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OUTCOME OF IMPLANT-SUPPORTED OVERDENTURE TREATMENT
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Abstract

The retention of a complete denture and the patient’s adaptation varies considerably among different individuals. Resorption of the edentulous alveolar ridge differs greatly and some patients need implant-retained overdentures to enable adequate retention of their prostheses. In some extreme cases it is necessary to increase the volume of the alveolar ridge with bone grafts. The aim of this study was to examine the outcome of implant-supported overdenture treatment conducted in Oulu University Hospital. The aim was also to assess the impact of treatment on oral health-related quality of life and patient satisfaction.

The study group was comprised of patients treated with a mandibular or maxillary implant overdenture and a group of patients with extreme mandibular bone resorption treated with extraoral bone grafts and implants. The treatments were performed in 1985–2013 thus also providing long-term results.

The results of this study showed predictable and successful treatment outcomes also among elderly patients and in severe situations with bone deficiency. The most frequent complication in the clinical follow-up was loosening of the retention mechanism, commonly noted in other previous studies. Despite some minor mechanical defects in prosthetic structures or mild mucosal inflammation around the implants, they did not hinder everyday use of the prostheses. Neither the number of supporting implants nor the connection type seemed to have a great impact on patient satisfaction. Older patients with a mandibular overdenture seemed to be most satisfied. In conclusion, treatment with implant overdentures seems to be successful also in the long-term.

Keywords: bone graft, edentulous mandible, edentulous maxilla, follow-up, implant, OHIP-14, overdenture, quality of life, tent pole
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Tiivistelmä
Kokoproteesin pysyvyys ja potilaan sopeutuminen proteesiin vaihtelee huomattavasti eri yksilöiden välillä. Hampaattoman luuharjanteen resorptiossa on eroja, ja osalle potilaista implanttiinnitteinen peittoproteesi on välttämätön riittävä proteesin pysymisen mahdollistamiseksi. Hyvin pitkälle edenneissä luuharjanteen resorptioissa voi leukaluun lisääminen luusiirteillä olla tarpeellista. Tutkimuksen tarkoituksena oli selvittää Oulun yliopistollisessa sairaalassa tehtyjen implanttiinnitteisten peittoproteesihoitojen tuloksia. Tavoitteena oli myös arvioida hoidon vaikutusta suunterveyteen liittyvään elämänlaatuun ja potilastyytyväisyyteen.


Asiasanat: elämänlaatu, hampaaton alaleuka, hampaaton yläleuka, implantti, luusiirre, OHIP-14, peittoproteesi, seuranta, telttakeppi
To Johanna and Markus,

for inspiration
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Oulu, December 2015

Ritva Kuoppala
Abbreviations

C-Pap  Continuous positive air pressure
IP     Intercuspal position
mBII   Modified bleeding index
mPII   Modified plaque index
OHIP   Oral health impact profile
OHIP-14 Oral health impact profile, short version (14 questions)
OHRQoL Oral health-related quality of life
RP     Retruded contact position
TMD    Temporomandibular disorder
TMJ    Temporomandibular joint
VAS    Visual analogue scale
List of original publications

This thesis is based on the following publications, which are referred throughout the text by their Roman numerals:


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1 Introduction

A removable complete denture is the fastest, simplest and lowest-priced method of compensating for missing teeth in edentulous patients. An implant connection improves the retention and stability of the denture and also enhances oral health-related quality of life (Heckmann et al. 2009, Emami et al. 2009, Thomason 2010). During the past decades advanced implantation techniques as well as experience and knowledge acquired in the field of implant treatments, have enabled fixed implant-supported prostheses as a treatment option for edentulous patients. There are still some patient groups for whom a removable implant-supported prosthesis offers a more beneficial and reasonable treatment choice than fixed restoration. The less demanding treatment process and aftercare as well as economic considerations in comparison with fixed prosthetic solutions could be a deciding factor when planning treatment. Individual anatomical circumstances and confines may also restrict fixed implant prosthetics. An overdenture retained by two implants has often been regarded as the minimum standard of care for an edentulous mandible. An implant overdenture could be considered as a realistic implant treatment option for the majority of edentulous people worldwide.

This study was conducted to assess information gathered from subjects living in the northern part of Finland and treated with mandibular or maxillary implant-supported overdentures in Oulu University Hospital. A very special patient group in this study was comprised of patients treated extraorally with bone grafts harvested from the iliac crest and with dental implants used as tent poles for the graft. This technique was presented by Marx R et al. (2002) and has been used successfully as a modified version in Oulu University Hospital (Kainulainen et al. 2003, Korpi et al. 2012). There are only few studies available related to prosthetic outcome using this surgical procedure in implantation.

The effects and strains resulting from occlusal forces to the implant-bone interface and in the jawbone have been studied using a finite element analysis model (Hussein 2013, Shigemitsu et al. 2014, Topkaya & Solmaz 2015). With this well-tried mathematical simulation method it has been possible to measure and demonstrate stress transmission and distribution in bone. The impact on stress-strain resulting from different attachment types, the number, dimension and inclination of implants and the site of loading on the dental arch has been determined.
Regardless of numerous studies of implant-supported overdentures, there are still varying conclusions concerning the number of implants needed to successfully support an overdenture in the mandible or maxilla, and whether the attachment type is superior to others. The cost-effectiveness of treatment is of interest, and therefore knowledge about treatment success and complications, need for retreatment and aftercare and patient satisfaction is important.
2 Review of the literature

2.1 Edentulousness in Finland

Edentulousness has decreased worldwide during the past decades and today it has accumulated in older age groups. (Suominen-Taipale et al. 1999, Allen et al. 2003). In Europe, edentulousness used to be more frequent among people in rural areas than in densely populated areas (Ekelund 1983, Ambjörnsen 1986) and also among institutionalized old people than in those living in their own homes (Mäkilä 1977a,b, Ekelund 1983). A low level of education and low income have also been observed to predict edentulousness among persons 45 to 69 years old (Palmqvist et al. 1992, Haikola et al. 2008). A study carried out in the Ostrobothnia area in Northern Finland in 1982–83 revealed that edentulousness in 65-year-old subjects was 61% (Tervonen et al. 1985), and further, in the city of Oulu in 1988-1990 edentulousness was 56% among 65-year-old residents (Hartikainen 1994). At the same time in a study carried out in Helsinki in 1989–1991 (Helsinki Ageing Study,) edentulousness among 76–86-year-old inhabitants was 46% (Nevalainen et al. 1996). Consequently it can be stated that edentulousness was more dominant even in younger age groups in Northern Finland than it was in Helsinki in Southern Finland among older people.

In Finland, edentulousness decreased clearly in both genders during the eleven years from the Health 2000 survey to the 2011 survey. In 2011 edentulousness among 55–64-year-olds was practically at the same level as it was in 2000 in a cohort of people ten years younger (45-54 years) (Koskinen et al. 2012). According to information gathered with this survey, every tenth Finn who was 30 years old or more was edentulous. The difference between men and women was small while differences between age groups were substantial. In the age group under 55 years of age less than one percent, in the age group of 55-64 years approximately seven percent and in the age group of 65 to 74 years every sixth individual was edentulous. Nearly half of women at the age of 75 years were edentulous, but only 29% of men were. In 2000 15-17% used conventional complete dentures while in 2011 only 8-9% did (Koskinen et al. 2012). It can be stated that edentulousness in Finland is more prevalent among women than among men, in older age groups than in younger, and in the northern part of Finland than in the southern part.
2.2 Impact of edentulousness on the masticatory system

Anatomical changes occur in the edentulous alveolar ridge over time. The amount of bone loss varies between individuals and greatly between the mandible and the maxilla, being four times greater in the mandible (Tallgren 1972). The reduction of the alveolar ridge causes problems with prosthesis retention and stability and also pain and soreness in the underlying mucosa when the denture-bearing area diminishes. The resorption is continuous and occasionally reaches extreme situations with no alveolar ridge or even a negative ridge in the mandible, making it impossible to treat acceptably with a conventional complete denture. It has been seen that elderly people who have been edentulous for a longer period of time are more adaptable to complete dentures and accept their limitations better than adults with a shorter period of wearing dentures (Allen & McMillan 2003a). On the other hand, elderly people might have more advanced bone resorption, especially women after the age of menopause, and therefore they may have problems with denture use (Närhi et al. 1997).

Poor retention and stability of complete dentures impedes adequate oral function, and lower bite forces and altered masticatory functions have been reported widely. Bite forces of complete denture wearers are around 20% of those achieved by dentate controls, which naturally has an impact on food selection and chewing ability (Helkimo et al. 1977, Haraldson 1979, Bakke et al. 2002, Allen & McMillan 2003a, van der Bilt et al. 2006, Boven et al. 2014). It has been shown that edentulous subjects lose their bone and muscle volume over time (Newton et al. 1993). The gonial angle becomes larger, while the ramus and condylar height become smaller. These changes are more extensive in women than in men (Huumonen et al. 2010, Uma et al. 2012). It has also been shown that the position of the glenoid fossa is more anterior in edentulous subjects than in dentate ones, and this change increases with a longer edentulous period (Raustia et al. 1998). The dominant factor associated with degeneration of the temporomandibular joint (TMJ) seems to be age and loss of molar support. Reduction of dental arch length may also be involved (Luder 2002). Decreased electromyographic activity and masticatory muscle atrophy have been found in edentulous patients (Raustia et al. 1996). These structural changes in the masticatory muscles are assumed to weaken their function and thereby chewing (Raustia et al. 1996). Complete edentulousness may result in more extensive deformative changes in the TMJ compared with patients with teeth-supported occlusion (Csado et al. 2012). Increased temporomandibular dysfunction (TMD) symptoms (Sipilä et al. 2013) and even
lordosis of the cervical spine and a backward head posture related to lowered occlusal height have also been noted (Salonen et al. 1993). Loss of the vertical dimension of occlusion seem to correlate positively with TMD.

Apart from these continuing morphological changes in the bone and muscles of the masticatory system, there may be problems with the underlying mucosa: hyperplasia, chronic abrasions and stomatitis. A denture base plate covering the palate can cause infections unless hygiene is not correct and when salivary flow is decreased with age or as a consequence of medication. Today elderly people are active and social concerns about their inadequate prostheses may have an impact on their quality of life.

2.3 Implant treatment of an edentulous jaw

Quality of life is affected also by oral health in the majority of people (McGrath & Bedi 2002, Steele et al. 2004, Siadat et al. 2008). The type and quality of prosthetic constructions—and nowadays more often implant-supported prostheses—can be considered one aspect of oral health in elderly patients. Earlier, when implant treatments were rare, advanced jaw bone resorption was treated by means of a surgical vestibuloplasty operation (Kotiranta et al. 1986) or ridge augmentation with bone grafts and artificial bone substitute material such as hydroxyapatite (Vanassche et al. 1988, Haers et al. 1991). The aim was to raise the ridge height and enlarge the denture-bearing area to stabilize the denture better. Loss of substitute material over time and the eventual minimal significance of the buccal sulcus depth were common problems for retention of dentures.

Implant treatment of edentulous jaws has been an established treatment option for several decades. Numerous studies substantiate the high survival rates of implants supporting overdentures, the overall survival rates being 95% in the maxilla to nearly 100% in the mandible (Chan et al. 1998, Chrcanovic et al. 2014). The possibility of installing endosseal implants to support an overdenture has been evaluated traditionally by means of panoramic radiographs. A study of 256 edentulous patients carried out in the Oulu district showed that all the males and 97% of the female participants could have been treated with an implant-retained overdenture in the lower jaw (Oikarinen et al. 1995). In the upper jaw the possibility was 62% for males and 59% for females. The anatomical features of an edentulous jaw have been studied to yield reliable clinical and radiological classification for implant sites (Juodzbalys & Raustia 2004). Clinical measurements of the horizontal alveolar process width and evaluation of the height
of the alveolar ridge using radiographs connect the information and bring out the differences in the mandible and maxilla for implant treatment planning. The choice between treatment modality—fixed implant prosthetics or removable prosthetics—has been observed to vary in different countries and cultures (Carlsson et al. 2004). The decision of treatment depends on the individual needs and conditions of the patients, but also the modes of treatment, individual experience and knowledge of the treatment options, and often economic circumstances.

The effect of smoking on the success of implant treatment has been proved in many studies (Levin & Schwartz-Arad 2005, Atieh et al. 2013, Bezerra Ferreira et al. 2015, Chrcanovic et al. 2015). Peri-implant diseases are seen more in smokers and marginal bone loss is higher. Especially the maxillary bone has been found to be more prone to detrimental effects of smoking. The effect of general diseases on implant success or failure rates is not clear (Chrcanovic et al. 2014). Diabetes has been presented as a risk for implant success, but all studies do not confirm this. However, a tendency for more implant failures has been noted in connection with hormone replacement and gastric problems, Crohn’s disease and type 1 diabetes and radical hysterectomy. Cardiovascular diseases and rheumatoid diseases are seen to be potential risk factors for marginal bone alterations, as well (Krenmair et al. 2015).

According to studies published over several decades the majority of complete denture wearers—65-90% of edentulous patients—are quite satisfied with their dentures functionally and esthetically (Carlsson & Omar 2010). There is, nevertheless, a significant group of denture wearers who cannot adapt to conventional dentures because of oral circumstances; i.e., severe resorption of the alveolar ridge, pain due to mucosal abrasions and retention problems (Carlsson & Omar 2010). When implant-supported overdenture wearers have been compared with edentulous conventional denture wearers, it has been found that implants offer significant improvements in oral functional status and quality of life especially in the mandible (MacEntee et al. 2005, Visser et al. 2006, Hobkirk et al. 2008).

Implant connection of dentures improves the neuromuscular activity of the masticatory system and adaptation to dentures. Implant treatment in edentulous jaws has been seen to significantly and clearly improve masticatory function and patients’ satisfaction and oral health-related quality of life (Närhi et al. 2001, Heydecke et al. 2003, Allen & McMillan 2003b, van Kampen et al. 2004, Hobkirk 2008, Heckmann et al. 2009, van der Bildt et al. 2010, Turkyilmaz et al. 2010). However, it has not been obvious that implant treatment has a clear positive effect

Supporting complete dentures with oral implants has been shown to nearly double maximum bite forces compared with patients with conventional complete dentures (Geckili et al. 2012). In addition to increasing maximum bite forces, the treatment has been found to affect chewing efficiency and to increase the thickness of the masseter muscles (Müller et al. 2012). On the other hand it has been suggested that mandibular residual ridge height in edentulous patients is a critical factor for providing greater improvement in masticatory performance with implant overdentures, i.e., when patients have average mandibular residual ridge height the advantages in masticatory performance cannot be noticed when compared with new complete dentures (Fueki et al. 2007).

Treatment with a removable implant overdenture offers the possibility of “reversible” treatment planning, meaning that if the patient’s health status necessitates it, the attachment system can be taken out of use, changing the denture into a conventional one. Changing the attachment system to a less retentive and tight solution like magnets can also be realistic when the strength of the patient’s hands has diminished (Müller et al. 2013).

The success of treatment with implant overdentures is estimated by assessing the success of the supporting implants and the prosthetics. Implant success can be estimated with radiographic and clinical parameters, the health of the peri-implant bone and mucosa, bleeding and hyperplasia. Prosthetic assessment often includes the stability and retention of the denture, breakage and defects in the denture and implant attachments, functional aspects and also oral health-related quality of life measured by patient satisfaction.

2.3.1 Mandibular implant overdentures

Implant-supported and -retained overdentures have become a widespread and predictable treatment option for edentulous mandibles. Comparatively low costs and simple treatment compared with fixed structures, easiness of hygiene and sometimes also better esthetic results when lost hard and soft tissues need to be replaced are factors that account for the success. A sufficient amount of bone is usually available in the interforaminal area of the mandible to enable implantation. The number of implants needed for a mandibular overdenture is smaller than for a fixed implant bridge—usually two to four implants—and this is advantageous when the amount of jawbone is reduced. Numerous studies confirm good treatment
results with two mandibular implants also in the long term (Meijer et al., 2003, 2009, Cune et al. 2010). It is generally stated that for an edentulous mandible, two-implant overdenture treatment should be the standard of care relative to conventional denture treatment (British Society for the Study of Prosthetic Dentistry, 2009, Feine et al. 2002 and Thomason et al. 2009).

Marx et al presented a technique in 2002 in which dental implants were used as “tent poles” in combination with bone grafts to maintain the bone volume (Marx et al. 2002). This surgical procedure use autogenous bone grafts from the iliac crest and implantation is performed extraorally underneath the tip of the mandible at the chin during the same operation. This technique has been called soft tissue matrix expansion and has also been used as a modified technique in Oulu University Hospital (Kainulainen et al. 2003, Korpi et al. 2012). This treatment modality was developed primarily for cases with extreme alveolar resorption of the mandibular bone, with typically approximately six mm or even less of ridge height left, and has helped alleviate severe problems with conventional complete dentures.

During the past decades several different attachment systems have been presented and compared with each other in terms of retentive force, easiness to use and hygiene, tendency to breakage and economic factors. It has been noted that when the attachment system or the number of implants is varied, there is no clear differences in satisfaction among patients with mandibular overdentures (Sadowsky 2001, Klemetti 2008, Cune et al. 2010, Roccuzzo et al. 2012).

2.3.2 Maxillary implant overdentures

Indications for a maxillary implant overdenture differ from those in the mandible. A maxillary overdenture is indicated for patients who have natural teeth or a fixed or removable prosthesis in the opposing mandible, while mandibular implant-supported overdentures are often indicated in completely edentulous situations. The success of the treatment is dependent not only the number of supporting implants, but also on the surgical treatment applied, the amount and quality of bone, the attachment system used and the design of the prosthesis (Närhi et al. 2001, Sadowsky et al. 2007, Slot et al. 2010).

Implant-supported overdentures in the maxilla have some advantages over fixed structures. Removable prostheses can be connected with a smaller number of implants while still producing adequate retention and stability, and implant placement in the remaining bone structures in a resorbed situation can be done without full congruence of tooth position on the denture. A removable construction
simplifies oral hygiene and the overdenture base material can be used to restore and correct facial morphology and lip support and also improve phonetics (Mericske-Stern et al. 2000). A higher frequency of prosthetic complications has been evident in the maxilla when compared with mandible overdentures (Watson et al. 1997, Andreiotelli et al. 2010). This is seen to result from poor bone quality and short implants in the maxilla and a lack of space for prosthetic components in a maxillary overdenture. Dissenting conclusions have, however, been presented by Cehreli et al. 2010, who found prosthetic maintenance requirements for implant overdentures to be similar in both in the maxilla and mandible.

Different bone grafting techniques have been used to enable adequate implant installation and positioning, but also to correct the inter-occlusal relationship altered by resorption of the maxillary alveolar crest (Cordaro et al. 2013a). The iliac crest has been used as a donor site when there has been a need for large grafts. A sinus lift operation is also often performed with maxillary grafts to create sufficient bone height for implantation. These surgical treatments have improved the prognosis of implant treatment in the maxilla (Jensen & Terheyden 2009).

There are dissenting views on whether implants in the maxilla should be splinted with a bar or not. Both attachment structures—a bar and a separate ball- or Locator-type attachments—function well in suitable situations, but mucosal hyperplasia and weakened retention are common problems (Närhi et al. 2001, Sadowsky 2007, Slot et al. 2010, Stoumpis & Kohal 2011). General peri-implant parameters often measured in implant studies don’t differ significantly when comparing different attachment types (Närhi et al. 2001, Naert et al. 2004a). Mucosal changes are common in patients with bar-retained overdentures, but the presence of plaque or peri-implant bleeding has not been observed to be associated with the type of attachment.

### 2.3.3 The number of implants and implant length in an edentulous jaw

Two is considered a sufficient number of implants for an overdenture in the mandible, being evidenced in several studies and systematic reviews (Meijer et al. 2009, Burns et al. 2011, Raghoebart et al. 2014). Increasing the number of supporting implants does not improve treatment results for sure, but it has been concluded that four implants and a bar attachment supporting an overdenture in the mandible shows the highest quality of life score, however patient satisfaction is not
influenced by the number of implants (Mumcu et al. 2012). More implants may make the attachment system more rigid, producing more stability and retention.

The use of very long implants (15–21mm) has decreased from earlier decades. Short implants (< 12 mm) have been seen to be usable also in resorbed mandibles with overdentures, making it possible to implement simpler surgical procedures than with, for example, bone grafting or distraction techniques (Stellingsma et al. 2004). In an assessment of removed dental implants in Finland in 1994–2012, it was noticed that shorter or up to 8-mm implants were removed more often (2.5% removal rate) than 9-mm or longer implants (1.5% removal rate) (Antalainen et al. 2013). The incidence of implant loss has been found to increase if the implants are 10 mm or less in length (Goodacre et al. 2003, Antalainen et al. 2013). However, a recent literature review verifies the high survival rates of very short implants, especially in the mandible (Srinivasan et al. 2014). When a resorbed mandible is treated with four short endosseus implants, the risk of mandibular fractures is possible, but this severe complication is quite rare (Stellingsma et al. 2000, Raghoebear et al. 2000) and the need for surgical retreatment is minimal (Stellingsma et al. 2014). The advantages of using short implants in resorbed mandibles are minimal complication rates, good primary stability, high survival rates and no need for hospitalization of the patient.

More supporting implants are needed in the maxilla than in the mandible. The recommended minimum number of implants for a maxillary overdenture is four, and even six implants have been suggested. The use of only two maxillary implants is usually not recommended, but in some cases it can enhance prosthesis retention and patient satisfaction sufficiently (Mericke-Stern et al. 2000, Slot et al. 2010, Stumpis & Kohal 2011, Roccuzzo et al. 2012, Zembic & Wismeijer 2014). It has been stated that an implant-supported maxillary overdenture with four or more supporting implants and a splinted anchorage provides a high implant and overdenture survival rate (both > 95% per year) (Raghoebear et al. 2014). When using four or less supporting implants with a non-splinted anchorage, there is an increased risk of implant loss. In compromised cases several implants have been recommended. The use of short implants in the maxilla with alveolar bone atrophy compensated with an autogenous bone graft seems to have potential (Felice et al. 2011).

It has been stated that inserting a thin implant is not recommended as it leads more easily to failure in osseointegration (Laine et al. 2005). In some cases with a substantially resorbed alveolar crest, the use of narrow-body mini-implants with immediate or early loading can be relevant to shorten treatment time and if bone
augmentation is not preferred. These mini-implants are normally 1.8–2.4 mm in diameter and 10–18 mm long, and they can be installed with flapless surgery, which shortens the operation time and post-operative recovery (Elsyad et al. 2011, Tomasi et al. 2013). The outcomes of this treatment modality have been encouraging, but comparatively high implant failure rates have been found especially in edentulous maxilla (Elsyad et al. 2011, Sohrabi et al. 2012, Tomasi et al. 2013, Elsyad et al. 2013, Maryod et al. 2014). The patients’ subjective opinions have been good; marked improvement in denture retention and stability as well as chewing ability have been reported. Treatment with mini-implants has been suggested as an alternative for geriatric patients with compromised constitution and when less invasive, quicker and lower-cost solutions are desired for denture stabilization (Mundt et al. 2013).

2.3.4 Immediate loading vs. delayed loading of implants in overdenture treatment

It has been generally admitted that immediate or early loading (two to six weeks after implantation) is possible when adequate primary stability of the implants is achieved with implantation surgery (Chiapasco et al. 1997, Rutkunas et al. 2008). Straumann implants (Straumann, Switzerland) were used widely in the 1980’s to support overdentures in edentulous mandibles. The idea of immediate loading without actual healing time after surgery was implemented by using four one-piece implants splinted together with a bar. The prosthetic work was started immediately or very soon and the patients got their new implant-supported overdentures quickly thus reducing the time of prosthetic rehabilitation. The results and experiences of the treatments were mainly positive and the success rates have been high (Chiapasco et al. 1997, Gatti et al. 2000, Romeo et al. 2002). The limitation of this kind of procedure is the need to use long implants to reach good primary stability and the four implants also need to be in the same vertical line. Resorption of the alveolar ridge and lack of bone have been the reasons for using shorter implants and a delayed treatment option with a suitable healing period.

The survival rates of implants are thought to be dependent on loading time–i.e., immediate, early or conventional loading–but also on other factors such as the number of implants supporting an overdenture, splinting, the length and diameter of implants as well as patient-dependent conditions. According to a systematic review of loading protocols for implant-supported overdentures in edentulous jaws it was concluded that early and conventional loading protocols are still better-
documented than immediate loading and seem to result in fewer implant failures during the first year (Schimmel et al. 2014).

Immediate two-implant-supported overdenture loading has been less documented, but several recent studies are available (Turkyilmaz et al. 2012, Menassa et al. 2014). These studies conclude that immediate or early loading protocols of two unsplinted implants with a mandibular overdenture produce similar clinical and radiographic outcomes as conventional loading and significantly improve patient satisfaction and oral health-related quality of life. It has also been stated that two-implant-supported mandibular overdentures produce similar outcomes with early loading protocol as with conventional loading, but presently there are no data showing that early loading is associated with higher patient satisfaction, however (Rutkunas et al. 2008).

2.3.5 Attachment types and splinting of implants with overdentures

Supporting implants can be splinted with a bar, customized or factory-made, or implant connection can be achieved with individual connectors: balls or other kind of stud elements and with magnets. The advantage of splinting the implants together has been thought to stabilize the implants to facilitate osseointegration, and also to support shorter or unstable implants in difficult and bone deficiency situations to distribute functional loads (Chrcanovic et al. 2014). No statistically significant difference has been found in implant failure rates when different attachment systems have been compared (Cakarer et al. 2011, Stoumpis & Kohal 2011, Chrcanovic et al. 2014).

The choice of attachment is determined by the limitations of oral status, the anatomy of the remaining alveolar bone and interocclusal and horizontal space. A bar construction requires more vertical space for attachment, whereas solitary anchors require less (Andreiotelli et al. 2010). When the implants are located in different jaw segments, splinting with a straight bar can be unfeasible and solitary attachments are needed. Implant angulation may compromise the retention of stud attachments; with bar constructions these problems can usually be avoided. The ball attachment system is often considered simple to use and a more economical treatment modality than bar attachment, and corrections in the laboratory are cheaper and simpler than with bars. The Locator abutment offers the possibility to choose between abutments of different heights if the implant is inserted deep in the alveolar bone. The Locator also has different changeable inserts in the matrix, allowing changes in retention values. Magnetic attachments have been favored in
situations where maximal retention force is not required. There is distinct evidence of lower retention force and patient dissatisfaction with magnetic attachments compared with other attachment types in the long run (Davis & Packer 1999, Naert et al. 2004b, Cune et al. 2005, Trakas et al. 2006, Ellis et al. 2009).

2.3.6 Peri-implant findings and prosthetic complications

Peri-implant tissue evaluation criteria vary between studies. Evaluation often includes plaque index, bleeding index, probing depth, amount of keratinized attached mucosa and marginal bone level, and possible exudation of peri-implant pockets is recorded if seen. There are varying opinions regarding the importance to and impact on peri-implant health of a zone of keratinized attached mucosa surrounding dental implants. It has been reported that healthy marginal mucosa around implants could be achieved in good oral hygiene conditions also in situations when no keratinized mucosa is present (Kaptein et al. 1999, Greenstein & Cavallaro 2011, Kim et al. 2014).

Complications seen with implant overdentures are usually biological and technical or mechanical. More mucosal hyperplasia has been noticed with bars than with ball attachments (Närhi et al. 2001, Naert et al. 2004b). It has been supposed that an insufficient space beneath the bar—which prevents proper cleaning—may cause a soft-tissue inflammatory response under the bar attachment. Another reason for mucosal hyperplasia with bars could be the less precise settling of the denture base to the mucosa compared with ball overdentures (Naert et al. 2004b). Peri-implant mucositis is rather often seen around implants. The incidence (an average of 19 %) associated with implant overdentures is greater than with fixed implants (Goodacre et al. 2003). It has been found that peri-implant tissue health is not related to the retention system used (Davis & Packer 1999, Carlsson et al. 2004, Naert et al. 2004a, Krennmair et al. 2012).

The most common technical complications with implant overdentures are loosening of the retentive mechanism, usually seen in about 30 % of cases (Andreiotelli et al. 2010). In addition, fracture of the retentive anchor, occlusal screw loosening with bars, fracture of the acrylic base material or broken teeth and fractured bars are common findings (Goodacre et al. 2003, Andreiotelli et al. 2010). Resilient attachments were observed to more frequently have broken, loose, or lost female parts and a need for repairs and relining of the denture base, whereas rigid bar attachments more typical need tightening of the bar retainers (Dudic & Mesricske-Stern 2002).
It has been shown that attachments wear over time and lose their retention force (Alsabeeha et al. 2009a, Bayer et al. 2009). Several studies have been published concerning the need for corrections and adjustments of overdentures after delivery of the prostheses. Prosthetic maintenance is needed with all attachments, but bar-supported overdentures have been observed to need it less (Stoumpis & Kohal 2011). A rigid milled bar attachment on four-implant overdentures has been shown to cause less prosthetic maintenance compared with resilient denture attachments with ovoid bars (Weinländer et al. 2010). On the other hand, Gotfredsen and Holm (2000) presented that the frequency of technical complications was higher with bars than with ball attachments with two implants and an overdenture. Recent studies conclude, however, that there is no correlation between attachments and prosthetic complications. Only bars with distal extensions have been seen to have more fractures (Andreiotelli et al. 2010). Maxillary overdentures have been found to have more prosthetic complications than mandibular overdentures (Andreiotelli et al. 2010), but the surveys vary (Cehreli et al. 2010).

2.3.7 Loading stress-strain in the jawbone – a finite element analysis

The distribution and consequences of stress-strain conducted to the implant-bone interface and the jawbone under the overdenture has been of interest in several studies (Hussein 2013, Shigemitsu et al. 2014, Petrie et al. 2014, Caetano et al. 2015, Topkaya & Solmaz 2015).

Finite element analysis is a numerical computer-based stress-strain analysis method which is used to analyze a configuration, for example, from a design of a mandible. It can be used to three-dimensionally illustrate differences in stress when different types and designs of attachments are used in implant overdentures; for example, two supporting implants compared with four, the location of loading stress seen most and the effect of oblique and vertical loading.

It has been noted that increasing the number of implants decreases stress values measured at the implant, and stresses around implants, especially in the cervical region, are higher than stresses on the jawbone (Hussein 2013, Shigemitsu et al. 2014, Topkaya & Solmaz 2015). The highest stresses have been measured at the cortical layer of the bone. The loading site on the dental arch is also important. Both the two- and four-implant-supported models in finite element analysis have shown that the first molar tooth area is the most critical loading site, causing the highest stresses (Topkaya & Solmaz 2015). Splinting of implants with a bar may induce a
favorable effect on stress-strain distribution at the bone-implant interface (Hussein 2013).

Inclination of an implant and misfit of prosthetic components like the implant-bar connection can contribute to higher stress values on prostheses and peri-implant bone tissue (Caetano et al. 2015). Mesial inclination of the implant caused an increase in the stress observed in the peri-implant bone tissue and also in prosthetic screws, while distal inclination decreased the stress values compared with the parallel implant model. A round bar design has presented favorable biomechanical function, causing less strain in the peri-implant bone (dos Santos et al. 2014). Cobalt-chromium framework material was seen to induce higher stress values in bone and prosthetic structures when compared with other frame materials (Caetano et al. 2015).

2.4 Oral health-related quality of life (OHRQoL)

Assessment of oral health-related quality of life (OHRQoL) has been developed since the 1980s by creating simple methods for measuring patients’ views of their oral health-related quality of life (Locker 1988). Assessments have been used for comprehensive and multidimensional evaluation of the results of treatment, and nowadays OHRQoL assessments are widely used in clinical studies (Miettinen et al. 2012, Silvola 2014, Kiline & Ertas 2015, Ishida et al. 2015) and also in surveys measuring the satisfaction of implant overdenture patients (Raghoebear et al. 2003, Awad et al. 2003a, b, Fitzpatrick 2006, Geckili et al. 2011). The use of implants has clearly improved ratings in the OHIP compared with ratings given after treatment with conventional dentures.

The oral health impact profile index (OHIP) (Slade 1997) was originally composed of 49 questions, but it is often used as a 14-item questionnaire (OHIP-14). The OHIP-14 questionnaire concerns sociodemographic and clinical oral status variables and has seven different dimensions: functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability and handicap. Every dimension includes two items, yielding altogether 14. The index measures people’s perception of the social impact of oral disorders on their well-being and it is the most frequently used and one of the best-documented instruments. The OHIP-14 questionnaire is established as an evaluation method, and it is one of the self-reported measurements of the impact of oral conditions on everyday life. The modified shortened version derived from the OHIP, OHIP-EDENT, has measurement properties comparable with the full 49-
item version (Allen & Locker 2002, Lahti et al. 2008). This version may be more appropriate for use in totally edentulous patients than the current short version which is less sensitive and lacks statements which are important to patients wearing dentures. The Visual Analogue Scale (VAS) has also been used to quantify patient satisfaction (Strassburger et al. 2004, MacEntee et al. 2005, Kim et al. 2014). The use of validated and standardized measuring instruments is needed and allows comparison between studies (Assunção et al. 2010). Patient-based evaluations are seen to provide essential information for the treating clinician.
3 Aims of the study

The aim of this retrospective study was to gather information on patients treated with implant-supported overdentures:

1. To evaluate the outcome of treatment, including the function and condition of the overdentures, the health of the peri-implant mucosa and how the patients get along with their prostheses.
2. To evaluate oral health-related quality of life based on the patients’ perceptions by using the OHIP-14 index and also in different age groups.
3. To study the effect of the number of implants supporting the overdenture, the attachment systems used, and the model of the maxillary overdentures on treatment outcome.
4. To evaluate the outcome of mandibular overdenture treatment in extreme bone deficiency cases, where the patients were treated with extraoral bone grafts. The aim was also to find out how the grafted bone around the supporting implants survived after the overdentures were in use.

The research hypothesis was that implants and implant connections in complete dentures function well and bring about a favorable assessment of patients’ OHRLQoL. Another hypothesis was that in extreme mandibular resorption cases the prosthetic treatment outcome will be successful if conventional-length implants are used with tent pole bone grafting to support the overdenture.
4 Material and methods

4.1 Subjects

The study group consisted of patients from the northern part of Finland who had problems with conventional complete dentures and had been referred to the Oral and Maxillofacial Department at Oulu University Hospital for specialist care. The study protocol was approved by the Ethical Committee of the Northern Ostrobothnia Hospital District. All the subjects had given their informed consent for the study. Of all of the patients in the study, 70 were women (75%) and 23 were men (25%); mean age in the follow-up varied from 62 to 69 years. The most usual general diseases were cardiovascular diseases and arterial hypertension, and 30–50% of the patients had medication for these diseases. Also rather usual were asthma, gastric and thyroid diseases. Only 11% of the patients examined were smokers.

4.1.1 Papers I and II

Altogether 112 patients treated with implant-supported mandibular overdentures in years 1985–2004 were invited to the follow-up and 58 (51.8%) of these patients (46 women and 12 men) attended the clinical examination (33/58 of these patients were treated in 1985–1994 and 22/58 in 1995–2004.) The mean follow-up time was 13.7 years (range 3.3–21.9 years). The mean age of the patients examined was 55.2 years (range 37–78 years) at the time of the implantation procedure and 69 years (range 56–90 years) at the time of the clinical follow-up. The implant types used were Straumann (Straumann AG, Waldenburg, Switzerland, including TPS, Bonefit models) in 42 overdentures, Astra (Astra Tech AB, Mölndal, Sweden) in five overdentures, Brånemark (Nobel Biocare AB, Gothenburg, Sweden) in five overdentures, IMZ (Friedrichsfeld AG, Mannheim, Germany) in two overdentures and Osteofix (Osteofix, Oulu, Finland) in four overdentures. The average number of implants installed in the mandible was three (range 2–4), and the mean length of the implants was 12 mm (range 8–21 mm). The total number of implants was 197, still in use and examined at the follow-up examination. All the implants were installed in regions 34–44 in the anterior mandible; 47% of the implants in incisive regions, 36% of the implants in canine regions, and 17% in premolar regions. Before the clinical examination, the patients filled in a questionnaire concerning
their general health, smoking habit and latest appointment with a dentist. They were also asked about their daily oral hygiene habits, i.e., hygiene products used and cleaning of dentures, their use of the overdentures, possible sore spots on the mucosa, changes in the stability and function of the overdentures, chewing and speech.

4.1.2 Paper III

The study population consisted of 17 patients treated with implant-supported mandibular overdentures and surgically with autogenous bone grafts using a modified tent pole augmentation of the mandible, which was done extraorally in conjunction with the installation of the implants. All the patients were referred to specialist care in the Oral and Maxillofacial Department of Oulu University Hospital. The main reasons for the referrals were advanced mandibular bone resorption, i.e., the situation was too difficult or impossible for a normal implantation procedure, and discomfort / problems with conventional complete dentures (Fig. 1A, B Paper 3). There were 14 women and 3 men; their mean age was 68.0 years (range 54 to 77 years) at the time of the follow-up examination. The mean follow-up time was 5 years (range 1.5 to 7.4 years).

All the patients were operated on under general anesthesia. After harvesting of the bone graft from the iliac crest, the grafting and implantation processes were performed. The implants were placed between the mental foramen areas in the anterior mandible. All the patients got a prescription of antibiotics, non-steroidal anti-inflammatory and paracetamol-codeine analgesics after the operation.

Surgical phase complications described were mild postoperative pain in the iliac crest donor site, prolonged mandibular paresthesia, prolonged oral pain and a small mucosal perforation in the oral cavity in conjunction with the primary surgery. These complications were found once in this patient group except for momentary mandibular nerve paresthesia. Two implants were lost and one implant was twisted off the bone in the second phase of surgery and was replaced with a new one. Another implant was lost three years later because of peri-implantitis and was then replaced then with a new one. No surgical infections of the mandible or iliac crest sites were observed during the follow-up.
4.1.3 Paper IV

The study group consisted of 18 patients (10 women and 8 men) treated with a maxillary implant overdenture in the Oral and Maxillofacial Department, Oulu University Hospital. Five patients were treated from 1992 through 1998, their mean age was 54.4 years (range 46–61 years) at the time of implantation, and they were examined clinically and by radiograph in 2007. Thirteen patients were treated in 2004–2013, their mean age was 55.5 years (range 35–69 years) at the time of implantation, and they were examined in the same way in 2014. The mean age of the patients was 62.0 years (range 41–75 years) at the time of the clinical follow-up examination. The mean follow-up time from delivery of the overdenture to the examination was 6.6 years (range 7 months to 14 years).

Of the 18 patients 11 were operated on with two-stage surgery and 7 with one-stage surgery leaving the implants non-submerged in the mouth. Most of the implants installed were situated in the premolar (37%) and canine (33%) regions. Fewer implants were placed in the molar (18%) and incisive (12%) regions. Complications recorded after surgery were a few mucosal sinus perforations in connection with implantation, infections (perimucositis, fistulation) and failures in osseointegration leading to loss of five implants in the early stage.

4.2 Clinical examination

Anamnestic information was gathered with a questionnaire dealing with general health, illnesses, medication, oral hygiene habits, use of the prostheses and possible problems with them. A clinical examination consisted of (1) assessment of the overdentures: retention, stability and occlusion of the dentures, (2) condition of the dentures and attachment, and possible breakage in the denture base or attachment components and (3) a peri-implant soft-tissue examination: plaque, bleeding, pocket formation and the presence of mucosal hyperplasia. The clinical examination of all the patients was performed by the same person specialised in prosthetic dentistry and stomatognathic physiology (RK).

4.2.1 Retention, stability and occlusion of dentures

The retention and stability of the overdentures were recorded as good, moderate or poor. Retention was checked by trying to displace the denture from its attachment in the mouth with a force at right angles to its occlusal forces. Retention was
assessed as good if the denture resisted displacement, moderate if only minor displacement was noted and poor if the denture loosened easily. Stability was checked by applying functional stresses and displacing lateral forces to the dentures. Stability was assessed as good if the denture remained steady, firm and constant in position, moderate if pushing the denture in the occlusal or lateral direction caused swinging or loosening and poor if the denture did not remain in position when occlusal or lateral stresses were applied (Watt & MacGregor 1986, Zarb et al. 1990). To determine the forces applied for removal of the prosthesis, the same researcher evaluated all the overdentures in the same way.

Occlusion was evaluated in the vertical, sagittal and horizontal dimensions with the naked eye; carbon was not used. The retruded contact position (RP) was examined and then repeated several times to confirm the contacts (Okeson 2008). Occlusion was recorded as stable if the slide from the RP to the intercuspal position (IP) was minimal, &lt;1 mm and straight, or unacceptable if the slide from the RP to the IP was considerable, &gt; 1 mm, and/or lateral deviation was noticed. The vertical height of occlusion was determined with a two-dot technique while the patient sat in an upright position in a chair. Distances between dots painted on the philtrum and chin were measured using a ruler. The vertical height of occlusion was evaluated when the upper and lower teeth were in contact. The interocclusal rest space (freeway space) was the difference between the rest vertical dimension (resting position) of the mandible and the measured vertical height of occlusion (Basker & Davenport 2002). The vertical height of occlusion was evaluated as acceptable if the freeway space was between 1 and 3 mm, decreased if the interocclusal distance was 4 mm or more.

**4.2.2 Prosthetic condition, complications and need for repairs**

The attachment system used and the total number of attachment parts in the overdenture base were recorded, including also distal extensions in bar constructions. Possible breakage in the attachment components or denture base was recorded. The number of existing installed implants and those lost after the prosthetic work was completed, and the reason for explatation/loss of the implants were recorded. The patients were asked whether their overdentures had been renewed after delivery or whether there had been any repairs or fixations of the overdenture or the implants in the last few years.
4.2.3 Peri-implant soft-tissue examination, clinical parameters

The amount of mucosal hyperplasia around the implants and implant abutments was recorded as none, moderate or abundant, and the quantity of these findings was evaluated by the same specialist. Modified Plaque Index (mPlI) scores (Mombelli et al. 1987) were used to measure (quantify) the amount of plaque on every implant surface: mesial, distal, buccal and lingual. Plaque accumulation was given a score of 0–3: 0 = no plaque detected; 1 = plaque detected only by running a probe across the smooth marginal surface of the implant; 2 = plaque seen with the naked eye; 3 = abundance of soft matter. Bleeding of the marginal peri-implant tissue was evaluated using a modified Sulcus Bleeding Index. This index also has a score of 0–3: 0 = no bleeding when a periodontal probe is passed along the gingival margin adjacent to the implant; 1 = isolated bleeding spots visible; 2 = blood forms a confluent red line on the margin; 3 = heavy or profuse bleeding. Probing depth around the implants was assessed by inserting a ball-ended periodontal probe (tip diameter 0.5 mm) with 2-mm graduations (LM-Instruments Inc., Parainen, Finland) into the peri-implant pocket on every implant surface.

4.3 Oral health-related quality of life evaluated with the OHIP-14 questionnaire

The oral health impact profile index (OHIP-14) (Slade 1997) was used as a shortened 14-item questionnaire to evaluate the impact of oral health on the quality of life. The index measures people’s perception of the social effect of oral disorders on their well-being. The OHIP-14 questionnaire (Table 1) deals with sociodemographic and clinical oral status variables and has seven different dimensions: functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability and handicap. Every dimension includes two items, yielding altogether 14. The five categories of response for each item are never (= 0), hardly ever (= 1), occasionally (= 2), fairly often (= 3) and very often (= 4). Higher OHIP scores indicate worse, and lower OHIP scores indicate better oral health-related quality of life. The OHIP-14 captures only negative impacts, whereas some other oral health-dependent quality of life instruments capture both positive and negative impacts (Slade et al. 2005).
Table 1. The questions of the Oral Health Impact Profile (OHIP-14). How often have you had problems with your teeth, mouth or dentures during the previous month? The five categories of response for each item are never (= 0), hardly ever (= 1), occasionally (= 2), fairly often (= 3) and very often (= 4).

The questions of the OHIP-14

<table>
<thead>
<tr>
<th>Category</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional limitation</td>
<td>1. Have you had trouble pronouncing words because of problems with teeth, mouth or dentures? (OHIP 1)</td>
</tr>
<tr>
<td></td>
<td>2. Have you felt that your sense of taste has worsened because of problems with teeth, mouth or dentures? (OHIP 2)</td>
</tr>
<tr>
<td>Physical pain</td>
<td>3. Have you had painful aching in the mouth? (OHIP 3)</td>
</tr>
<tr>
<td></td>
<td>4. Have you found it uncomfortable to eat any foods because of problems with teeth, mouth or dentures? (OHIP 4)</td>
</tr>
<tr>
<td>Psychological discomfort</td>
<td>5. Have been self-conscious because of teeth, mouth or dentures? (OHIP 5)</td>
</tr>
<tr>
<td></td>
<td>6. Have felt tense because of problems with teeth, mouth or dentures? (OHIP 6)</td>
</tr>
<tr>
<td>Physical disability</td>
<td>7. Has your diet has been unsatisfactory because of problems with teeth, mouth or dentures? (OHIP 7)</td>
</tr>
<tr>
<td></td>
<td>8. Have had to interrupt meals because of problems with teeth, mouth or dentures? (OHIP 8)</td>
</tr>
<tr>
<td>Psychological disability</td>
<td>9. Have you found it difficult to relax because of problems with teeth, mouth or dentures? (OHIP 9)</td>
</tr>
<tr>
<td></td>
<td>10. Have you been a bit embarrassed because of problems with teeth, mouth or dentures? (OHIP 10)</td>
</tr>
<tr>
<td>Social disability</td>
<td>11. Have you been a bit irritable with other people because of problems with teeth, mouth or dentures? (OHIP 11)</td>
</tr>
<tr>
<td></td>
<td>12. Have you had difficulty doing usual jobs because of problems with teeth, mouth or dentures? (OHIP 12)</td>
</tr>
<tr>
<td>Handicap</td>
<td>13. Have you felt that life in general is less satisfying because of problems with teeth, mouth or dentures? (OHIP 13)</td>
</tr>
<tr>
<td></td>
<td>14. Have you been totally unable to function because of problems with teeth, mouth or dentures? (OHIP 14)</td>
</tr>
</tbody>
</table>

4.4 Radiological examination

A radiological examination (panoramic radiographs) was conducted before the clinical examination. The aim was to record possible pathological findings in bone structures, radiolucency or advanced marginal alveolar bone loss around the implants. In the study concerning the patients treated with bone grafts with the tent
pole technique and implantation (Paper III), the analysis assumed that the implants were covered by bone grafts to the same height as the height of the dental implants at the crest of the alveolar ridge (Korpi et al. 2012). The radiographs were evaluated by measuring the amount of bone resorption in millimeters at every implant approximal site, showing the mean amount of bone resorption around the implants. Being aware of the precise implant lengths, bone resorption in millimeters could be calculated, adjusting for distortion in the magnification of the radiographs. All clinical and radiologic measurements were evaluated by the same investigator specialized in prosthetic dentistry and stomatognathic physiology (R.K).

4.5 Statistical methods

Statistical analysis of the results concerning the plaque and bleeding indices and the associations between sulcus pocket depths was performed using the Wilcoxon signed-rank test. Statistical analysis related to mucosal hyperplasia and associations between plaque and bleeding indices and sulcus pocket depths was performed using the Kruskal-Wallis test. (Papers I and III). In Paper IV the statistical analysis of the results concerning plaque and bleeding indices and associations between sulcus pocket depths was performed using a two-level hierarchial ANOVA model with the SAS mixed procedure (SAS Enterprise Quide 4.3). The model has two error terms, one measuring the variation between different patients and the second representing variation within the same patient.

The average values of the OHIP-14 were calculated using non-missing score values and the results were analyzed using analysis of variance and Student’s T-test. SPSS software (SPSS, Version 16.0, SPSS, Chicago, IL, USA / SPSS, Inc, Chicago, IL) was used to perform the statistical analyses of the data. A significant level of P < 0.05 was used. (Papers II and III). In Paper IV the OHIP-14 questionnaire was analyzed using Student’s T-test, the Mann-Whitney test, the Chi-Square test and Fisher’s exact test, and SPSS software (SPSS, version 20.0, SPSS, Chigaco) was used to perform these analyses.
5 Results

5.1 General health and oral hygiene habits reported by the patients

General health based on anamnestic information was good in 53% of the patients treated with a mandibular overdenture, and 76% had regular medication (Paper I, Table 1). Altogether 74% of the patients performed oral cleanings at least twice a day (Paper I, Table 2). In the patient groups with tent pole grafting and mandibular implant overdentures (Paper III), as much as 67% of the patients reported having good general health; 76% of them had regular medication. Of the patients treated with maxillary implant overdentures (Paper IV), 67% reported having good general health and 78% had regular medication. Most of the patients (72%) performed oral cleanings at least twice a day. It seemed that the patients treated with tent pole grafting and implants were extremely diligent with their oral hygiene: as much as 94% of them performed oral cleaning at least twice a day.

5.2 Clinical findings

5.2.1 Stability and retention of mandibular implant overdentures (Papers I, III)

The stability of the mandibular overdenture was recorded as good in 46.6%, moderate in 37.9% and poor in 15.5% of the 58 cases treated in 1985–2004 (Table 2). The oldest overdenture was 20 years old and still in good condition, and its stability and retention were good. In the patient group (17 cases) with a severely resorbed mandible treated by using the modified tent pole technique, stability was recorded as good in 58.8%, moderate in 29.4% and poor in 11.8% of the cases.

Retention was recorded as good in 74.1%, moderate in 15.5% and poor in 10.3% of the 58 cases treated intraorally, and in the cases treated extraorally with the tent pole technique, retention was good in 64.7% and moderate in 35.3%. The recordings of stability and retention with mandibular overdentures are approximately similar both with ordinary implant-supported and in cases treated with tent-pole grafting and implant overdentures. All the cases treated with tent-pole grafting and implant overdentures had a bar construction as an attachment and the number of implants was four, except in one case being three. The importance of the attachment system to stability and retention seemed to be rather low; the
retention of the overdentures was slightly better with a bar attachment than with a ball attachment. (Table 2).

Table 2. Attachment system and stability and retention of 58 mandibular overdentures evaluated at the follow-up.

<table>
<thead>
<tr>
<th>Attachment system</th>
<th>Good</th>
<th>Moderate</th>
<th>Poor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ball attachment</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Bar attachment</td>
<td>23</td>
<td>19</td>
<td>6</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>22</td>
<td>9</td>
<td>58</td>
</tr>
<tr>
<td>Retention</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ball attachment</td>
<td>6</td>
<td>-</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Bar attachment</td>
<td>37</td>
<td>9</td>
<td>2</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>43</td>
<td>9</td>
<td>6</td>
<td>58</td>
</tr>
</tbody>
</table>

The number of supporting implants seemed to be significant. It seemed that increasing the number of implants also increased the retention and stability of the mandibular overdenture (Table 3).

Table 3. Number of implants and stability and retention of 58 mandibular overdentures examined (n = number of overdentures).

<table>
<thead>
<tr>
<th>Number of implants</th>
<th>Good</th>
<th>Moderate</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>2 (n = 10)</td>
<td>3</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>3 (n = 15)</td>
<td>6</td>
<td>40</td>
<td>7</td>
</tr>
<tr>
<td>4 (n = 33)</td>
<td>18</td>
<td>54.5</td>
<td>12</td>
</tr>
<tr>
<td>Retention</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>2 (n = 10)</td>
<td>5</td>
<td>50</td>
<td>-</td>
</tr>
<tr>
<td>3 (n = 15)</td>
<td>12</td>
<td>80</td>
<td>3</td>
</tr>
<tr>
<td>4 (n = 33)</td>
<td>26</td>
<td>78.8</td>
<td>6</td>
</tr>
</tbody>
</table>

5.2.2 Stability and retention of maxillary implant overdentures (Paper IV)

The stability of the maxillary overdenture was recorded as good in 15 out of 18 cases (83%) (Paper IV, Table 2). However, in three of these patients the overdenture tipped slightly when strongly compressed through the anterior teeth. Stability was recorded as moderate in three cases: two prostheses with palatal coverage and one
without palatal coverage (horseshoe shape). Retention was good in 17 cases and moderate in one case.

5.2.3 Technical and mechanical complications

Technical failures in mandibular overdentures were seen mostly in attachment components; usually loosening, less often breakage or loss of the female retainer in the overdenture. Slight fractures in the acrylic base material were also seen as well as complications in the attachment component attached to the implants. The usual finding regarding these mechanical failures in implant overdentures was that the patients rarely had noticed them at all.

Mandibular overdentures

In 32 overdentures in which a technical failure was recorded, 28/32 had a bar attachment and 4/32 had a ball attachment. Implant-supported overdentures were renewed in 19/58 (33%) patients, and 39/58 (67%) patients still used their original overdentures. A need to reline the overdenture was noted at the time of the examination in 25/58 (43%) of the prostheses. Altogether, 30/58 (52%) patients reported that their overdenture had been repaired or relined within the past few years, while 21/58 (36%) patients reported that no repairs had been made to their overdenture recently.

In a study of 17 patients treated with tent-pole grafting and an implant overdenture, about half (53%) had no mechanical failures in their prostheses, while five overdentures were noted to need relining. Ten patients reported that corrections and repairs had been made to their prostheses within the past few years.

Table 4. Technical/mechanical failures recorded in 58 implant-supported mandibular overdentures.

<table>
<thead>
<tr>
<th>Mechanical failures</th>
<th>n</th>
<th>% of all overdentures</th>
<th>% of all failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakage or loss of the female retainer in the overdenture</td>
<td>3</td>
<td>5.2</td>
<td>9.4</td>
</tr>
<tr>
<td>Breakage or loss of attachment in the implant</td>
<td>1</td>
<td>1.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Loosening of attachment components</td>
<td>23</td>
<td>39.7</td>
<td>71.9</td>
</tr>
<tr>
<td>Several failures mentioned</td>
<td>5</td>
<td>8.6</td>
<td>15.6</td>
</tr>
<tr>
<td>No breakages</td>
<td>26</td>
<td>44.8</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>58</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 5. Technical/mechanical failures recorded in implant-retained overdentures evaluated in 17 patients treated with a modified tent pole technique.

<table>
<thead>
<tr>
<th>Mechanical failures</th>
<th>n</th>
<th>% of all overdentures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakage / fracture in base material in the overdenture</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>Fracture in denture tooth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loosening of attachment components</td>
<td>6</td>
<td>35.3</td>
</tr>
<tr>
<td>Several failures mentioned</td>
<td>1</td>
<td>5.9</td>
</tr>
<tr>
<td>No breakages</td>
<td>9</td>
<td>52.9</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>100</td>
</tr>
</tbody>
</table>

Maxillary overdentures

At the time of examination, mechanical failures were seen in eight patients, all minor fractures in the acrylic base or artificial tooth or loosening of matrices, while 10 patients had no mechanical failures (Paper IV, Table 2). A need to reline the overdenture was noted in one case. Eight patients reported that several corrections and repairs had been made to their prostheses within the past few years. The overdenture was renewed in three cases, and the other 15 patients had the original implant-supported overdenture. Nevertheless, examination of the patients’ prosthodontic history files after delivery of the overdenture revealed several appointments for repairs and retreatment.

5.2.4 Peri-implant findings

The most common peri-implant soft-tissue findings were bleeding and mucosal hyperplasia – more than half of the implants supporting an overdenture had hyperplasia around them. Mucosal hyperplasia was seen more often in cases with bars, 28/48 (58.3%), than with a ball attachment, 2/10 (20%) in the mandible (Paper I).

The amount of plaque and bleeding was more marked on the lingual surfaces of the mandibular implants and less marked on the buccal surfaces, which was statistically significant (Table 6, 7). In maxillary implants no differences between the implant surfaces were noticed except between distal and buccal implant pockets.

No statistically significant difference in pocket depths was noted between mesial and distal pockets or between buccal and lingual pockets, but there was a statistically significant difference ($p < 0.05$) between buccal and lingual pocket depths when compared with approximal pocket depths in the mandible. In
maxillary implants the pocket depths were mostly 2–4 mm (79%); very low pockets (1 mm) were seen most often on the buccal surfaces (10.5%) and least often on the palatal surfaces (1.3%). The mean pocket depth on the buccal surfaces of the implants was 2.5 mm and 4.1 mm on the palatal surfaces. Deeper pockets, 5–8 mm, were recorded most often on the palatal surfaces (34.3%), caused partly by the thick palatal mucosal anatomy. Statistical differences (p < 0.05) between implant pocket depths were found with all surfaces except when comparing mesial and distal pocket depths.

The presence and/or amount of mucosal hyperplasia around the implant structures did not seem to correlate with plaque accumulation, but it did correlate with bleeding, especially on the buccal and lingual surfaces, and with pocket depths on the lingual surfaces around the implants in the mandible (Paper I).

Table 6. Mean modified Plaque index (mPlI), mean modified Bleeding index (mBlI) and mean pocket depth measured on different implant surfaces in the mandible according to Mombelli et al. (1987) (Paper I).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mesial</th>
<th>Distal</th>
<th>Buccal</th>
<th>Lingual</th>
</tr>
</thead>
<tbody>
<tr>
<td>mPlI</td>
<td>1.23</td>
<td>1.07</td>
<td>1.14</td>
<td>1.59</td>
</tr>
<tr>
<td>mBlI</td>
<td>1.41</td>
<td>1.50</td>
<td>1.29</td>
<td>1.66</td>
</tr>
<tr>
<td>Pocket depth</td>
<td>2.879</td>
<td>2.762</td>
<td>2.300</td>
<td>2.446</td>
</tr>
<tr>
<td>(range 0.5-8 mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Mean modified Plaque index (mPlI), mean modified Bleeding index (mBlI) and mean pocket depth measured on different implant surfaces in 17 patients treated with a modified tent pole technique (Paper III).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mesial</th>
<th>Distal</th>
<th>Buccal</th>
<th>Lingual</th>
</tr>
</thead>
<tbody>
<tr>
<td>mPlI</td>
<td>1.21</td>
<td>0.94</td>
<td>0.85</td>
<td>1.66</td>
</tr>
<tr>
<td>mBlI</td>
<td>1.09</td>
<td>0.96</td>
<td>0.87</td>
<td>1.45</td>
</tr>
<tr>
<td>Pocket depth</td>
<td>3.007</td>
<td>2.987</td>
<td>2.522</td>
<td>2.276</td>
</tr>
<tr>
<td>(range 1-8 mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Mean modified Plaque index (mPlI), mean modified Bleeding index (mBlI) and mean pocket depth measured on different implant surfaces in the maxilla (Paper IV).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mesial</th>
<th>Distal</th>
<th>Buccal</th>
<th>Palatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>mPlI</td>
<td>0.62</td>
<td>0.57</td>
<td>0.51</td>
<td>0.47</td>
</tr>
<tr>
<td>mBlI</td>
<td>1.33</td>
<td>1.39</td>
<td>1.22</td>
<td>1.37</td>
</tr>
<tr>
<td>Pocket depth</td>
<td>3.125</td>
<td>3.474</td>
<td>2.513</td>
<td>4.079</td>
</tr>
<tr>
<td>(range 1-10 mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5.3 Radiological findings

A panoramic radiograph was taken from all the study participants. Pathological findings obtained in radiograph–advanced bone resorption, radiolucency of bone attached to implants or inflammatory changes–caused a referral to treatment and further examination. Four patients of the 58 examined in the mandibular overdenture study (Paper I, II) were referred for further dental care because of peri-implant mucosal problems and/or radiographic findings.

In the patients implanted with the modified tent pole technique and bone grafts (Paper III) the analysis of grafted bone resorption disclosed only minimal bone resorption around the implants in the mandible. The mean resorption measured was 0.78 mm per implant (range 0 to 2.98 mm per implant approximal site).

In the maxillary overdenture study (Paper IV), in the former patient group examined in 2007, one patient was found to have advanced resorption of the alveolar bone around the implants. This patient had treatment periods several times after the first implantation; some of the implants had explanted during the follow-up period and a few new implants had been inserted. According to later patient files, this patient had finally lost all his implants after a few years (Paper IV, Table 1, 2 patient 2). No pathological radiographic findings were found around the implants in the patient group examined in 2014.

5.4 Findings of OHRQoL

The results showed that patients with implant-supported mandibular and maxillary overdentures were satisfied with their oral health-related quality of life (OHRQoL). The distribution of the patients’ responses to the OHIP-14 questions was mostly uniform in all seven dimensions of OHIP-14 except in the dimensions of ‘physical pain’ (OHIP-3 and OHIP-4) and ‘psychological discomfort’ (OHIP-5), where fewer ‘never’ and ‘hardly ever’ answers, i.e., more complaints were reported by the patients (Paper II, III, IV).

Older patients with mandibular overdentures were more satisfied than younger ones in both genders (Fig.1). This finding was not seen in patients treated with bone grafts and tent pole implantation (III) nor in maxillary implant overdenture patients in age groups under 62 years of age and in the group 62 years or older (IV).

Neither the number of supporting implants nor the implant connection type seemed to have a statistically significant influence on OHRQoL with implant-supported overdentures (Fig. 2–4). However, the patients with two implants and an
overdenture in the mandible reported higher OHIP-14 values, but not significantly higher, which means more dissatisfaction with OHRQoL compared with patients with four implants and an overdenture. Slightly higher OHIP-14 values, i.e. more dissatisfaction, were also noted with a ball connection than with bars (Fig. 3). In maxillary implant overdentures it was also noticed that there were no statistically significant differences in OHIP scores between groups treated with only two implants or more implants (Fig.4), or treated with a denture with palatal coverage or with a horseshoe design (Fig.5).

Fig. 1. Mean OHIP-14 sum scores in three different age groups with mandibular implant overdentures.
Fig. 2. Mean OHIP-14 scores and number of implants per mandibular overdenture.

Fig. 3. Mean OHIP-14 scores and attachment type in mandibular implant overdentures.
Fig. 4. Mean OHIP-14 scores and the number of supporting maxillary implants.

Fig. 5. Mean OHIP-14 scores and a model of a maxillary denture.
6 Discussion

6.1 Material

The current study has evident shortcomings partly due to the relatively small patient groups who participated in the examination. The distances in Northern Finland are long, and the threshold to refer patients for specialist care is high. As edentulousness is still more prevalent in Northern Finland, it could be assumed, that the real need for implant overdenture treatment is higher than has been implemented. Problems in data recording were caused by the old, partly handwritten patient files and out-of-date registers of patients, making the process of finding the right subjects for the study time-consuming. A limitation of our study was that splinting bars were not taken off with every patient and the success of every single implant was not examined. A radiological examination was not performed systematically in the former patient groups treated in 1980-1990, and part of the x-ray films were missing and of poor quality, preventing accurate observation. Patients did not have regular follow-ups in the Oral and Maxillofacial Department of Oulu University Hospital and no information was available afterwards from patients treated outside of the University Hospital.

6.2 Mandible

The high survival rate of implants supporting overdentures in the mandible was good in this study, as noted earlier (Sadowsky 2001, Timmerman et al. 2004, Schwartz-Arad et al. 2005, Meijer et al. 2009). A mandibular overdenture has been shown to be a highly successful prosthetic treatment similar to fixed implant prostheses. It has been noted that patients treated with removable implant-supported overdentures have been equally or even more satisfied with their overdentures than patients with fixed implant-supported prostheses (Sadowsky 2001, Carlsson et al. 2004). Traditions in prosthetic treatment are supposed to influence the decision on whether to treat an edentulous mandible with a fixed or a removable solution, and there is a great variation among countries in the choice of implant treatment of edentulous mandibles (Carlsson et al. 2004).

Treatment with mini-implants has become more common, although their outcomes have varied and implant failure rates have been comparatively high. It may be that the lower cost of mini-implant equipment and the simplified surgical
procedure without flap elevation of the mucosa have created an illusion of the easiness of the overdenture treatment and lowered the threshold for these treatments. It might be reasonable to choose a treatment with two standard implants in the mandible, which is thoroughly well-tried and has proved to be predictable in a perspective of several decades. Furthermore, it has been shown that patients’ satisfaction with two-standard-implant overdentures remains good in the long run, notably in the mandible.

The average number of implants used in the present study of 58 mandibular overdentures was three (Paper I). A consensus report published after the third EAO (European Association for Osseointegration) consensus conference in 2012 concerning implant-supported overdentures stated (Gotfredsen & Wiskott 2012), that there are no differences in biological, technical and patient-reported outcomes, up to 10 years, when comparing two implants or four implants supporting an overdenture in the mandible. The incidence of complications with two implants supporting an overdenture seemed to be so low and patient satisfaction so high that two implants suffice (Gotfredsen & Wiskott 2012) (Paper I, II).

The results with only one single midline implant inserted in the mandible have been encouraging in several studies, however, long-term results are not yet available (Walton et al. 2009, Harder et al. 2011, Cheng et al. 2012, Passia et al. 2014, Carlsson 2014). One symphyseal implant functions as an anchorage for a mandibular complete denture and can bring improvement in patient satisfaction and a reduction in reported problems. This treatment is a therapeutic and economical alternative and might be a reasonable option for geriatric patients (Krennmaier & Ulm 2001, Alsabeeha et al. 2009b, 2011). When treatment outcomes of patients treated with two or only one implant were compared, it was noted that after five years there was no statistical difference in overall satisfaction or survival of the implants with mandibular overdentures (Kern et al. 2015). Analysis of a mandibular overdenture supported by one implant revealed higher implant loss rates than with an overdenture on two implants. The incidence of denture base fractures was not significantly different between overdentures retained by one implant and those retained by two implants (Gonda et al. 2010). On the other hand, Bryant et al. (2015) concluded that one-implant dentures had more fractures and needed more prosthetic maintenance. When the strain conducted to the bone surrounding a single implant was evaluated, it was noted that the strain was low, as was stress in the abutment. It seems that a median single-implant overdenture could be a practical option in situations where simple treatment is preferred. Awareness
of possible complications and the need for prosthetic maintenance should be informed.

The most common complication with mandibular overdentures in the present study was loosening of the retention mechanism, mostly the female retainer (Paper I, III), as noted also in earlier studies (Goodacre et al. 2003, Naert et al. 2004a, Trakas et al. 2006, Andreiotelli et al. 2010). The number of supporting implants was seen to have significance, and increasing the number of implants also increased the retention and stability of mandibular overdentures (Paper I). Distal extensions have been used here with bar attachments, but their effect on denture stability and retention is unclear (Paper I). When only two or three implants are available, it could be expected, however, that these additional bits of bar give extra retention by means of two clips.

The outcomes of treatment of severely resorbed mandibles using a modified tent pole grafting technique and implant overdentures in Oulu University Hospital have been successful. The implants used in these patients were 12–15 mm in length to the raised bone with the graft. Consequently, conventional-length implants could be inserted instead of short ones (Paper III). This could have a positive influence on the long-term success of treatment (Korpi et al. 2012). Because the grafting and implantation are done in the same operation, healing time is shorter and the final prosthesis with an implant connection can be completed relatively soon (Paper III). The implants are covered by mucosa during the healing time and they are exposed before prosthetic treatment. This patient group was highly motivated to oral hygiene and home care; as much as 94% of the patients cleaned their prosthesis at least twice a day. It could be concluded that the patients appreciated the treatment very much, as they understood how demanding the treatment process was (Paper III).

6.3 Maxilla

Stability and retention assessments seemed to be somewhat better with maxillary overdentures than with mandibular ones in our study, which is understandable because of the large palatal support provided to the dentures (Paper I, IV). However, the type of prosthesis—with or without palatal coverage—does not seem to play an important role in patient satisfaction (Sadowsky 2007, Zembic et al. 2013), and our study goes along with this finding (Paper IV). On the other hand, dissenting opinions have been stated by Al-Zubeidi et al. (2012). They found that 85% of patients chose an overdenture without palatal coverage if they had the possibility
to choose. Patients often adapt to complete dentures that cover the palate. It might, however, improve the nutritional aspects of a diet if taste would improve. There are hardly any studies concerning the relationship between covering/uncovering the palate and taste of foods and the possible impact on nutritional status.

It has been stated that it isn’t possible to recommend an exact number of implants to support an overdenture in the maxilla; which alternative might offer better biological, technical or patient-reported outcomes compared with another. When implant post-loading loss has been analysed, the implant loss rate per 100 implant years was significantly higher in the maxilla than in the mandible (Kern et al. 2015). The same was noted when comparing two versus four implants retaining a mandibular overdenture or a maxillary overdenture with less than four implants compared with overdenture with four implants. Nowadays the implant survival rate in maxillary overdentures is so high that it can be considered overtreatment to insert extra implants, i.e., more than four, and based on cost-effectiveness it is also advantageous to place four implants (Slot et al. 2014).

Implant types used earlier to support an overdenture in the maxilla survived worse than in the mandible, and the success/survival rates have varied (from 42% success to 87% survival) (Jent & Lekholm 1995, Buser et al. 1997, Bergendal & Engquist 1998, Goodacre et al. 2003, Schwartz-Arad et al. 2005, Sadowsky 2007, Carlsson 2014). This could result from the fact that the alveolar bone has been of poor quality and a fixed implant prosthesis could not be used.

Ten patients out of 18 treated with a maxillary implant overdenture in this study did not have any prosthetic complications at the time of the follow-up (Paper IV). Examining the patient files after treatment and follow-up revealed, however, many prosthetic and mucosal problems in these patients. Still, most of them were simple and easily treatable. Only two patients had problems with matrices at the follow-up, which is a common complication noted. According to the patients’ files, an additional seven patients had had problems with matrices after the treatment was completed initially. Mucosal hyperplasia was surgically treated in seven patients, and several relinings had also been made. It seems that some patients have few or minor complications or none at all after treatment, but some will have more complications (IV).

6.4 Attachment system

The impact of the attachment system on the retention and stability of the overdentures seemed to be rather low in the present study. Bars were used in 73
cases, ball attachments in 16 cases, a Locator in four cases and magnets were not
used. Bars gave slightly better assessments in the mandible, but in the maxilla this
could not be noticed (Paper I, III, IV). More technical complications and repairs
have been noted with bar attachments than with balls (Gotfredsen & Holm 2000),
while contrary results have been also presented. No relevant clinical differences
have been found when comparing splinting or non-splinting of implants in the
maxilla, either (Gotfredsen & Wiskott 2012), although Naert et al. (2004b) stated
that a bar connection provides lower comfort and stability of the maxillary denture.

When evaluating the retention and stability of the different attachment types,
varying outcomes have been found. The bar attachment seems to have a high
retention force immediately after treatment, but retention decreases over time,
which is explained by deactivation of the bar clips. In the present study four patients
had two implants and a bar supporting a mandibular overdenture. These patients
had survived well, however, complications seen were usually loosening of the
retentive clips. The common finding regarding these mechanical failures in
attachment components was that the patients rarely had noticed them at all.
Loosening of a single, sometimes even several retainers, usually has a minor effect
on the use of an overdenture and retention is not clearly worsened subjectively
(Papers I, III, IV).

Ball-retained overdentures have been shown to have the greatest vertical
retention force compared with bars and especially with magnets, which had the
lowest retention force after a 10-year follow-up (Naert et al. 2004b). Magnets
corrode and cease to function over time (Davis &Packer 1999, Naert et al. 2004b,
Ellis et al. 2009). Prosthesis stability has been shown to be significantly lower in
magnet-retained overdentures in the mandible compared with balls and bars.
Magnetic attachments have been found to provide less patient satisfaction and
chewing is less effective when compared with ball attachments. A few in vitro
studies reported clearly better retention forces with Locator abutments than with
balls and magnets (Sadig 2009), while Scherer et al. (2013) found best retention
and stability with ball attachments. On the other hand, because of the need for a
higher number of aftercare appointments for overdentures retained with ball
attachments, an overdenture with a bar on two implants might be the most cost-
effective treatment option (Dudic & Mericske-Stern 2002, Stoker et al. 2007,
Klemetti 2008).

The locator attachment system has become popular nowadays and this
attachment has proved to have good clinical results in both the maxilla and the
mandible (Roccuzzo et al. 2012, Cordaro et al. 2013b). The Locator attachment
used also in the present study seems to be an alternative that is especially suitable also in more complicated cases. It contains an abutment part that is available for divergent implant positions and its retention force is easily regulated with changeable matrices. A Locator connection has been found to be less susceptible to damage (Cakarer et al. 2011, Akca et al. 2013), but this study does not, however, support this finding (Paper IV). Krenmair et al. (2012) presented also that somewhat more post-insertion aftercare is needed with Locator abutments than with balls, but the repairs are neither time-consuming nor expensive (Vere et al. 2012, Daou 2013).

In the study of 18 maxillary overdentures, four cases had Locator abutments and three of them had undergone several replacements of matrices according to patient files (Paper IV, Table 2). At the time of the follow-up the same three cases had some prosthetic complications. The reason for these divergent findings might result partly from the status of edentulism. In the present study the opposite jaw of the patients was not totally edentulous, but partially dentate. In the study by Cakarer et al. (2011), all the participants were completely edentulous, which may strain the attachment of the overdenture less.

It seems that neither the number of implants used nor the attachment type chosen or splinting the implants in mandible has a significant impact on treatment success and patient satisfaction, although different results have also been reported (Naert et al. 2004b, Timmerman et al. 2004, Trakas et al. 2006, Cune et al. 2010). Divergent conclusions can be confusing. Some authors prefer some particular attachments better than others, and they report more complications being linked to certain attachment types which other studies refute. These disparities can sometimes be due to technique sensitivity of the technical work of implant overdenture prosthodontics (Payne et al. 2000). The work of a dental technician demands utmost precision and minor defects can be produced. There is no standardization of the technical work and this might have an effect on treatment outcomes. Longitudinal clinical studies have not found any significant differences in implant survival rates, peri-implant tissue health and marginal bone loss related to the retention system (Bergendal & Engquist 1998, Gotfredsen & Holm 2000, Carlsson et al. 2004, Naert et al. 2004a, Bryant et al. 2007).

### 6.5 Overdentures contribute to good quality of life

The present results showed that patients treated with implant-supported mandibular and maxillary overdentures were satisfied with their oral health-related quality of
life (OHRQoL). Responses to the OHIP-14 seemed to resemble each other in the mandible and maxilla; patients showed more dissatisfaction in the dimension of ‘physical pain’ than in the other six dimensions. A limitation of our study was that due to the study design, it was not possible to assess the OHIP-14 prior to implant treatment, which is common in retrospective studies (Mundt et al. 2013). It would have been considerable more informative if the OHRQoL had been studied also before treatment, whereupon the real change and improvement in quality of life would had been distinct. The impact of the support of implants could have been studied if a control group—for example a group of patients treated with new conventional complete dentures—had been available. Bias related to questionnaires inquiring about treatment results may appear when the interviewee tends to respond to please the interviewer. In our study this was avoided because the questionnaire was filled in by the patients themselves earlier.

Treatment satisfaction is a very multifaceted question influenced by many factors, commonly not directly related to the stomatognathic system (Al Quran et al. 2001). Phonetic and functional problems seem to decrease after the first year of use of implant dentures, while patient comfort becomes better. Patient satisfaction with implant overdenture treatment can be good even though at the same time the researcher’s assessment of examined retention and stability is not as high. It is presumable that patients adapt and content themselves when function improves and no pain or discomfort exists. The reason for choosing an overdenture instead of a fixed structure is commonly lower cost, but it has been noted that the patients with implant overdentures are equally or even more satisfied with their overdentures as those with fixed implant-supported prostheses (Carlsson et al. 2004).

A mandibular implant-supported overdenture with four implants and a bar has been shown to produce the highest quality of life scores. At the same time it has been noted that patient satisfaction is not dependent on the number of implants or the attachment type or the coverage of the palatal plate. (Närhi et al. 2001, Klemetti 2008, Balaguer et al. 2011, Zembic et al. 2013, Zembic & Wismeijer 2014). Implant overdenture treatment has clearly proved to improve OHRQoL regardless of the number of supporting implants or the type of attachment system (Strassburger et al. 2006). Increasing the number of supporting implants usually results in only a slight increase in patient satisfaction (Mumcu et al. 2012). In the present study no statistically significant differences in QHIP scores were seen when comparing attachments with two or more implants supporting the overdenture in either the mandible or the maxilla (Paper II, IV).
6.6 General discussion

The results of this study showed that the outcome of treatment with implant-supported overdentures was good, predictable and successful in the long-term. A panoramic radiograph was used as a radiological research method in this study. The weakness in this method is the one-dimensional x-ray of the jawbone, being somewhat inaccurate and not very diagnostic in the anterior parts of the jaws. Using a panoramic radiograph as a primary overview of the study participant usually provides the information required, making it a diagnostic aid. Regardless of the shortcomings of this radiographic method, it is still often used in evaluations of implant marginal bone levels (Krennmaier et al. 2015, Merheb et al. 2015).

The outcome of treatment has been good also in elderly patients as well as in severe situations with alveolar bone deficiency. Regardless of some minor mechanical defects noted in the overdentures, they did not hinder everyday use and the prostheses functioned well. In the study of 58 mandibular overdentures, 67% of the patients still used the original overdenture, the oldest one having been in use for 20 years. The results clearly substantiate earlier findings related to the success of implant overdenture treatment in the mandible in the long term (Raghoebar et al. 2003, Meijer et al. 2009, Cune et al. 2010).

The most frequent prosthetic complication in the study was loosening of the retention mechanism, usually matrices; similar findings have been commonly shown (Payne et al. 2000, Cakarer et al. 2011, Stoumpis & Kohal 2011). Most of the mechanical complications (both ball and bar/clip systems) have been seen to occur within the first year after treatment, which could be explained by the fact that the prosthesis needs some time to “settle down” in the mouth (Trakas et al. 2006). Most common peri-implant soft-tissue findings were hyperplasia around the implants and attachment constructions, and bleeding especially on the lingual surfaces of the mandibular implants (Paper I, III). Mucosal hyperplasia was seen more with bar attachments than balls, and that is often shown in other studies.

Sophisticated treatment procedures and methods and new innovations in implant prosthetics have been taken into use over the decades. The attachment types used here were bar, ball and Locator attachments. None of the patients had magnetic attachments or telescopic crowns. According to Carlsson (2014), there is no strong evidence of the superiority of one attachment system over others in terms of patient satisfaction, survival, peri-implant bone loss and relevant clinical factors. This simplifies the clinician in choosing and suggesting different anchorage options for patients in implant overdenture treatment.
The good treatment outcome seen here with maxillary overdentures even with only two implants was encouraging. It has to be kept in mind that this alternative cannot be recommended in cases with unfavorable alveolar bone conditions or compromised implantation. Palatal coverage is needed when only two implants are used.

Analysis of the radiographs taken from the patient group treated with tent-pole bone grafting and implant overdentures revealed encouraging treatment outcomes. Only minimal bone resorption was noticed around the supporting implants, the mean follow-up being five years. This study confirms the good results of grafted bone survival under prosthesis pressure with this technique (Marx et al. 2002). Patients with an extremely resorbed mandibular bone will benefit from this treatment not only because of a retentive prosthesis, but also because lost bone is restored, toughening the mandible and therefore preventing fractures of the jawbone.

When the patients’ satisfaction was explored with the OHIP -survey it was seen that older age groups were more satisfied than younger ones, and no significant differences were seen between genders. The patients in the youngest age group were mainly still involved in working life and confronted demanding social situations which could explain their greater dissatisfaction. For that reason, if the retention force is not good enough, the possibility of replacing the attachment system with a more retentive one is offered with implant overdentures.

Patients treated with an implant-supported overdenture need more treatment interventions, treatment time and aftercare maintenance visits than patients treated with conventional dentures, which raises costs (Visser et al. 2006). Despite that, the significantly higher patient satisfaction noticed must be taken into consideration when making decisions on treatment options. It has been stated that stabilization of mandibular complete dentures by means of osseointegrated implants is one of the most effective interventions in dentistry (Müller 2014). On the grounds of 30 years of clinical experience and knowledge gathered from numerous studies from 1980 on, this cannot be denied.
7 Summary and conclusions

It has been noted that tooth loss will remain a reality in old age, but will occur later in life. Based on the results of this study it could be stated that overdenture treatment with two implants and ball attachments in the mandible is recommended especially for elderly patients. In the maxilla even two implants may be enough if palatal coverage is enforced. Treatment with two implants is not especially demanding, and aftercare, relinings and repairs are easy to do. For younger overdenture patients, tight retention and good stability of the denture may be more important and therefore more implants are recommended. On the other hand, the anatomy of the alveolar ridge can affect the stability of the overdenture in the mandible. If the alveolar ridges are well-shaped and less resorbed, increasing the number of supporting implants does not necessarily improve stability. In the maxilla a horseshoe-type denture that doesn’t cover the palatal mucosa allows the person to taste and sense heat better when having meals. These patients have been very content with their type of prosthesis, however it does not affect the OHRQoL studied.

Implant overdenture treatment in the mandible has been shown to be highly successful also among very old patients. The standard of care in geriatric patients can be adapted considering the patient's functional capability as well as motivation and social requirements. It can be expected that if forthcoming clinical follow-up studies show good treatment outcomes and more practical experience is gained with mandibles with only one implant or maxilla with two implants, this will be helpful in making treatment decisions.

Implant overdentures will doubtless be a more frequent treatment alternative in the future. Average life expectancy is rising, the number of elderly is growing and senior citizens are more aware of the possibilities of improving their general and oral health and, by implication, their masticatory performance. Removable overdentures are easier to maintain than fixed solutions, which enhances the prognosis of implant treatment, especially among geriatric institutionalized patients.

Several points should be considered during treatment planning and especially during selection of the attachment mechanism. Apart from general health status, also the patient’s expectations, social status and risk factors including occlusal forces, retention of the construction needed, amount and quality of available bone, pain inflicted on the soft tissue, expected level of oral hygiene, relationship and status of the opposing jaw and inter-implant distance as well as cost effectiveness should be considered. Finding out the possible existence of parodontopathogens
and individual prophylactic antimicrobial treatment before implant therapy could be advantageous.

Patient satisfaction is one of the principal goals in the treatment of edentulous individuals, and this can be achieved with reasonable treatment and costs. Every edentulous patient case doesn’t need complex treatment, but it is desirable to have the know-how for demanding cases. With all the knowledge and experience related to implant overdentures gathered and learned over the years, patient satisfaction can be achieved in a worthwhile way.

The results of this study indicate that:

1. Implant supported overdenture treatment is successful in the long term and most overdentures function well despite possible minor breakage in the prosthetic structures. Peri-implant mucosal changes, bleeding and hyperplasia were seen commonly, but severe problems were rarely seen. Patients had high motivation for oral hygiene and they got along well with their overdentures.

2. The OHIP-14 questionnaire revealed the patients’ high satisfaction with their prostheses and oral health-related quality of life. Older patients with mandibular overdentures seemed to be more satisfied than younger ones.

3. Neither the number of supporting implants nor the connection type in maxillary overdentures seemed to have a statistically significant impact on OHRQoL. There were no significant differences in OHIP scores between groups treated with a palatal-covering or a horseshoe design maxillary overdenture.

4. Prosthetic treatment with implant overdentures is successful also in cases with extreme mandibular bone resorption treated with tent pole grafting. Resorption of the grafted bone around the mandibular implants was low, the mean follow-up time being five years. This patient group was highly motivated to home care and the patients were satisfied with their overdentures and oral health.
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