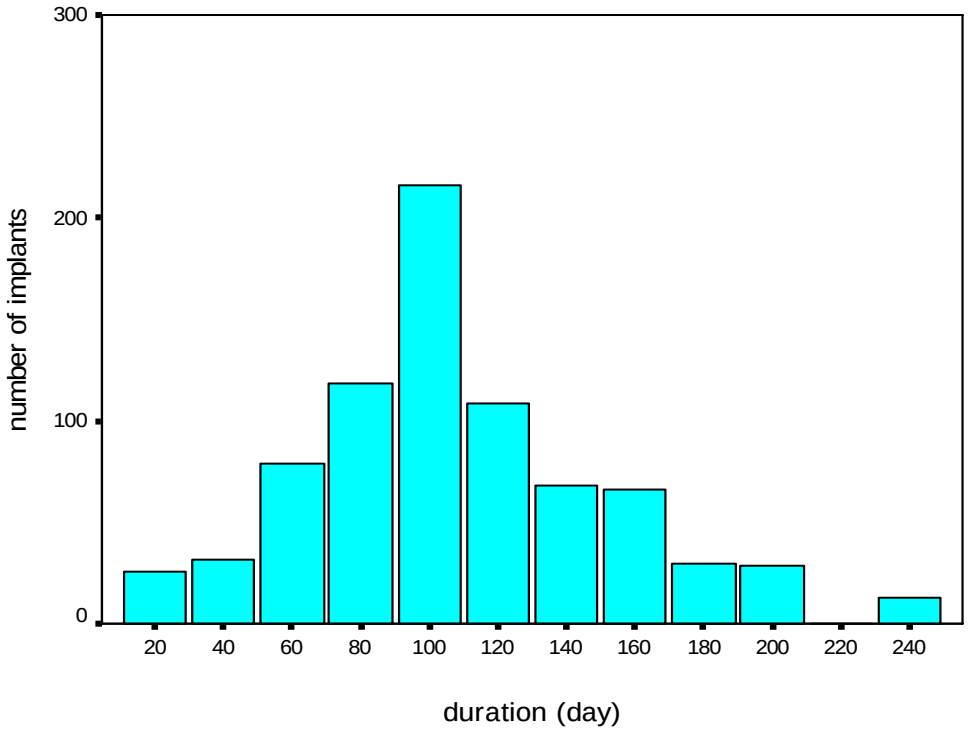

Figure 17: Healing duration in mandible

4.5.2. The observation duration (function time)

From the time the prostheses were functional to 1st Jan 2006, the observation period ranged 0.8 to 11 years, the mean observation period was 4.32 years (Table 23). The distribution of the observation periods in jawbone is shown in Figure 18. The distribution of the observation periods broken down by maxilla and mandible is shown in Figures 19 and 20). The detailed distribution of the observation period in the maxilla and mandible is listed in Tables 24 and 25.

	Minimum period (years)	Maximum period (years)	Mean period (years)	SD(year)
Maxilla	0.80	10.40	4.00	2.13
Mandible	0.87	11.07	4.67	2.48
Jaws	0.80	11.07	4.32	2.33

Table 23: Descriptive statistics of observation periods of jaws

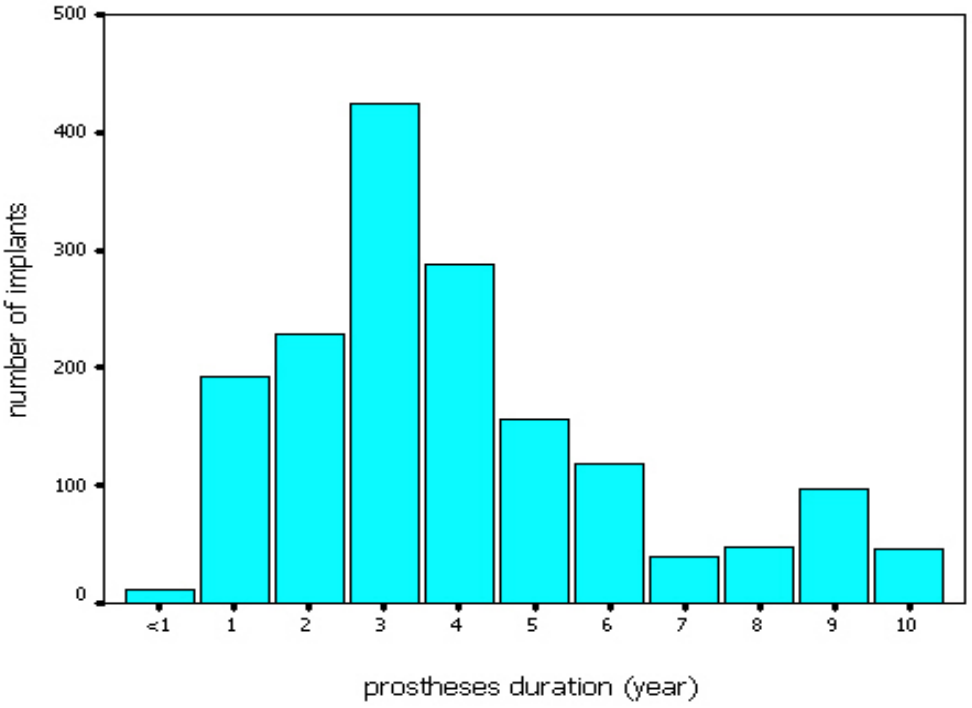

Figure 18: Distribution of observation periods of jawbone

Observation period (years)	Number of implants	Relative ratio
<1	8	0.009238
1-2	106	0.122402
2-3	134	0.154734
3-4	234	0.270208
4-5	179	0.206697
5-6	67	0.077367
6-7	41	0.047344
7-8	19	0.02194
8-9	23	0.026559
9-10	44	0.050808
>10	11	0.012702
Total	866	1

Table 24: Distribution of observation period of maxilla

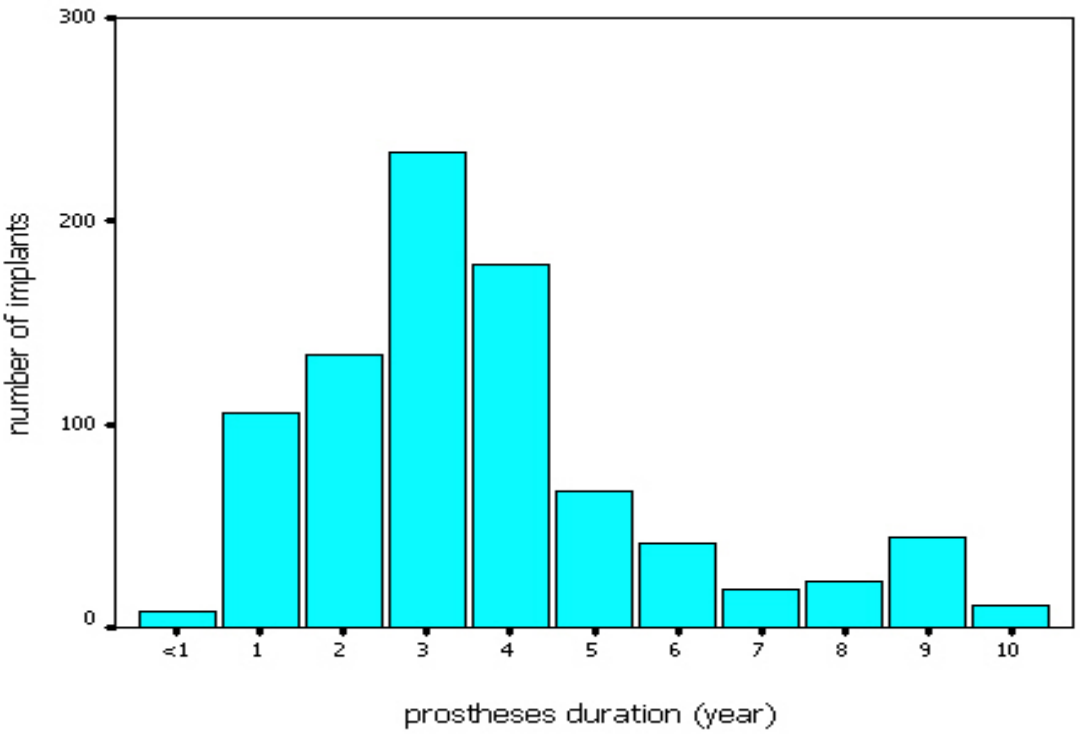

Figure 19: Distribution of observation periods of maxilla

Observation period (years)	Number of implants	Relative ratio
<1	4	0.005089
1-2	87	0.110687
2-3	95	0.120865
3-4	191	0.243003
4-5	109	0.138677
5-6	89	0.113232
6-7	77	0.097964
7-8	21	0.026718
8-9	25	0.031807
9-10	53	0.06743
>10	35	0.044529
Total	786	1

Table 25: Distribution of observation period in mandible

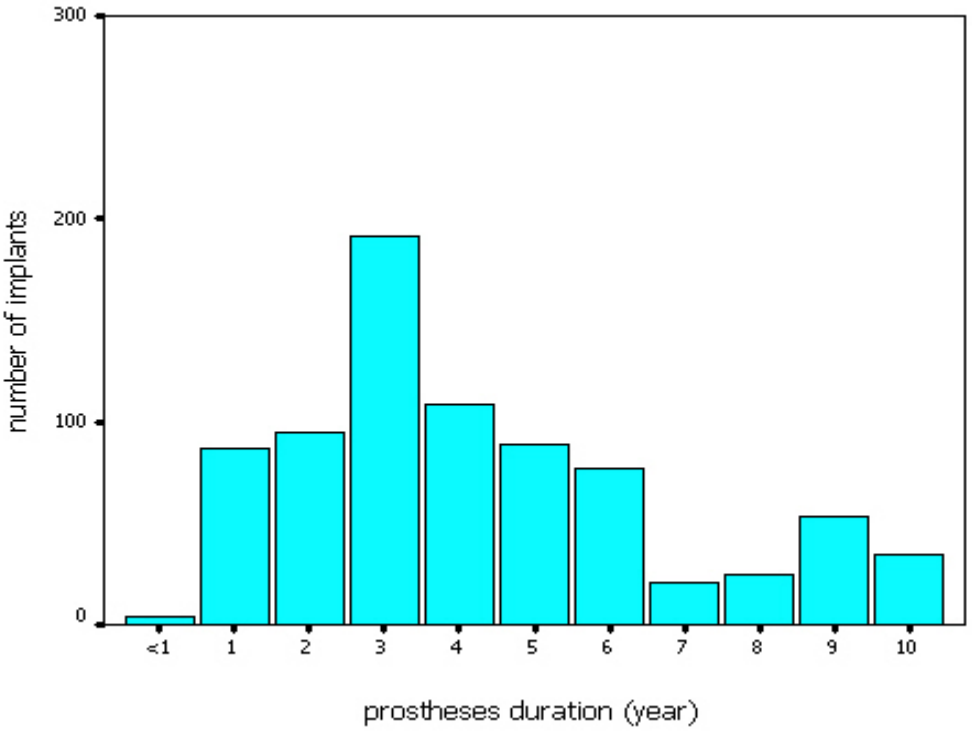

Figure 20: Distribution of observation periods in mandible

4.6. Implant loss & cumulative implant survival rate

Throughout the observation period, chart review was conducted and life-table analysis was performed using the Kaplan-Meier method. Of the 227 patients with 1652 implants, 50 patients (19 male, 31 female) lost a total of 73 implants, which translates into a cumulative implant survival rate for all the patients of 94.76% (Figure 21).

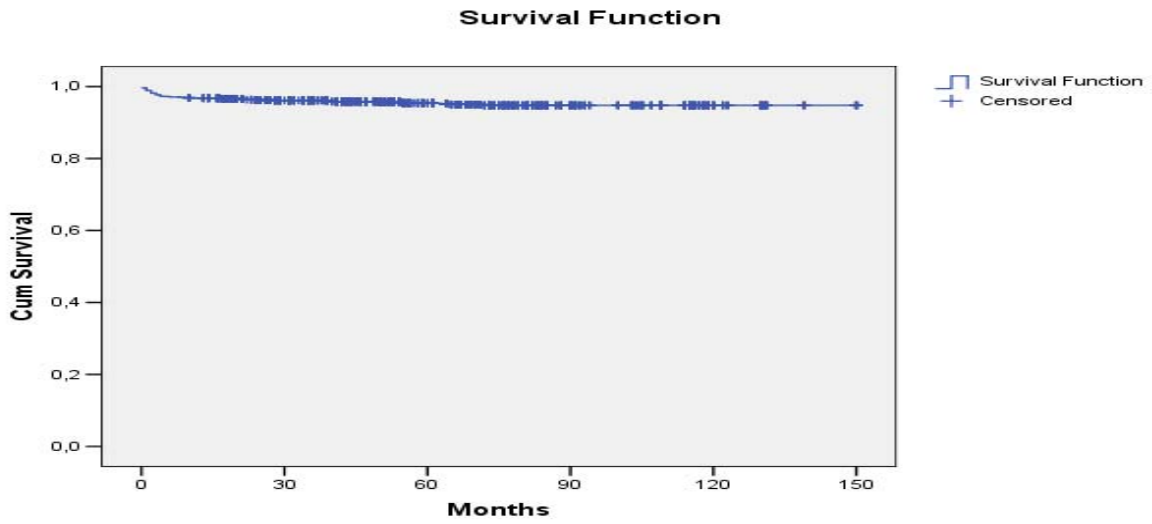

Figure 21: The cumulative implant survival rate

Of the 73 lost implants, 27 implants were lost in males, 46 implants were lost in females, yielding a cumulative implant survival rate in males and females of 95.93% and 93.93%, respectively (Figure 22).

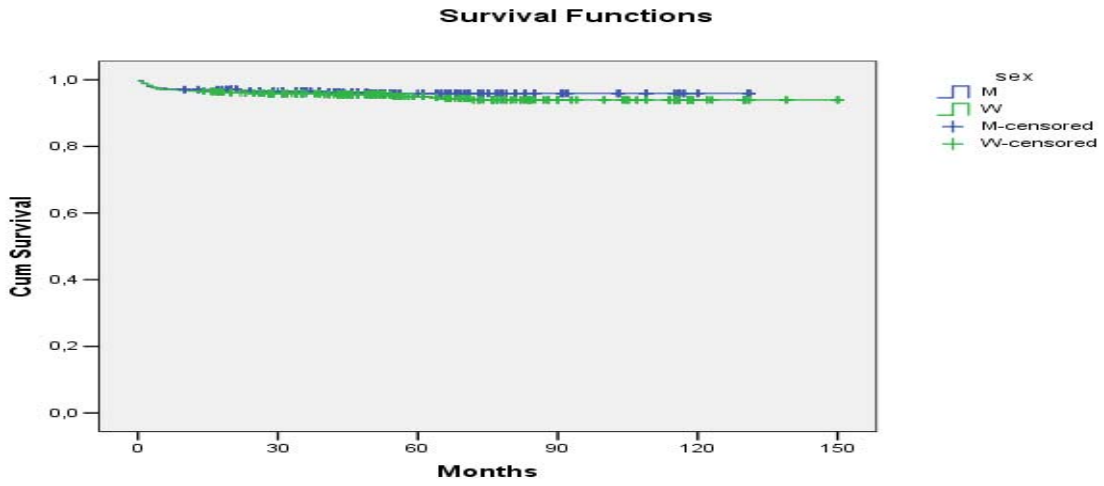

Figure 22: The cumulative implant survival rate in gender.

Of 227 patients, 177 patients (77.97%) lost no implants, but 50 patients (22.03%) lost 73 implants. Of 92 males with total of 711 implants, 19 (20.65%) lost 27 implants; of the 135 females with 941 implants, 31 (22.96%) lost 46 implants. The detailed distribution of the lost implants is seen in Tables 26 and 27.

Patients	Male(n)	Female(n)	Total(n)	Relative ratio
Implant survival	73	104	177	77.97
Implant failure	19	31	50	22.03
Total	92	135	227	100

Table 26: Distribution of implant survival and failure in patients, n= number of patient

Gender	No .of lost implants	No. of survival implants	Total	Cumulative implant survival rate (%)
Male	27	684	711	95.93
Female	46	895	941	93.93
Total	73	1579	1652	94.76

Table 27: Distribution of the number of lost implants according gender

The implant losses occurred as 38 patients (16.74%) lost one implant, 4 patients (1.76%) lost two implants, 5 patients (2.20%) lost three implants and 3 patients (1.33%) lost four implants, The detailed distribution of lost implants in maxilla; mandible and both jaws are listed in Tables 28, 29 and 30, Figures 23, 24 and 25.

No. of lost implants	No. of patients	Relative ratio (%)
0	177	77.97
1	38	16.74
2	4	1.76
3	5	2.20
4	3	1.33
Total	227	100

Table 28: Patient distribution of lost implants in jawbone

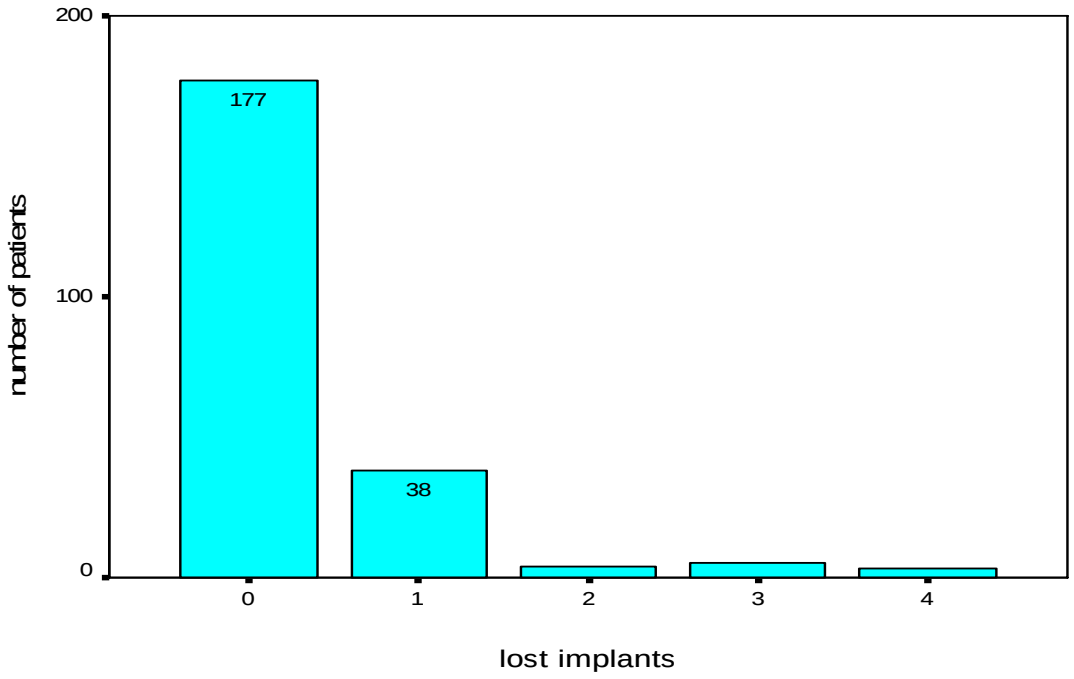

Figure 23: Patient distribution of lost implants in jawbone

No. of lost implants	No. of patients	Relative ratio (%)
0	203	89.43
1	18	7.93
2	3	1.32
3	2	0.88
4	1	0.44
Total	227	100

Table 29: Patient distribution of lost implants in maxilla

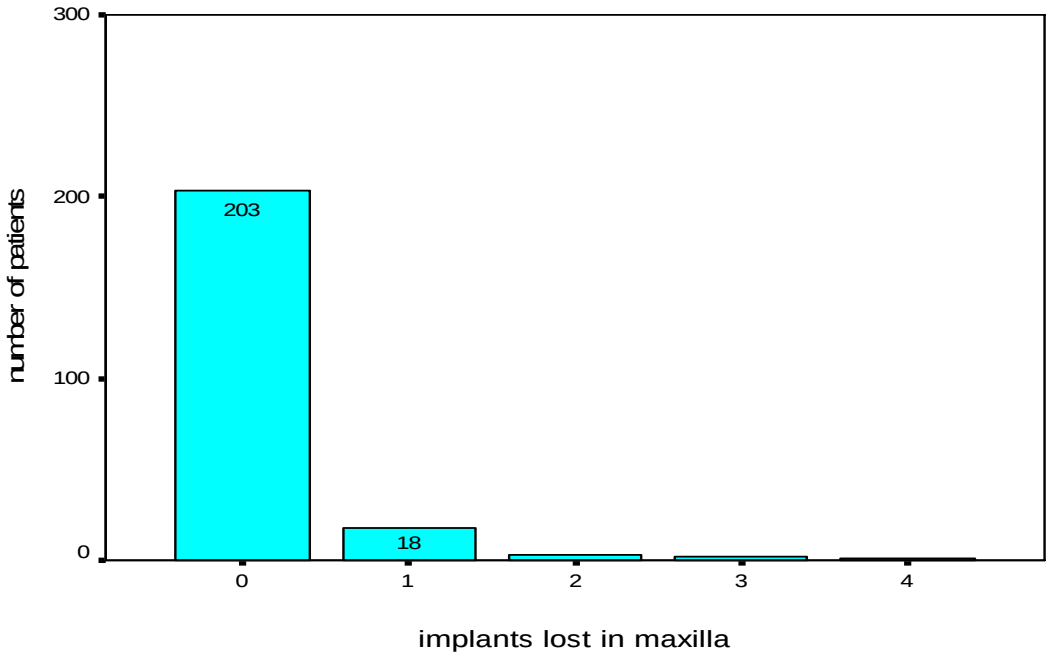

Figure 24: The patient distribution of lost implants in maxilla

Number of lost implants	Number of patients	Relative ratio (%)
0	201	88.55
1	20	8.81
2	1	0.44
3	3	1.32
4	2	0.88
Total	227	100

Table 30: Patient distribution of lost implants in mandible

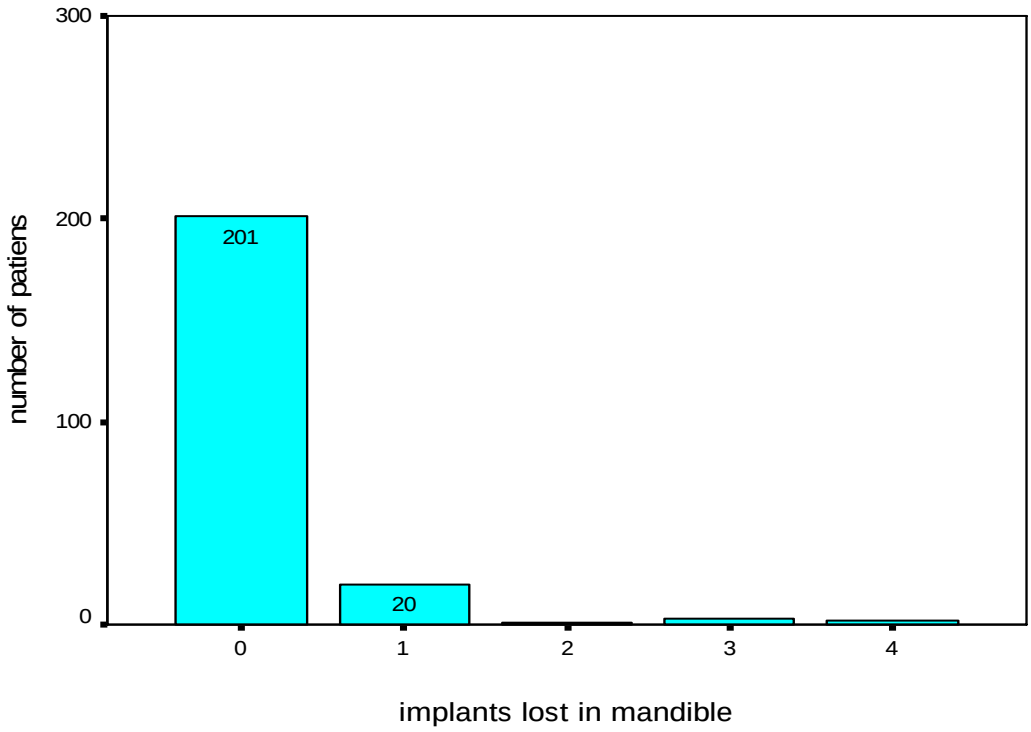

Figure 25: The patient distribution of lost implants in mandible

Of 73 lost implants, 34 implants (46.58%) were lost in the maxilla, 39 (53.42%) implants were lost in the mandible. The cumulative implant survival rate in the maxilla was 94.87%, and in the mandible 94.53% (Figure 26). Of 73 lost implants, 38 implants (52.05%) were lost in the anterior region and 35 implants (47.95%) were lost in the posterior region (Table 31).

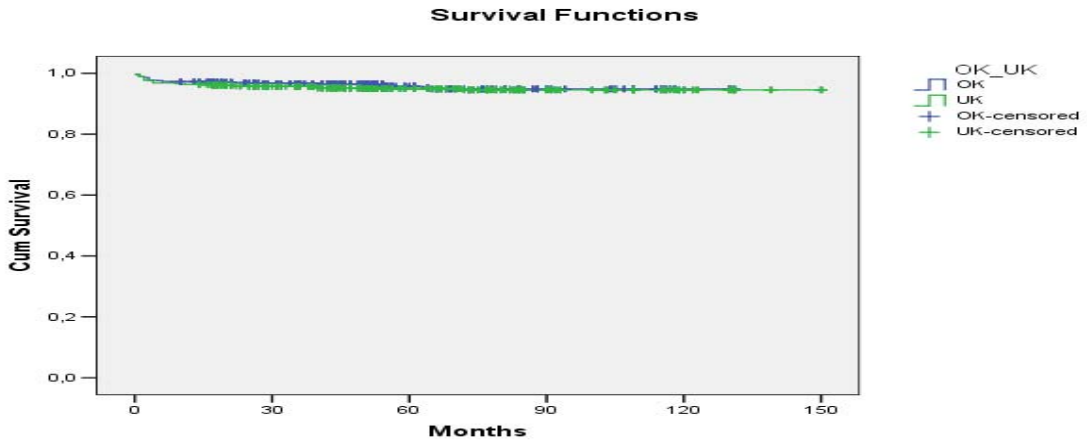

Figure 26: The cumulative implant survival rate in jawbone

Jawbone	No. of lost implants in anterior region	No. of lost implants in posterior region	Total	Total (%)
Maxilla	16	18	34	46.58
Mandible	22	17	39	53.42
Total	38	35	73	
Total (%)	52.05	47.95		100

Table 31: Distribution of lost implants in jawbone

Of 73 lost implants, 51 implants (69.86%) were lost before prosthetic rehabilitation, 22 implants (30.14%) were lost after prosthetic rehabilitation. Of 34 implants lost in the maxilla, 24 implants were lost prior to loading, 10 implants were lost after loading; and 39 implants were lost in the mandible, of which 27 implants were lost before loading, 12 implants were lost after loading (Table 32).

Jaws	No. of lost implants before rehabilitation	No. of lost implants after rehabilitation	Total	Total (%)
Maxilla	24	10	34	46.58
Mandible	27	12	39	53.42
Total	51	22	73	
Total (%)	69.86	30.14		100

Table 32: Distribution of lost implants before and after prosthetic rehabilitation

Of 73 lost implants, 63 implants were lost in removable overdentures and 10 in fixed prostheses. The cumulative implant survival rate in removable and fixed prostheses was thus 93.55% and 98.02%, respectively (Figure 27, Table 33). Details of the lost implants in removable and fixed prostheses are shown in Table 34.

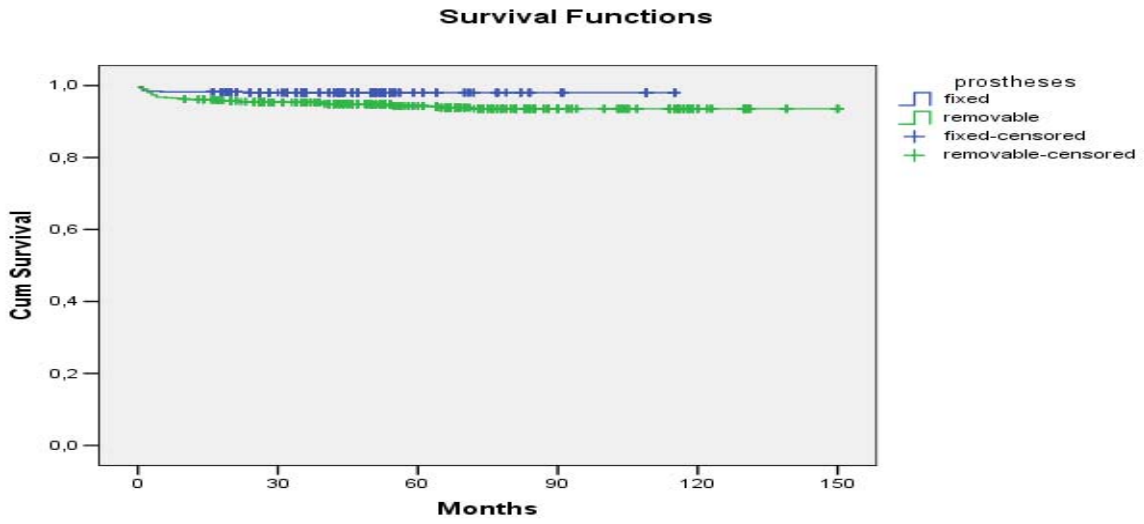

Figure 27: The cumulative implant survival rate in fixed and removable prostheses

Prostheses	No. of lost implants	No. of survival implants	Total	Cumulative implant survival rate (%)
Removable	63	1079	1142	93.55
Fixed	10	500	510	98.02
Total	73	1579	1652	94.76

Table 33: Distribution of lost implants with different prostheses

Prostheses	No. of lost implants	No. of success implants	No. of total implants
Max rem	29	535	564
Max fix	5	297	302
Man rem	34	544	578
Man fix	5	203	208
Total	73	1579	1652

Table 34: Distribution of lost implants and prostheses in jawbone

73 lost implants were found in every prosthetic project in 50 patients (Table 35). One implant was lost in maxillary fixed prostheses, 3 in mandible fixed prostheses, 16 in maxillary removable overdentures, 25 in mandible removable overdentures, 5 in fully fixed prostheses (completely edentulous in maxilla and mandible) , 16 in fully removable overdentures, and 4 in fully mixed prostheses(completely edentulous in maxilla and mandible, but with different prosthetic rehabilitation in maxilla and mandible). One implant was lost in fixed mandible prostheses, 2 in removable maxillary overdentures and 1 in removable mandible overdentures.

Prosthetic rehabilitation	Gender	No. of lost implants	No. of patients (implant lost)	No. of implants at start of interval	Relative implant success rate (%)
Max fix	M	-	-	46	100
	F	1	1	61	98.36
Max rem	M	2	2	90	97.78
	F	14	8	172	91.86
Max/Man fix	M	2	2	168	98.81
	F	3	2	118	97.46
Max/Man rem	M	8	6	285	97.19
	F	11	9	200	94.50
Max fix/Man rem	M	-	-	14	100
	F	1	1	47	97.87
Max rem/Man fix	M	2	2	42	95.24
	F	1	1	31	96.77
Man fix	M	3	3	32	90.61
	F	-	-	6	100
Man rem	M	10	4	127	92.13
	F	15	9	213	92.96
Total		73	50	1652	95.58

Table 35: Distribution of lost implants in different prosthetic project

The distribution of lost implants in different implant systems and their success rate are listed (Table 36). 96.92 % of Camlog implants; 95.24% Straumann implants; 94.95%

Branemark implants; 93.20% Steri-Oss implants and 93.02% Replace implants were clinically integrated.

Type	No. of lost implants in maxilla	No. of lost implants in mandible	Total no. of lost implants	No. of implants at start of interval	Success rate of implant
Camlog	16	12	28	910	96.92
Steri-Oss	12	12	24	353	93.20
Branemark	2	8	10	198	94.95
Straumann	1	5	6	126	95.24
Replace	2	1	3	43	93.02
IMZ	1	1	2	21	90.48
Zygoma	0			1	100
Total	34	39	73	1652	95.58

Table 36: Distribution of lost implants in different implant systems in jaw

The distribution of 73 lost implants in different implant systems before and after prosthetic rehabilitation was as follow: of 73 lost implants, 51 (69.86%) were lost before loading and 22 (30.14%) after loading (Table 37).

Type	Before loading	After loading	Total
Camlog	18	10	28
Steri-Oss	20	4	24
Branemark	5	5	10
Straumann	5	1	6
Replace	3	0	3
IMZ	0	2	2
Total	51	22	73
Total (%)	69.86	30.14	100

Table 37: Distribution of lost implants in different implant systems before and after loading

The remaining implants showed no clinical signs of infection or mobility, and radiographs revealed no continuous peri-implant translucency. No implant-related adverse effects were observed after abutment placement.

4.7. Statistical Comparison

Within the observation period of 12 months a comparison of the maxilla vs. mandible, male vs. female and fixed vs. removable prostheses was performed using the chi-square Test. Due to imbalanced samples, the exact Test of Fisher was used.
Within the first 12 months after implant placement an implant loss of n=53 was observed and n=1575 implants were successful.
Statistical analysis was accomplished using SPSS 11.5 for Windows, and Chi-square test was performed ($x^2_{0.05}$ >3.84, $x^2_{0.01}$>6.63), P value < 0.05 was considered significant. The cumulative implant survival rates showed no significant difference between gender (male/female x^2=0.67), jaws (maxilla/mandible x^2=1.05) or implant location (anterior/posterior region x^2=0.77) (p>0.05). As regards implant loss before and after rehabilitation, the result (x^2=11.78) showed a significant difference between them. Comparing with the two kinds of restoration (fixed/removable x^2=10.55), the result shows a significant difference (p<0.05). With regard to the kind of restoration in maxilla or mandible, the results also show a significant difference between fixed vs. removable prostheses in maxilla (x^2=6.34) and mandible (x^2=3.92). Comparison of the 22 implants lost after rehabilitation showed no significant difference between fixed and removable prostheses (x^2=3.27). The type of implant systems showed no significant difference (p>0.05).

5. Discussion

The aim of this retrospective study was to investigate the fixed and removable implant-supported prostheses in fully edentulous patients within a functional period and to evaluate the implant survival rates with reference to gender, jawbone, implant systems and type of prostheses.

The purpose of the present analysis was to test the specific hypothesis that there is no difference in implant survival rate between fixed and removable prostheses in edentulous jawbone. The possible effects of other variations in prosthetic type (such as splinting, rotational characteristics, prosthetic materials and the number of implants) as well as the effect on crestal bone loss and maintenance outcomes are not addressed in detail in this study, but are subject of a dissertation currently being written (Michael Melerski, personal communication). As most commonly reported in implant outcome studies, implant survival was assessed from the time of implant placement rather than from prosthesis assembling. In this study, both implant insertion and the follow-up care were performed by only 3 surgeons and 2 prosthodontists qualified for this type of operation and prosthetic rehabilitation. This guaranteed a high degree of standardization of all subsequent observations over the entire period of the study.

The study was carried out with a consecutive inclusion of 227 edentulous patients with 1652 implants over a mean period of 4.3 years. Compared to other studies (listed throughout the discussion) on implant-retained restorations this represents an adequate sample size and observation period ensuring a high degree of validity for clinical conclusions. This retrospective analysis was not performed on a homogenous group of patients as only limited exclusion criteria were applied and inclusion criteria were not set to defined conditions resulting in an inhomogenous group represented in every day practice. Even though the recall-findings were standardized, as they are collected following a protocol used on all implant-patients treated in the department, gingival parameters were not continuously monitored and therefore no statistical evaluation of the overall gingival health was performed. The random probing of the pocket depth adjacent to the implants allows the detection of suppuration to assess one of the criteria of Buser.

Primary stability and absence of early loading are considered fundamental prerequisites for osseointegration of endosseous implants. For this reason, a waiting period of between 3 and 6 months is usually recommended (Branemark, P. I. et al. 1977).

Traditional implant protocols recommend a two-stage surgical procedure and a rest period of at least 3 months before applying load from masticatory forces to the implants and surrounding bone via prostheses (Albrektsson, T. 1983).
This long-term treatment may create discomfort for the patients, due to a long waiting period for osseointegration and consequent delay of final rehabilitation. Now more and more researches are working on ways to shorten these time periods through the modification of implant surfaces (Aparicio, C. et al. 2003; Balshi, T. J. and Wolfinger, G. J. 1997; Buser, D. et al. 1990; Carlsson, G. E. 2000; Esposito, M. et al. 2007; Jo, H. Y. et al. 2001; Karoussis, I. K. et al. 2004; Kawai, Y. and Taylor, J. A. 2007; Randow, K. et al. 1999; Tawil, G. and Younan, R. 2003; Zechner, W. et al. 2003; Zubery, Y. et al. 1999). Mechanical and histomorphometric analysis of SLA implants placed in animals has proven that the bone to implant contact is much earlier than postulated (Severson, S. et al. 2000; Wennerberg, A. et al. 1997). Histological evidence has been provided showing the rapid induction of cellular mechanisms and accelerated adhesion of osteoblasts to give a firm anchorage of the fibrin scaffold to the roughened surface (Davies, J. E. 1998; Sullivan, D. et al. 2005). Prospective studies of implants with SLA® surface in humans have demonstrated that implants placed in defined conditions with shortened healing periods show a long-term success comparable to that found in implants loaded after a classical time protocol (Bornstein, M. M. et al. 2005; Cochran, D. L. et al. 2002; Salvi, G. E. et al. 2004). Initially, the variable time period for osseointegration was established on the basis differing bone quality found at implant sites. The evaluation of bone quality at the implant site at the time of placement was not performed in this study, it was therefore not possible to make a statistical evaluation with regard to the bone density. The sample size of maxillary implants placed is comparatively large and the equal distribution of the implants in the anterior or posterior region of the maxilla allows the assumption that the shortened healing protocol is applicable to all regions of the maxilla. The quantity of implants placed in the posterior region of the mandible comprises a small number in comparison to other studies performed on implants of the posterior mandibular region, thus restricting its universal validity.
The implant forms used in this survey were divergent in that they showed a conical, a hybrid cylindrical and a cylindrical design. Several investigations employing the subject of macro-architecture design and its associated three-dimensional structures, which are characterized amongst other things by shape and thread design, discuss their functional

role in primary stability and force transfer (Cehreli, M. et al. 2004; Sakoh, J. et al. 2006). Force distribution analysis of the conical and hybrid cylindrical implant employed in the study has not been evaluated yet, but the clinical long-term success and the low failure rate may allow the assumption that the implant shapes utilized show adequate properties for osseointegration within a shortened healing period. During the healing period non-submerged healing modes were applied on two-stage implants, single-stage implants were left to heal transmucosally. Several investigations including the present analysis indicate that the use of two-stage implants in a single-stage procedure is as predictable in the successful outcome as one-stage implants (Heydenrijk, K. et al. 2002; Zechner, W. et al. 2004).

The time period and mechanisms of bone response to an implant surface depends on several cellular reactions and matrices to the material surface and is not yet completely understood. The role of mechanical strains on cells of the bone matrix during the period of osseointegration also needs to be studied in long-term observations with a precise time-dependent protocol (Huiskes, R. 2000; Joos, U. et al. 2005).

Dental implant failures do occur early in this study. In previous publications, the failure rate has been reported to be variable. Esposito et al.(Esposito, M. et al. 1998) in a study of 2812 implants reported a failure rate of 7.7% over 5 years, although failure rates as high as 35% have been described elsewhere (Jaffin, R. A. and Berman, C. L. 1991). Buser et al.(Buser, D. et al. 1997) evaluated the long-term prognosis of 2359 implants in fully and partially edentulous patients over a period of up to eight years. Using the life table analysis technique of Cutler & Ederer (Cutler, S. J. and Ederer, F. 1958), these authors estimated a 5-year cumulative survival rate of 97.9% .The corresponding values for the first 536 implants that were inserted, with a actual follow-up period of five years, showed a survival rate of 98.2%. During the 10-year observation period (the mean observation period was 4.32 years) in this retrospective study, the results for all 1652 implants show a cumulative survival rate of 94.76%. Among the long-term studies of the outcome of implant-supported prostheses in edentulous jaws, one shows an 86% cumulative survival rate over 15 years with 524 implants placed originally to support 80 completely fixed mandibular prostheses and a 78% cumulative survival rate over 15 years with 524 implants placed originally to support 80 completely fixed maxillary prostheses (Adell, R. et al. 1990). Ekelund et al (Ekelund, J. A. et al. 2003) achieved a 98.9% cumulative survival rate over 20 years in 273 implants placed originally to support 47 complete fixed mandibular prostheses. Attard et al (Attard, N. J. and Zarb,

G. A. 2004; Attard, N. J. and Zarb, G. A. 2004) achieved an 86.7% cumulative survival rate over 18 to 23 years in 265 implants placed originally to support 47 complete fixed prostheses and a 93.1% cumulative survival rate over 10 to 19 years in 132 implants placed originally to support 47 complete removable overdentures.

The 10-year studies of outcomes of implant-supported prostheses in edentulous jaw show a cumulative implant survival rate between 70.3% and 80.7% for maxillary removable and fixed prostheses, respectively, and a 95.4% and 91.0% cumulative implant survival rate for mandibular removable and fixed prostheses, respectively.

The 5-year studies of outcome for implant-supported prostheses in edentulous jaw achieved by Jemt et al (Jemt, T. et al. 1996; Jemt, T. and Lekholm, U. 1995) show a 76.6% and 87.7% cumulative implant survival rate in maxillary removable and fixed prostheses, respectively, and a 95.7% and 96.7% cumulative implant survival rate in mandibular removable and fixed prostheses, respectively.

In regard to the gender of patients who received implant treatment, many studies have shown that more implants are lost in females than in males, because of the different jawbone quality, bone density and for other physiological reasons (Adell, R. et al. 1981; Carr, A. B. 1998; Engquist, B. et al. 1988; Jemt, T. et al. 1989). In this study, a total of 941 implants and 711 implants were inserted in females (Nelson, K. et al. 2008)and males respectively, over a nearly 5-year observation period, lost 46 implants (4.89 %) in females and 27 implants (3.80%) in males resulting in a cumulative implant survival rate of 95.93% in males and 93.93% in females. The result agrees with the above study, showing a slightly lower survival rate for females but there was no significant difference between the genders.

Concerning the analysis of various implant locations, although there was a trend for better results in favor of the mandible, implants in the maxilla, which has a higher prevalence of flabby ridge, are not as successful as in the mandible. The survival rates for maxillary implants have been shown to be as low as 78.7% (Jemt, T. et al. 1992). In various review articles (Berglundh, T. et al. 2002; van Steenberghe, D. et al. 1999), it was concluded that implant failures were more frequent in the maxilla than in the mandible and in the posterior segments of the dentition than in the anterior parts. It was suggested that the reason for these differences in treatment outcome was related to the quality of bone tissue in various regions of the alveolar processes and to the amount and direction of load that was distributed to the implants during function. But in this study, out of a total of 866 implants in the maxilla, 34 implants (3.93%) were lost and out

of a total of 786 implants in the mandible, 39 implants (4.96%) were lost, the cumulative implant survival rate in maxilla (94.87%) was higher than in the mandible (94.53%), but the observed differences were minimal and not statistically significant. These findings are consistent with the meta-analysis results of Cochran (Cochran, D. L. 1999) for rough-surfaced implants, but are in contrast with above studies (Berglundh, T. et al. 2002; van Steenberghe, D. et al. 1999) where implants that were positioned in the maxilla appeared to have a less favorable prognosis when compared to mandibular implants. The reason for these surprising results is most likely the type of prosthetic restorations that were used in the treatment of the edentulous upper jaw, as well as the surface characteristics of the implant. All removable overdentures in this study were mainly supported by four to six implants and rigidly connected by a milled bar, thus probably providing an adequate bone stress distribution. In addition, maybe the strict selection of patients also plays an important role in the results.

A direct comparison of the various implant systems was also carried out in the study, 7 different implant systems were used and compared for prostheses supported by implants. The implants either had a rough or a machined surface. The cumulative success rates for Camlog, Steri-Oss, Branemark, Straumann, Replace and IMZ implant systems was 96.92 %, 93.20 %, 94.95 %, 95.25 %, 93.02 % and 90.48 %, respectively. But when comparing each type of implant system, there was no significant difference between them. Early loading was only performed in the implants showing a rough surface, therefore no conclusions can be drawn concerning the healing period in machined-surface implants. This result is also comparable to other studies (Adell, R. et al. 1981; Attard, N. J. and Zarb, G. A. 2004; Attard, N. J. and Zarb, G. A. 2004; Jemt, T. et al. 1996; Johns, R. B. et al. 1992; Lindquist, L. W. et al. 1996; McGlumphy, E. A. et al. 2003; Meijer, H. J. et al. 2001; Meijer, H. J. et al. 2003; Naert, I. et al. 1992; Palmqvist, S. et al. 1994; Schmitt, A. and Zarb, G. A. 1993; Spiekermann, H. et al. 1995; Weber, H. P. et al. 2000; Zarb, G. A. and Schmitt, A. 1993; Zitzmann, N. U. and Marinello, C. P. 1999) and the comparison between the 7 different implant systems is of limited clinical significance because the implant systems used were not randomized, and the choice of the implants was generally determined by the clinician's experience and individual bone morphology.

In the present study, implant failures fall broadly into two categories: the failure to achieve osseointegration (before rehabilitation) and the failure to maintain osseointegration (after rehabilitation). In this study, 51 implants of 1652 implants (3.09%

of all) failed to osseointegrate during the healing period (before rehabilitation) and had to be surgically removed prior to loading, 22 of 1601 remaining implants (1.37% of all)were lost during function of prostheses (after rehabilitation). Before the prosthetic rehabilitation period in the study (3-6months), 3.09 % (n=51) did not fulfill the criteria for successful tissue integration. The reasons for the early loss of implants are multi-lfactorial including host related factors, the primary stability of an implant, micro-motion and surgical experience (Sennerby, L. and Roos, J. 1998). This low frequency of early failures is in agreement with findings from previous studies using different implant systems in fully and partially edentulous patients (Adell, R. et al. 1990; Becker, W. et al. 1997; Berglundh, T. et al. 2002; Friberg, B. et al. 1991). So the careful evaluation of bone quality and quantity might be of importance and necessary for the clinicians, and it must be stressed that although the clinical evaluation of bone quality is quite subjective, immediate loading of implants is performed only in the case of class Ⅰ-Ⅱ-Ⅲ according to Lekholm (Lekholm, U. 1988).

After prosthetic rehabilitation and during the follow-up observation period, 22 implants (1.37%) were lost due to implant mobility or an evident progressive bone loss and were removed. These failures typically occurred in patients that were scheduled for restorations with removable dentures suggesting a compromised recipient site due to extreme atrophy, which is assumed to play a role in a higher failure rate (Palmqvist, S. et al. 1996). This means that despite the rather high average patient age and the type of prosthetic rehabilitation, the implants with rough surface had a low risk of developing a peri-implant infection after reaching a stable osseointegration. From the clinical point of view, these represent the real success that doctors and patients can expect from implant therapy.

The low percentage of failures before and after prosthetic rehabilitation shows no significant difference between them, and this result shows that implant loss occurs more often during the healing period rather than in the rehabilitation period. These findings are consistent with the results from previous studies (Buser, D. et al. 1997; Buser, D. et al. 1990; Mericske-Stern, R. and Zarb, G. A. 1993; Weber, H. P. et al. 2000).

The evaluation of cumulative implant survival rates according to prosthetic rehabilitation technique was undertaken on the hypothesis that a long-term statistical study on dental implants in the treatment of edentulous jaws could be strongly influenced by the type of prosthesis used and the amount of loading to which the implants were subjected. In other words, the inadequate rehabilitation of fully edentulous patients could cause

implant failures, with a consequent reduction of the implant success rates, while instead these implant failures should mostly be attributed to a wrong choice of prosthesis. Currently, there is no clear evidence that implant survival rate is affected by prostheses type based on established designs that have been studied for at least 5 years. However, this should not be interpreted to mean that all prosthetic designs can be applied with equal merit and that the results can be applied beyond 5 years. Studies are simply not yet available to guide clinicians sufficiently for many of the possible permutations and combinations of prosthetic design. The 10-year cumulative survival rate of implants that support a fixed restoration in maxilla was 98.34 %. These results seem to demonstrate that a maxillary-fixed full-arch prosthesis that is supported by at least six implants in that particular distribution allows good long-term success rates for loaded implants. As to removable overdentures in the study, 100 patients with fully edentulous maxilla were treated with removable implant-retained overdentures with 564 implants. Similar conclusions can be made for overdentures that have a milled bar that is mainly supported by four to six implants inserted in locations 12–22, 14–24 or 16–26. In fact, the 10-year cumulative implant survival rate was 94.86%. These results are nevertheless rather better than the results which have been published in previous studies, where very high failure rates (over 20%) were reported for maxillary overdentures (Engquist, B. et al. 1988; Hutton, J. E. et al. 1995; Jemt, T. et al. 1992; Jemt, T. et al. 1996). A critical analysis of these latter studies revealed that the indication for overdentures was often given in an emergency situation (Palmqvist, S. et al. 1994; Palmqvist, S. et al. 1996), which meant that the overdentures were a substitute for failing fixed prostheses or were a second choice when the placement of implants to support fixed full-arch prostheses was not possible or when a fixed restoration was planned, but the loss of implants made such a placement impossible (Jemt, T. et al. 1996). Otherwise, for maxillary overdentures as the first-choice treatment in the rehabilitation of edentulous ridges, an increased implant survival was observed (Palmqvist, S. et al. 1996). Nevertheless, recent studies (Bergendal, T. and Engquist, B. 1998; Hutton, J. E. et al. 1995) have reported a cumulative implant survival rate of about 75% even in maxillary overdentures planned as a first solution. In this study, none of the maxillary overdentures were used in emergency situations, but were chosen because they would provide better and easier resolution of problems related to asymmetrical anatomic and morphologic structure of the maxilla, facial and lip support, high lip-line (gummy smile), tooth length, phonetics, soft tissue management and economical

considerations. From the point of view of implant survival, however, the results of this study appear to suggest that milled bar-supported overdentures can be proposed to patients as a valid alternative to a fixed full-arch bridge. This is probably the consequence of three different conditions: the selection of patients, the symmetrical distribution of the implants over the arch, and the use of TPS and SLA surfaces, which achieve a stronger bone anchorage in comparison to smooth and other rough titanium surfaces (Buser, D. et al. 1999; Buser, D. et al. 1998; Buser, D. et al. 1991; Cochran, D. L. 1999). Nevertheless, the overall results for implants that supported restorations in the fully edentulous maxilla demonstrated that the cumulative implant survival rates are not significantly influenced by the type of prosthetic rehabilitation. Indeed, during the study period, a total of 564 implants were loaded to realize 100 maxillary prostheses; of these 100 prostheses, 10 implants were considered as failures.

In regard to the edentulous mandible in this study, the concept of installing five or six endosseous implants in the interforaminal region, followed by the construction of a fixed bridge, was developed by the Brånemark group and has been evaluated in several studies (Adell, R. et al. 1981; Albrektsson, T. et al. 1986; Lindquist, L. W. et al. 1996; Naert, I. et al. 1992; Quirynen, M. et al. 1992). Provided a strict protocol is followed, it is a reliable treatment option, and the survival rates of the endosseous implants in mandible fixed prostheses are high (97.60 %), as to removable overdentures in mandible, the cumulative implant survival rates are 94.12%. It can be concluded from this study that implant-retained overdentures are an established treatment modality with implant survival rates that are similar to the results obtained with fixed implant-supported prostheses.

This study also suggests that the brand of implant system used to support implant-retained prostheses has a weak correlation with the survival rate.

Future research should focus not only on long-term, detailed follow-up clinical trials in which clinical and radiographic aspects are analyzed, but also on the evaluation of the restoration of function and other patient-based parameters, including the maintenance of various implant-retained superstructures.

6. Summary

Various prosthetic design variables must be considered for dentists or patients when implant prosthodontic treatment is indicated for the completely edentulous jaw. One of the most fundamental of these is the selection of a fixed versus removable type. The outcome of oral implant treatment for edentulous jaw has been reported in numerous publications. Of these studies only few compared the two different modes of implant-retained superstructures. The results are controversial. Some studies found that the oral implant outcomes were differentiated by jaw (maxilla or mandible), by gender, by kind of implant system or by type of prosthetic design (fixed or removable prostheses), some found no relation with any of the above factors. There remains little conclusive evidence to guide clinicians or patients as to the optimal type of prosthesis for rehabilitation of the fully edentulous maxilla or mandible.

Chart reviews of 227 completely edentulous patients with 1652 implants were performed with a total of 308 prostheses (25 % fixed/ 75 % removable). Sixty patients with 15 fixed and 45 removable implant-retained restorations in the maxilla and 86 patients with 7 fixed and 79 removable implant-retained prostheses in the mandible were evaluated. Eighty-one patients were rehabilitated in both jaws with 162 prostheses.

There were two types of retaining methods for removable dentures, 98.7 % were bar-retained and 1.3 % telescope-retained and usually supported by 6 maxillary implants or 4 implants in the mandible. Of 76 fixed prostheses, 24 (31.58%) were cement-retained and 52 were screw-retained prostheses (68.42%). The fixed implant-retained prostheses were usually supported by 6-8 implants and 5-6 implants in the maxilla and mandible, respectively.

Seven implant systems were utilized: Camlog (55.08%), NobelBiocare (Steri-Oss 21.37%, Branemark 11.99%, Replace 2.60%, Zygoma implants 0.06%), Straumann (7.63%) and IMZ (1.27%). The cumulative implant survival rate, with a mean observation period of 4.3 years, was 94.76% for all implants. Among 73 lost implants, 34 were lost in the maxilla and 39 in the mandible, the cumulative implant survival rate was 94.87% and 94.53% respectively. As to 73 lost implants in gender, 27 were lost in males and and 46 were lost in females, the cumulative implant survival rate was 95.93% and 93.93% respectively. There was no significant difference in cumulative implant survival rate between maxilla and mandible, or between male and female. There was

also no significant difference between the implant systems used. A significant difference between the survival of fixed (98.02%) and removable (93.55%) prostheses was seen. This retrospective study confirms good clinical outcome of implant-supported treatment concepts for the rehabilitation of totally edentulous patients in a medium-term perspective, and suggests that the implant survival rate is not correlated with gender and implant location or the use of different implant systems. The type of prostheses is correlated with the survival rate. Implant-supported fixed prostheses seem to have a better prognosis than removable prostheses. Future research should be focused on long-term evaluation of the restoration in function-monitoring maintenance parameters.

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Curriculum Vitae

For reasons of data protection, I can not forward you these documents in this electric version of my dissertation.

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Own Work Declaration

„Ich, Lixin Xiang, erkläre, dass ich die vorgelegte Dissertationsschrift mit dem Thema: “The clinical retrospective analysis of fixed and removable implant-supported prostheses in edentulous patients-a 10-year study” selbst verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt, ohne die (unzulässige) Hilfe Dritter verfasst und auch in Teilen keine Kopien anderer Arbeiten dargestellt habe.“

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