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Sixty Years of Clinical Experience with Nobel Biocare Osseointegrated Implants

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A CIP record for this book is available from
the German National Library.
ISBN 978-1-78698-175-2

QUINTESSENCE PUBLISHING
DEUTSCHLAND

Quintessenz Verlags-GmbH
Ifenpfad 2–4
12107 Berlin, Germany
www.quintessence-publishing.com

Quintessence Publishing Co Ltd
Grafton Road, New Malden, Surrey KT3 3AB
United Kingdom
www.quintessence-publishing.com

Editing and Production: Quintessenz Verlags-GmbH,
Berlin, Germany

Printed and bound in Croatia

Foreword

I first met Per-Ingvar Brånemark in 1967. I had been recruited to Per-Ingvar's laboratories through my elder brother Björn Albrektsson, who defended his PhD thesis with Brånemark as a tutor in 1969 and then went on to become an orthopedic surgeon. It was customary for young coworkers of Brånemark to run a research project parallel to one's studies at the medical school. I started investigating microcirculation by using the rabbit ear chamber to visualize the capillaries. My PhD project was a combination of microcirculation, bone grafts, and implants; I used a further development of Per-Ingvar's old bone chamber and was able to autologically graft an implant with surrounding bone tissues (Fig 1).

Per-Ingvar's laboratories were a melting pot vibrating with research efforts in different fields, such as nerve reconstruction, microcirculation, and bone biology, the latter subgroup with time under my own command. Subgroup leaders were given great freedom in selecting research topics, and it became quite natural for me early on to include implant research. When you were one of Brånemark's pupils, you always looked for clinical applications of your findings; what we conducted was a sort of directed basic research with the ultimate aim to increase our knowledge in the clinical field. In retrospect, our laboratory scientists were pioneers in applied biomaterials research, and we belonged to the first generation ever using foreign materials to replace dysfunctional anatomical structures.

Certainly not everyone supported our ambitions in the beginning. Per-Ingvar had a long-standing feud with traditional dentists who did not believe in dental implants, which they considered impossible to connect with clinical function. The academic feud, I fear, was worsened a bit by Per-Ingvar's personality; he was not one who, when attacked, would turn his other cheek to his opponents. For example, a journalist had written a paper about Per-Ingvar's microcirculatory research and published his report in *Reader's Digest*, and a dentist accused Per-Ingvar of publishing in low-grade journals. Per-Ingvar's response to this dentist who had previously issued and recommended a particular toothpick was that "publishing oneself on the reverse side of toothpick boxes" was definitely anything but a scientific achievement.

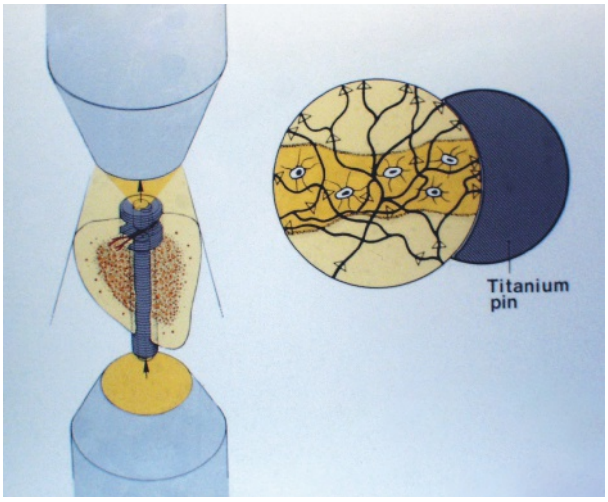

Fig 1 Modified bone chamber for the study of bone vascularization and remodeling.

Finally in 1977, our Board of Welfare sent three independent experts from our northernmost University of Umeå to Gothenburg, picked out a number of our patients randomly from our clinical records, and then wrote the first academic support of dental implants ever published. From then on, we started educating Scandinavian dentists on how to place dental implants, even if our own major clinical efforts at the time were directed toward ENT implants in close cooperation with Anders Tjellström, one of the authors of the present volume.

Another author in this volume came for training in Sweden in the latter part of 1978, when we trained the team under George Zarb of the University of Toronto in how to place dental implants. Zarb became instrumental in spreading the news about osseointegration to colleagues outside Scandinavia, as is evident from his chapter about the Toronto conference of 1982. George Zarb further became my personal mentor, and I feel proud today having had mentors like Per-Ingvar and George, both of whom have meant a lot to me personally (Fig 2).

Per-Ingvar himself signed a consultancy agreement with Nobelpharma in 1978 that (if in different forms) lasted until he passed away in 2014. Nobelpharma (later renamed Nobel Biocare) was initially a university-affiliated research endeavor that was transformed into a large-cap

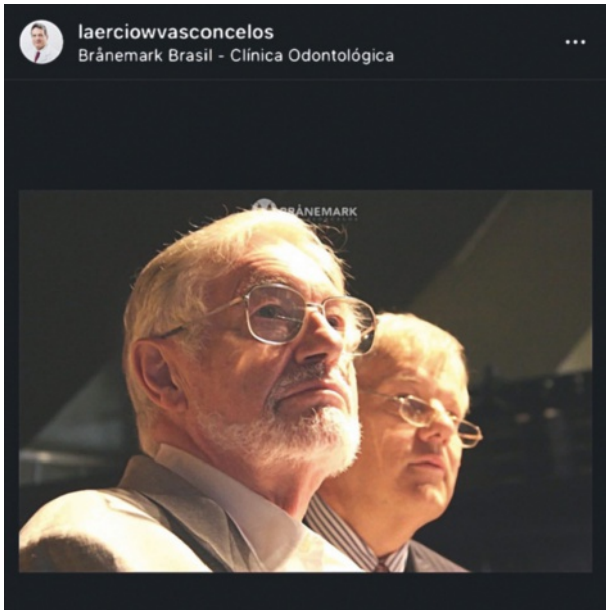

Fig 2 Per-Ingvar Brånemark and Tomas Albrektsson in São Paulo, Brazil, in 2005. (Courtesy of Dr Laércio Vasconcelos.)

company on the Swedish stock exchange in less than 10 years by leading managers Ek and Holmberg, who were invited to write another chapter in this volume describing their experience in this field. During their time, Nobel was a general biomaterials company, supporting the development of extraoral and orthopaedic implants too, but they made the decision to transition Nobel to a dental implant company alone, and the other clinical applications were sold to other interests.

Implant veterans such as John Brunski, with his first publications in the dental implant field dating back to the 1970s; Matts Andersson, with the first implant-related CAD/CAM solutions ever; Paulo Maló, with his all-on-four solution introduced more than 25 years ago; and Oded Bahat, of world renown for his clinical excellence, represent other friends of mine who have decided to contribute to this volume. There are a number of younger people, all of whom I cannot list here, who have generously devoted their time in writing landmark chapters on various aspects of osseointegration. Our younger coworkers write about how we will step into the future, whereas we old folks usually talk about what we did in the past. Nevertheless, I feel that this volume will considerably increase our knowledge about osseointegrated implants and will be a landmark for the future.

Bruno Chrcanovic, my co-editor, has so far been academically active at the University of Malmö in southern Sweden, but he was originally trained in dentistry in Brazil and worked there as a clinician for more than 10 years. In fact, Bruno has published so many papers on dental implants that today he is the most-quoted (still professionally active and not retired) researcher in Swedish Odontology according to Ioannidis of Stanford papers on scientific quotations.

We have decided to publish this book in 2025 because this September 23rd commemorates the 60-year anniversary of Per-Ingvar treating his very first totally edentulous patient—Mr Gösta Larsson, who allowed us to quote his name in different publications. Mr Larsson, like many of our other first patients, meant a lot for our understanding of how biomaterials worked over time in the human body. Today it is said that the world production of dental implants is about 20 million devices annually, and we have seen a similar positive development in the field of hip and knee arthroplasties too. However, despite this present popularity of implants, we still have many situations where we lack adequate clinical knowledge, which is why dental implants are anything but a commodity product. We are always in need of publications in peer-reviewed journals to learn more and for the benefit of our patients; implants without any clinical documentation of their own should be avoided by any serious dentist in our field. With that in mind, start reading our book. We, the editors, feel certain you will learn a lot from the many chapters.

Tomas Albrektsson, MD, PhD, OD hc, RCPSG
Professor Emeritus of the Department of Biomaterials
University of Gothenburg, Sweden

Preface

I started working as a surgical assistant to my late husband Per-Ingvar Brånemark during the 1970s. We worked initially with oral and later with craniofacial implants. I commonly witnessed the enormous patient benefits from osseointegrated dental implants, which at the time represented a relatively new mode of clinical treatment, since they were first found clinically acceptable by the Swedish Board of Social Welfare in 1977. Our early edentulous patients were commonly public performers who refrained from singing their arias or praising their preferred political party due to the risk of losing their false teeth. The extraoral implants were used as retention for silicone prostheses or as support for bone-anchored hearing aids. We worked with patients with facial injuries or deformities due to congenital or acquired conditions, including after tumor resection. Hearing disorders resulting from the absence of ossicular bones were managed by placing an implant directly into the bone behind the ear to facilitate sound waves reaching the intact inner ear through bone conduction.

The international breakthrough of these treatment modalities followed during the 1980s. With time, this meant that we started traveling all over the world to help patients in need (Fig 1). We certainly worked in close collaboration with many local clinicians and were able to treat patients everyone had previously labeled as hopeless cases. This was most rewarding for Per-Ingvar in particular, but we all shared his feelings for the patients who could now be helped. Our implants were originally all manufactured by our own employed staff, but with time Nobelpharma (later Nobel Biocare) delivered the hardware. Major implants used for placement in partially amputated femurs that were coupled to false legs continued being individually manufactured by associated staff members.

In the new millennium, we started an institute for clinical treatment in Bauru, Brazil, where Per-Ingvar and I spent several years as residents. Volunteer clinical experts from all over the world helped us in treating a great number of patients, in many cases patients who could not afford proper dental care. Nobel gave generous support to the Bauru clinic until my husband passed away in 2014.

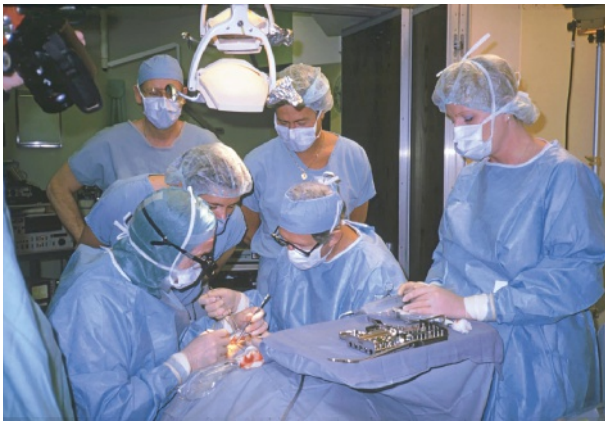

Fig 1 Doing surgery together.

In all modesty, the efforts from assisting staff members such as myself played an important role in the treatment of handicapped human beings. Per-Ingvar himself commonly stressed the importance of the team members behind successful clinical results. Today, I assume that clinical approaches never before tested in our time are now routine surgery. I am thinking back on the nurse Per-Ingvar met in 1952 who lost her false teeth at a coffee break—for her a most embarrassing moment. There were few possibilities to help her because she had severely resorbed alveolar ridges. At the age of 23, Per-Ingvar decided to solve this problem of edentulousness. It was first in 1965—60 years ago—that he was able to start his clinical treatments of such patients. It was the dawn of a new era made possible by titanium implants.

Barbro Brånemark

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Direct Bone Anchorage of Oral Implants: Discovery of a New Treatment Concept

Tomas Albrektsson
Bruno Chrcanovic

Editors' Note: *The discovery of osseointegration is probably the most remarkable serendipity ever in dentistry.*

Something happened in 1952 that, at first glance, had little to do with scientific discovery. A nurse lost her false teeth during her coffee break. The doctor, still in training as an MD, figured that poor denture retention would be an easy problem to solve and sent the nurse to a dental school for treatment. Unfortunately, the university dentists couldn't do much. The nurse had severely resorbed alveolar ridges, meaning her false teeth were doomed to have poor retention. This young doctor was 23-year-old Per-Ingvar Brånemark, and this was the event that caused him to want to solve the problem of poorly fitting false teeth, despite his own lack of training in dentistry.

Discovering Bone-to-Implant Contact

At the time, Brånemark was also working on a PhD project in which he ground down the fibula of research animals to transparency to become the first ever to describe bone and marrow circulation in vivo. In 1959, he defended his PhD thesis on this subject at the University of Lund.[1] A couple of years later, he was promoted to Associate Professor of Anatomy at the University of Gothenburg and was provided with laboratories of his own. He decided to use implant to continue his vital microscopic analyses of bone and marrow blood flow in animals. He constructed hollow titanium screws with a space containing a glass rod and cover glass where bone and blood vessels grew straight through. Brånemark would place these implants, allow bone and blood vessels to invade the space, and then transilluminate the ingrown tissues and perform analyses at the resolution level of light microscopy.

After conducting one of these studies, Brånemark wanted to remove an implant for cleaning and placement in another animal but found it impossible to remove without damaging it. Brånemark realized that an implant stuck in bone could have implications for clinical patient care. He remembered the nurse and decided almost immediately to start developing implants for edentulous patients (Fig 1-1). If titanium implants could become anchored stably in tibial bone in animals (Fig 1-2), why couldn't similar implants be used for retention for false teeth in the mandible and maxilla?

Brånemark was entering a most controversial field of science. A small number of oral implants did exist at the time, and they had one thing in common: They were not recognized as a clinical treatment by any university because clinical results had been so poor. Many patients who had received blade-vent implants and other similar products had ended up at various university clinics requiring implant removal to prevent destruction of the jaw bone complex where they had been placed. The oral cavity is filled with bacteria, and academic dentists viewed implants as being doomed to fail as a result of infection. Other researchers who had tried to anchor implants directly into bone tissue had failed,[2,3] and the formation of a soft tissue layer between bone and any metal interface was regarded as inevitable. But here came Brånemark, a young researcher with no training in dentistry, claiming that *his* implants were directly bone anchored and functioned properly as retention elements for artificial teeth (Fig 1-3)—a view held by no one else at the time.

It is not surprising that dental academies refused to accept Brånemark's thinking. In fact, he sparked an academic feud when he ignored critics and continued his experimental and clinical work. Criticism was reduced in 1977 when the Swedish Board of Health and Welfare sent three experts to Gothenburg to examine Brånemark's patients and wrote the first positive academic statement regarding oral implants ever published.[4] Final evidence of direct bone bone-to-implant contact (BIC) without any interposed soft tissues was presented in 1981[5] with the help of the cutting and grinding technique of Karl Donath (Fig 1-4). Brånemark, of course, had been convinced of direct bone anchorage since he started working with oral implants, and he had coined the term *osseointegration* in 1976.

Clinical Applications of Osseointegration

Brånemark was only 33 years old when he discovered osseointegration in 1962, and he subsequently created a remarkable career for himself by testing the clinical possibilities of his discovery, with 2025 marking the 60-year anniversary of his clinical treatment of edentulous patients. His research was performed earlier than peers in Germany and Switzerland who were also exploring the possibilities of osseointegration, with Brånemark's first publications on oral implants introduced in the 1960s and the German and Swiss work not appearing until 1976. However, Brånemark's papers were published in orthopedic and plastic surgery journals that were not widely read by dentists. Because there were no computers available at the time, these other pioneers of oral implants were simply not aware of Brånemark's original work.

Fig 1-1 Per-Ingvar Brånemark after recently being named Head of the Department of Experimental Biology at the Gothenburg University Institute of Anatomy.

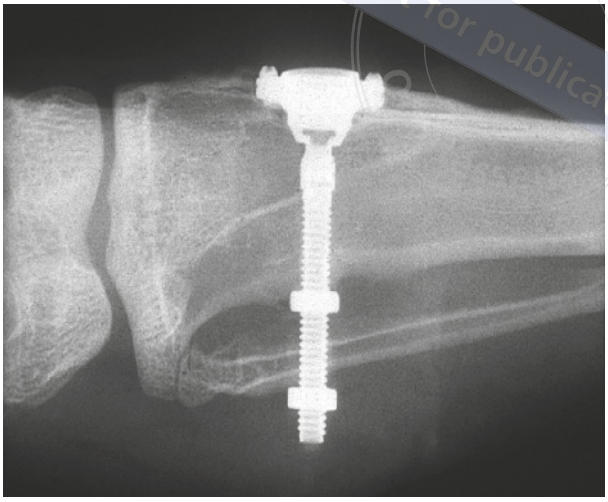

Fig 1-2 The original titanium implant Brånemark placed in rabbit bone and found to be stably anchored there.

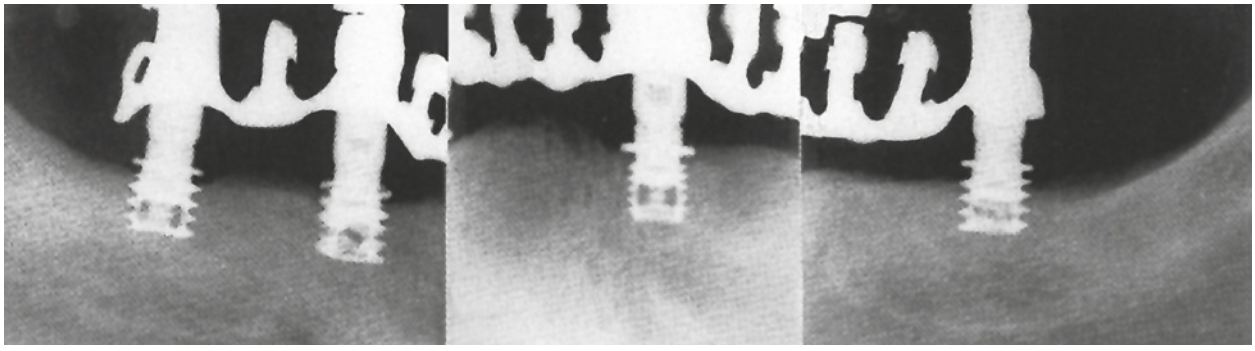

Fig 1-3 Radiographs showing one of Brånemark´s first patients, who received three implants that functioned for more than 50 years in situ.

Throughout his life Brånemark was inspired by the patients for whom treatment was considered hopeless by other clinicians. The nurse he met in 1952 was only the first of these patients. Brånemark's team used osseointegrated implants in the craniofacial skeleton to treat patients with congenital and acquired facial defects. Later, it was found that certain hearing disorders involving malfunctioning ossicular bones could be improved by placing implants behind the ear of the patient as anchorage for newly developed hearing aids. These hearing aids benefited from the direct bone anchorage and the pathway to the intact inner ear.[6,7]

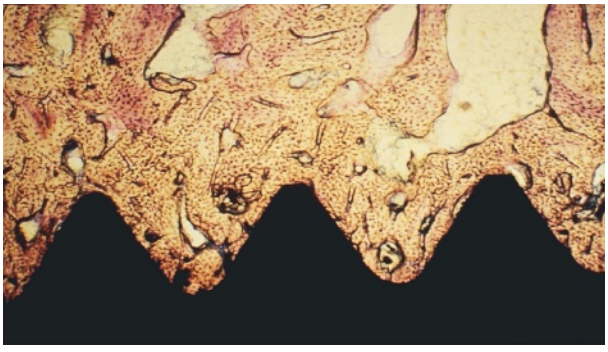

Fig 1-4 Cut and ground specimen of a Brånemark titanium implant, verifying osseointegration.

In one clinical case, a teenage girl suffering from thalidomide embryopathy came to the clinic. Patients with this condition are often born with missing extremities, and because the ossicular bones are developed in the fetus at the same time as the extremities, these patients often present with hearing disorders as well. Prior to surgery, this patient's poor hearing affected her ability to speak properly. After receiving a newly made hearing aid coupled to a temporal bone implant, she was able to overcome her speech difficulties. Chapter 7 describes these implants in further detail.

Orthopedic applications included placing implants in the femoral bone of patients with amputations and

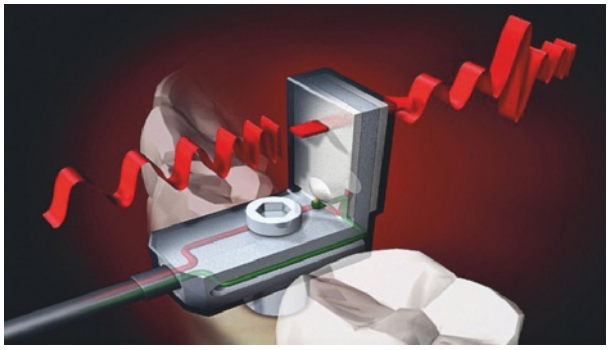

Fig 1-5 An experimental setup for testing implant stability.

attaching them to a prosthetic limb, and using implants to restore grip function in patients with amputated thumbs. They were also used in cases involving the replacement of malfunctioning metacarpophalangeal joints, and as anchorage for hip prosthesis cases. In all these situations, researchers relied on the ability of titanium to osseointegrate with bone tissue. More details about orthopedic surgery and osseointegration are found in chapter 8.

Yet another area of research was aimed at determining implant stability in the bone by evaluating an implant's reaction to energy input (Fig 1-5). The technical part of this work was conducted at London University, with the clinical controls conducted in Gothenburg.[8] Several companies today market these stability indicators.

The osseointegration that makes these clinical applications possible is dependent on minimally traumatic surgery. Although titanium was initially considered a bioinert material, it is now known that titanium, similar metals, and some ceramic materials induce the formation of a bone envelope that embeds the implant to protect nearby tissues (see chapter 3). Osseointegration is thus dependent on the immune system, as is the for potential peri-implant marginal bone loss.[9]

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2

From Animal Studies to Clinical Trials

Tomas Albrektsson
Bruno Chrcanovic

Editors' Note: *The long-term (> 5 years) studies on Nobel implants represent 85% of all long-term documented studies on implant performance, which is indicative of Nobel's strong focus on clinical documentation.*

After his discovery of the stable implant in the rabbit, Brånemark extracted teeth from 10 beagle dogs and replaced them with newly fabricated oral implants (Fig 2-1). The implants were threaded and made of commercially pure titanium with a top flange (Fig 2-2). Some of the dogs were used for studying the long-term clinical function of the implants, whereas others were sacrificed to enable study of the bone-and-implant interface.

Unfortunately, evaluating the implants and bone required decalcification of the bone with a weak acid to transform the hard tissue to a sponge-like consistency. This allowed the implants to be unscrewed from the bone to obtain histologic sections. These sections revealed contact between the threads and bone at low power.[1] However, due to this indirect approach, critics were convinced that the soft tissue capsule thought to form inevitably around any metallic construction was being accidentally removed during section preparation. Brånemark tried to prepare some specimens that were ground down in situ, but he never managed to obtain satisfactory resolution of these preparations. It was not until the advent of the Donath cutting and grinding technique that it was possible to prepare sections proving that a soft tissue–free border is possible around commercially pure titanium implants.

Nevertheless, his initial work with dogs convinced Brånemark that treating humans with oral implants was a possibility. In 1965, he initiated clinical trials for the treatment of completely edentulous patients, particularly patients who struggled with poor retention of their false teeth due to alveolar ridge resorption, including public performers who needed reliable, stable dentition for their work. Many of these early patients had such severely resorbed alveolar ridges that they would be regarded as difficult cases to treat even with modern equipment and today's information about the long-term use of oral implants.

Results of the First Clinical Trials

A retrospective review of results during the first years of clinical trials revealed a success rate that was quite low.[2] In fact, during the "initial period" between September 1965 and March 1968, when the implants were designed with a flange and loaded 3 weeks after placement, 50% of maxillary implants and 48% of mandibular implants required removal. Only 37.5% of 8 maxillary implants and 52% of 25 mandibular implants remained stable.

In the "development period" between 1968 and 1971, 24% of 168 mandibular implants were removed. Results for 384 maxillary implants remained poor. Brånemark, however, never seemed to question that higher survival rates could be achieved in the future, and a number of changes were introduced prior to the "routine period" between 1971 and 1975. All implants used at the time had a hex connection (Fig 2-3) and were allowed to heal for a minimum of 3 months after placement in the mandible and 6 months after placement in the maxilla prior to connection to a restoration framework. Some of the cases also involved bone grafting of severely resorbed alveolar ridges prior to surgery.

During the routine period, a total of 503 maxillary implants were placed with a failure rate of 23%, and 351 mandibular implants were placed with a failure rate of 10%. However, because an individual implant could fail without threatening the overall stability of the framework it was supporting, 76% of maxillary cases and 99% of mandibular cases provided patients with stable bridges.[2] Between 1969 and 1974, most of the patients treated by Brånemark's team were first interviewed by a psychiatrist to identify individuals who might suffer from body dysmorphia.[3] Patients also participated in a postoperative psychiatric evaluation, which showed that 1% suffered a negative psychologic effect and 86% reported a marked improvement compared with their previous edentulous state.[2] By the time of the Toronto conference in 1982, 5-year clinical results for oral implant survival had improved to about 85% in the maxilla and greater than 90% in the mandible.[4]

Improving Oral Implants

The implants used for these first patient series were all manufactured at the workshop of Viktor Kuikka at the Gothenburg University Department of Anatomy. Kuikka had escaped his native country of Estonia when the Russians invaded after World War II and had then been trained in fine mechanics in Sweden. He was quite alone in preparing the turned implants in his workshop until after 1978, when Brånemark signed a contract with Nobelpharma. During the first 20 years of implant production, titanium Grade 1 was used. However, too many implant fractures were occurring with this softer grade, so from the mid-1980s onward, implants manufactured by Nobel in

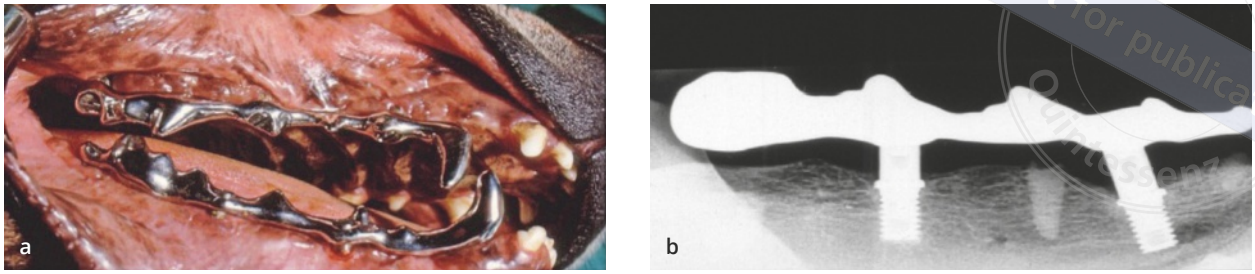

Fig 2-1 (a and b) Oral implants placed in dogs for one of Brånemark's experimental studies conducted between 1962 and 1965.

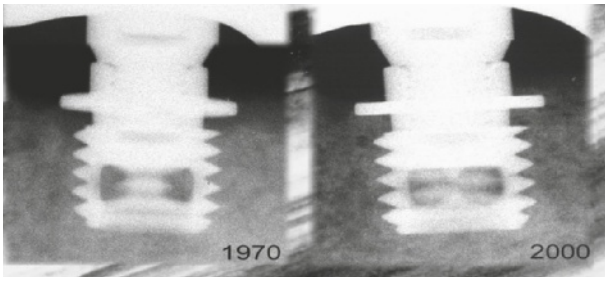

Fig 2-2 The early turned implants used by Brånemark all had flanges, which were later abandoned.

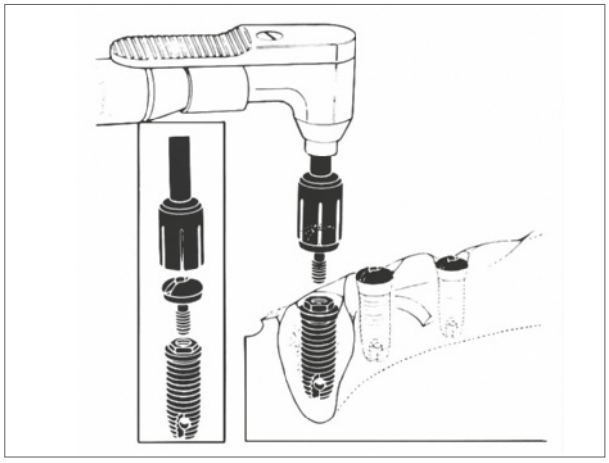

Fig 2-3 Placement of a turned mandibular implant with a hex connection.

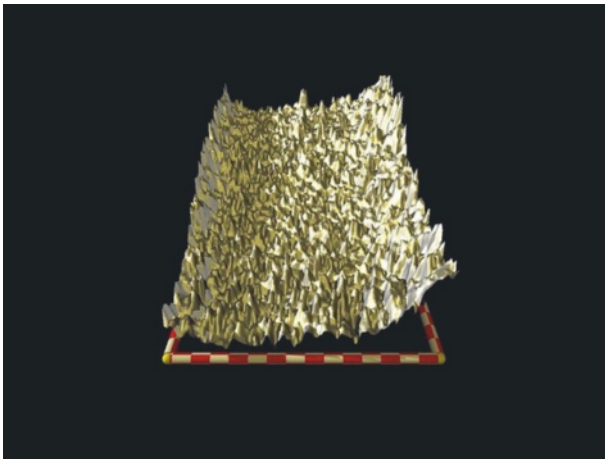

Fig 2-4 A micrograph of the surface of a moderately rough TiUnite anodized implant, which has been used since the turn of the millennium until the present day.

Karlskoga, Sweden, were made from stronger titanium Grade 4.

With time, numerous long-term reports about Nobel's turned implant surfaces were published in the world literature. One review reveals that of studies with follow-ups of at least 5 years, no fewer than 75% involve the use of turned implants.[5] Here we highlight reported clinical outcomes for Nobel turned implants over spans of 15 to 36 years. Single turned implants have been found to have a cumulative success rate (CSR) of 91.5% to 100% at 15 to 25 years of follow-up.[6–13] Implants used to treat partially edentulous patients have shown survival rates of 90% after 20 years[14,15] and 88.3% after 25 years.[16] One study with follow-ups spanning 10 to 20 years reported a CSR of 93% to 95.5% for implant overdentures.[17] In edentulous patients, CSR values between 89.8% and 95.5% have been reported in a series of studies.[18–25] Some of the longest follow-up studies have found no failures at follow-ups between 23 to 28 years,[26] a CSR of 97.7% at up to 32 years,[27] and a CSR of 87.9% at up to 36 years.[28] Furthermore, the failures that were noted in this series of studies occurred during the first few years after implantation, meaning they had nothing to do with peri-implantitis.[10,12,14,20,23,24,28]

Remarkably, after only minor changes to the turned implant design and several changes to clinical protocols, failure rates for oral implants were reduced from 50% at relatively short follow-up times to about 10% at 20 years or more of follow-up.

Research with optical profilometry using laser light conducted by Wennerberg during the 1990s[29] made it possible to evaluate the topography of implant surfaces embedded in bone,[30] which had previously not been possible with threaded implant surfaces. Instead, the norm had been to evaluate various flat surfaces of the implant, despite the fact that those were never integrated with the bone and could have a substantial difference in roughness compared with the parts of the implant actually anchored in the bone. This new laser approach (today we prefer white light interferometry) allowed Wennerberg and Albrektsson[31] to demonstrate that the Nobelpharma screw—then the most popular implant in the world—was only 25% as rough as the plasma-sprayed implants that were also quite popular during the 1990s. Wennerberg and Albrektsson[31] reported that turned implants like the original Brånemark implant were minimally rough (Sa: 0.5 to 1.0 µm), whereas plasma sprayed surfaces were rough (Sa > 2.0 µm).

Following this discovery, animal experiments were conducted to test which type of implant surface developed the best bone response. The optimal implant surface for bone was found to have a roughness of 1 to 2 µm, which was considered a moderately rough surface at the time. Wennerberg's research efforts proved to have great clinical importance, with major companies designing their implants with moderately rough surfaces. Nobel Biocare launched the TiUnite implant (Fig 2-4) around the turn of the millennium, resulting in improved clinical results. Wennerberg et al[32] reported a 10-year clinical outcome of only 1.3% failed implants, with no difference in outcome between implants placed in the maxilla and mandible. This implant is covered in more detail in chapter 10.

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18

Development of Novel Anodized Implant Surfaces: Xeal, TiUltra, and N1

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Ana Ferro
Miguel de Araújo Nobre

Editors' Note: *This chapter summarizes the clinical documentation for Nobel Biocare implant surfaces introduced in 2019.*

Evolution of Micro Design in Implant Dentistry

The evolution of dental implants has been marked by dramatic improvements in both macro- and microscopic implant surface features across 60 years of osseointegration research. The first machined implants with turned surfaces were introduced by Professor Per-Ingvar Brånemark in the early 1960s and used in human trials in 1965.[1–3] At that time, the development of oral implants as a new alternative for rehabilitating edentulous patients was a remarkable breakthrough. Another breakthrough was the introduction of immediate loading, with the connection of the prosthetic restoration on the same day of implant surgery. This procedure became standard between the 1990s and the beginning of the millennium for all types of rehabilitations, from single-tooth restorations to full-arch cases.[4–17]

New implant surfaces, such as Nobel Biocare TiUnite anodized surfaces, have been designed to accelerate the osseointegration process and maintain long-term implant stability.[18] Today, the evidence confirms high long-term success rates for immediately loaded implants with anodized surfaces, regardless of the type of rehabilitation (single, partial, or full-arch).[19–25]

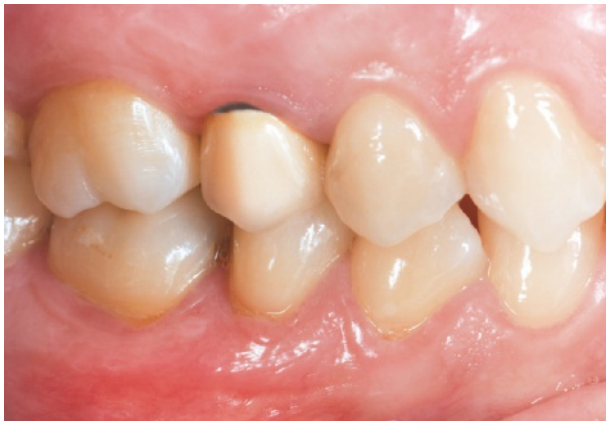
The success criteria used in the field of implant dentistry have also evolved, shifting from implant immobility and peri-implant radiolucency (implant survival/implant function) to describe the quality of implant survival, including esthetics, patient satisfaction/quality of life, and soft tissue parameters.[26–32] Despite the high implant survival rates that have been reported, there is ongoing significant effort from the dental community and industry to introduce innovations that further increase implant survival rates (aiming for 100%) and improve the soft tissue conditions around implant abutments, which is paramount for long-term implant stability.

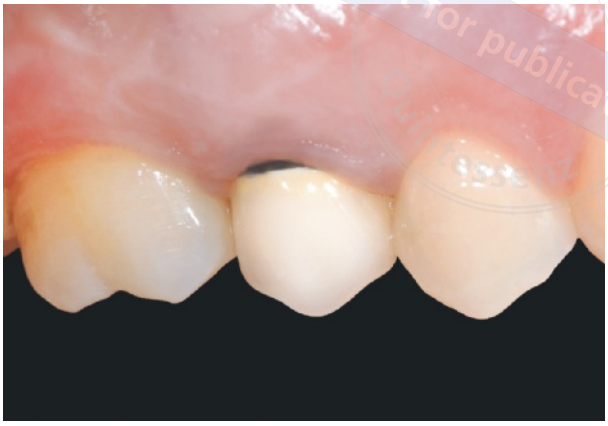
The most recent Nobel Biocare innovation concerning implant micro design was the introduction of ultra-hydrophilic implant (TiUltra) and abutment (Xeal) surfaces. *Hydrophilicity* describes the affinity of a material to water. If the water contact angle of a material is less than 90 degrees, the material is considered hydrophilic. A material with a water contact angle close to 0 degrees is considered ultra-hydrophilic.[33] The hydrophilicity of titanium can be increased via anodization by submerging the titanium in electrolytic fluid and applying voltage, which alters the topography of the titanium by increasing the titanium oxide layer while allowing for the high-density formation of hydroxyl groups (important for the promotion of bone formation) and increasing osteoblast attachment (via the addition of phosphates to the electrolytic fluid).[33,34]

The hydrophilic anodized surfaces of Xeal abutments are smooth, nonporous, and nanostructured to support soft tissue stability and attachment to the abutment.[35] Recent studies show that anodized surfaces could enhance the adhesion of fibroblasts and epithelial cells[36] and are associated with better soft tissue outcomes (a reduced bleeding index at abutment removal and consistently improved levels of keratinized mucosa) over the course of 2 years of follow-up,[37] representing a promising option for implant dentistry.

TiUltra implants have ultra-hydrophilic multi-zone anodized surfaces with a topography that gradually changes from moderately rough and porous at the apex to minimally rough and nonporous with a nanostructured oxide layer at the implant collar. This surface is designed to achieve better interactions with the surrounding environment to support early osseointegration and long-term bone stability (Fig 18-1).[38]

Fig 18-1 The ultra-hydrophilic multizone anodized surface of a TiUltra dental implant and the anodized Xeal abutment surface designed to enhance tissue integration from the abutment to the implant apex. (Image copyright of Nobel Biocare Services AG.)





Figs 18-2 and 18-3 Preoperative intraoral photographs of the maxillary right second premolar.

Clinical Application of Implants and Abutments With Ultra-Hydrophilic Surfaces

Given the recency of their development and introduction to the clinical environment, dental implants with ultra-hydrophilic multizone anodized surfaces and abutments with hydrophilic surfaces still have only a small body of supporting literature with short follow-ups. In this section, the existing literature is summarized, and new data on the 2-year follow-ups for implants with ultra-hydrophilic multizone anodized surfaces is presented, and when possible, compared with previous data from the same groups or implant groups with similar rehabilitation conditions but different implants surfaces.

Study summaries are presented in Table 18-1. To date, there are nine pertinent published clinical studies,[39–47] representing 1,300 patients and over 2,000 implants with ultra-hydrophilic multizone anodized surfaces, including Nobel Biocare NobelParallel Conical Connection implants, NobelActive implants, Nobel Biocare N1 implants, and NobelReplace Conical Connection implants, with mean follow-ups of 15.9 months. The main outcome measures have revealed a cumulative implant success rate ranging between 95.8% and 100% and marginal bone loss (MBL) ranging between 0.39 and 1.08 mm, together with a low incidence of mechanical and biologic complications.[39–47] The studies from Fabbri et al[44] (2023) and de Araújo Nobre et al[47] (2024) on single teeth/partial rehabilitations and Ferro and de Araújo Nobre[46] (2023) on full-arch rehabilitations via the All-on-4 Concept will be object of evaluation in light of new and previously unpublished data with 2 years of follow-up.

TiUltra Ultra-Hydrophilic Multizone Anodized Implants for Single-Tooth and Partial Implant-Supported Restorations: Updated Data With 2 Years of Follow-Up

The use of ultra-hydrophilic multizone anodized implants for single-tooth and partial rehabilitations with 2 years of follow-up was evaluated using a sample of 206 patients (104 women and 102 men) with a mean age of 54.5 years (range: 20 to 88 years). A total of 314 implants with ultra-hydrophilic multizone anodized surfaces were placed, including 61 NobelActive TiUltra implants and 253 NobelParallel Conical Connection TiUltra implants.

With consideration for the rehabilitation protocol for the NobelActive TiUltra implants, enrollment for the study took place between April 2019 and May 2020, with a pretreatment examination performed on each subject via CBCT and clinical photographs (Figs 18-2 to 18-5). Sufficient bone was required for the placement of NobelActive TiUltra implants with a minimum length of 7 mm.

A one-stage surgical protocol with delayed implant loading was performed, typically via a minimally invasive protocol (mini flap), and the implant site was prepared according to standard procedures[44] (Figs 18-6 and 18-7). The implants were positioned subcrestally with final insertion torque ranging between 32 and 90 Ncm, and all implants were judged to be stable after placement (Figs 18-8 and 18-9). The implants were either 3.5, 4.3, or 5 mm in width. In case of implant insertion in a post-extraction socket, the gap between the implant and socket was filled with bone substitute (creos xenogain, Nobel Biocare; Fig 18-10). The On1 Base Xeal abutment was connected to the NobelActive TiUltra implant using

Table 18-1 Clinical studies on implants with ultra-hydrophilic multizone anodized surfaces (TiUltra) and abutments with hydrophilic anodized surfaces (Xeal) used with the On1 Base Concept

Study	Study design	Sample (patients)	Sample (implants)	Zone and type of rehabilitation	
Pozzi et al[39] (2021)	Prospective	10 patients (7 F, 3 M); Mean age: 62.5 y	60 implants (32 NobelParallel Conical Connection TiUltra; 28 NobelActive TiUltra); immediate loading	Maxilla and mandible; full-arch	
Ferro and de Araújo Nobre[40] (2021)	Prospective	16 patients (10 F, 6 M); Mean age: 60.3 y	64 implants (NobelParallel Conical Connection TiUltra); multi-unit Xeal abutments; immediate loading	Maxilla: 11 rehabilitations, 44 implants; mandible: 5 rehabilitations, 20 implants; full-arch: All-on-4	
Battista et al[41] (2022)	Retrospective	12 patients (7 F, 5 M); Mean age: 45.5 y	22 implants (NobelActive TiUltra); immediate loading; two-stage surgery	Anterior maxilla; partial rehabilitation	
Pozzi et al[42] (2022)	Retrospective	18 patients (12 F, 6 M); Mean age: 52.5 y	27 implants (NobelParallel Conical Connection TiUltra); immediate loading	Maxilla; single-tooth and full-arch	
Fabbri et al[43] (2022)	Retrospective	95 patients (54 F, 41 M); Mean age: 58 y	165 implants (Nobel Biocare N1 TiUltra); two-stage surgery; single-stage surgery; immediate loading; On1 Base TCC Xeal; multi-unit Xeal abutments	Maxilla: n = 110; mandible: n = 55; single-tooth: 78; partial: 43; full-arch: 44	
Fabbri et al[44] (2023)	Prospective	61 patients (30 F, 31 M); Mean age: 51.4 y	61 implants (NobelActive TiUltra); single-stage surgery; On1 Base Xeal	Maxilla: 26 implants; mandible: 35 implants; Single-tooth	
Royg Cayón et al[45] (2023)	Prospective	916 patients; Mean age: 53.3 y	1,250 implants (Nobel Active TiUltra, NobelParallel Conical Connection TiUltra, NobelReplace Conical Connection TiUltra, Nobel Biocare N1 TiUltra); all indications and loading protocols; On1 Base Xeal, Nobel Biocare N1 Base Xeal; multi-unit Xeal abutments	All positions	
Ferro and De Araújo Nobre[46] (2023)	Prospective	43 patients (28 F, 15 M); Mean age: 62 y	172 implants (NobelParallel Conical Connection TiUltra); immediate loading; multi-unit Xeal abutments	Maxilla: 80 implants; mandible: n = 92; full-arch All-on-4 Concept	
De Araújo Nobre et al[47] (2024)	Retrospective	145 patients (74 F, 71 M); Mean age: 55.8 y	253 implants (NobelParallel Conical Connection TiUltra); 56 immediate loading; 197 single-stage surgery	Maxilla: n = 119; mandible: n = 134; single-tooth: n = 218; partial: n = 35	

F = female; M = male; NR = not reported.

	Follow-up	Implant success rate	Mean MBL assessed from implant insertion	Other outcomes measured	Complications
	Mean: 16 mo (range: 14–18 mo)	98.3%	0.53 mm	Plaque score: 14.4 ± 8.18; bleeding score: 7.15 ± 4.4	No complications
	1 y	100%	0.46 mm	Modified plaque index mode: 1; modified bleeding index mode: 1	3 mechanical complications (fracture of provisional prosthesis = 2; prosthetic screw loosening = 1)
	6 mo	100%	NR	NR	No complications
	20 mo	100%	0.72 mm	Pink esthetic score: 12.84 ± 0.92; plaque score: 18.5 ± 6.12; bleeding score 3.15 ± 2.21	2 root-shield exposures (2.9%)
	21 mo	95.8%	0.53 mm	NR	1 buccal plate fracture
	2 y	96.5%	1.08 mm (1 y); 1.06 mm (2 y)	90.6% optimal soft tissue contour; 92.5% absence of sulcus bleeding; 98.1% absence of inflammation	NR
	5 mo	99.1%	NR	NR	NR
	Mean: 23 mo (range: 6–36 mo)	100%	0.39 mm (1 y)	Modified plaque index mode: 1; modified bleeding index mode: 1	Mechanical complications (9 patients): fracture of provisional prosthesis = 9; abutment screw loosening = 3
	1 y	99.2%	0.52 mm	NR	Mechanical complications (7 patients, 8 implants): fracture of prosthesis = 5, prosthetic screw loosening = 2, abutment screw loosening = 1; biologic complications (1 patient, 1 implant with infection)

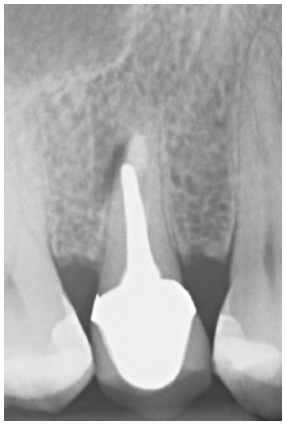


Fig 18-4 Periapical image of the maxillary right second premolar in a compromised condition.

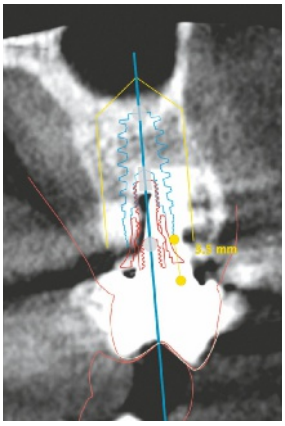


Fig 18-5 Implant planning using CBCT scan data.

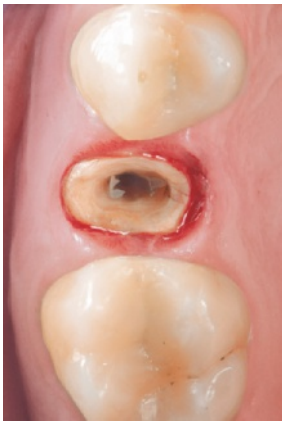


Fig 18-6 Intraoral occlusal photograph after crown removal.

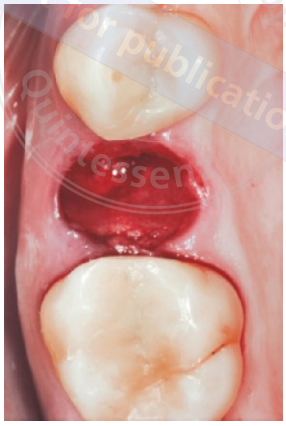


Fig 18-7 Intraoral occlusal photograph after root extraction.

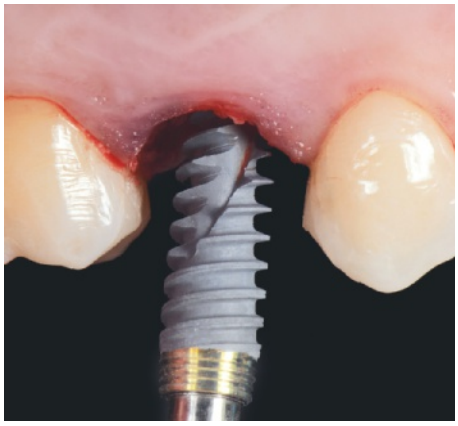


Fig 18-8 Intraoral photograph after NobelActive TiUltra implant placement.

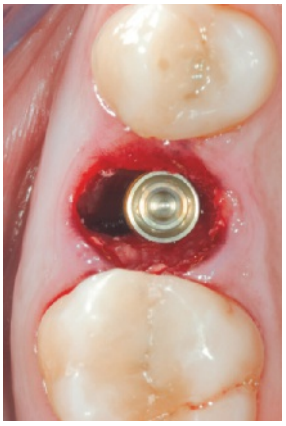


Fig 18-9 Intraoral occlusal photograph after implant placement.

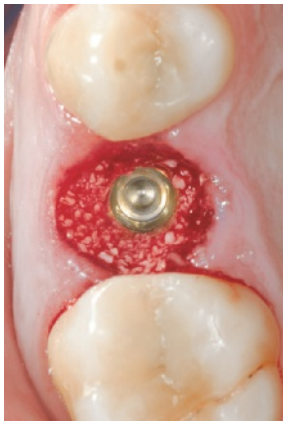


Fig 18-10 Intraoral occlusal photograph after filling the defect with a bone substitute.

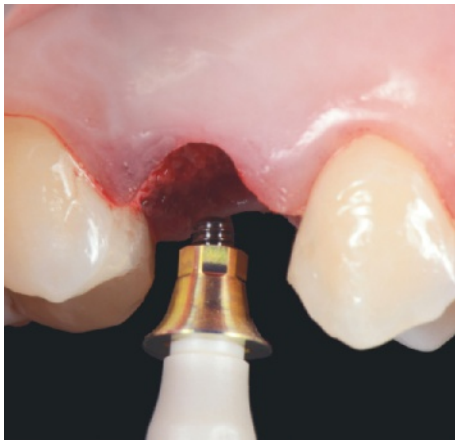


Fig 18-11 Intraoral photograph showing insertion of the On1 Xeal Base.

torque of 30 to 35 Ncm (Fig 18-11). Final prostheses were NobelProcera screw-retained single crowns typically manufactured and connected 12 weeks after healing (Fig 18-12). Follow-up examinations were performed to evaluate clinical outcomes, with the final evaluation at 24 months (Figs 18-13 to 18-15).

With consideration for the rehabilitation protocol for the NobelParallel Conical Connection TiUltra implants, study enrollment took place between April 2019 and May 2021, with a pretreatment examination performed on each subject via CBCT, panoramic radiography, and clinical photography (Figs 18-16 to 18-19). Sufficient bone was required for the placement of NobelParallel Conical Connection TiUltra implants with a minimum length of 7 mm.

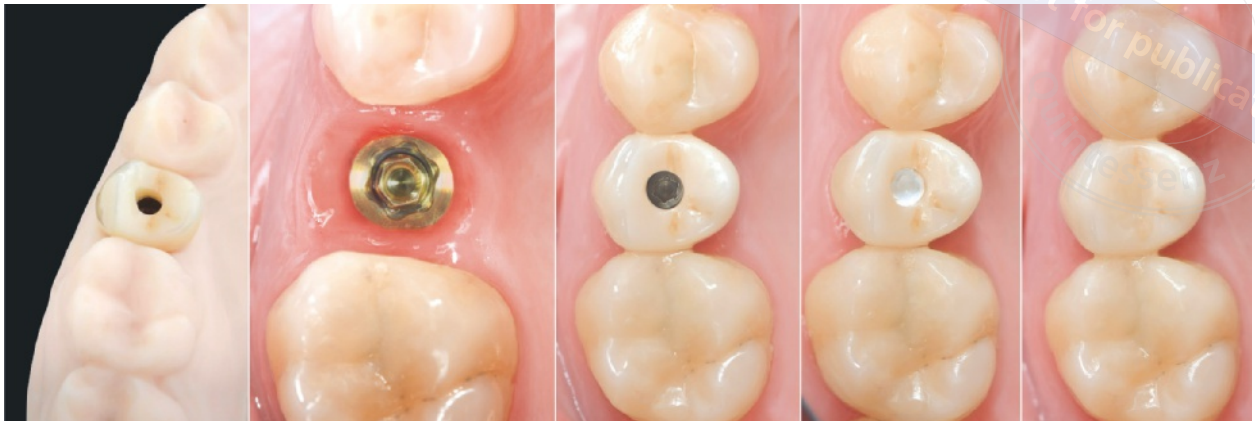
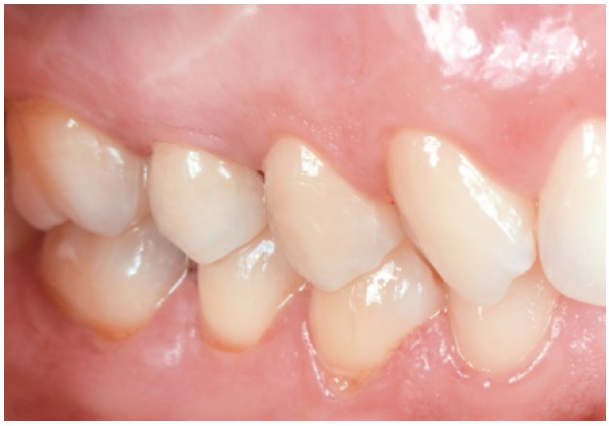
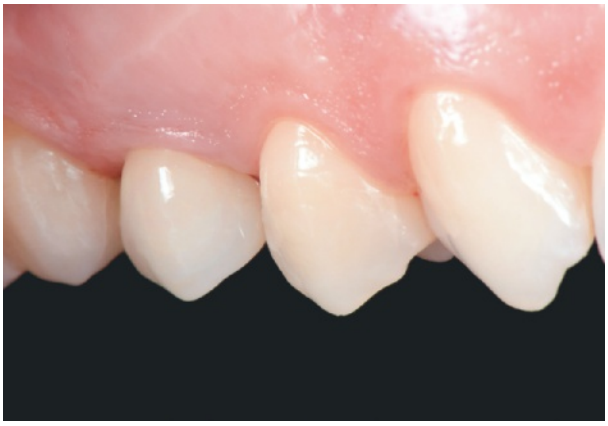


Fig 18-12 Prosthetic delivery scheme.





Figs 18-13 and 18-14 Intraoral lateral photographs of an implant in the site of the maxillary right second premolar with the definitive restoration.

For the flap procedure used in the majority of patients, the placement of implants followed the standard protocol, with the following adjustments:[47] For optimal tissue repositioning of the buccal aspect of the flap, the incision was performed on the palatal side of the crest, with two parallel releases toward the vestibule. For both techniques, the drilling sequence was adjusted to achieve maximum bone compression and anchorage. The implants placed were either 3.75 or 4.3 mm in width. The implant platforms were placed with the aim of being flush with the bone crest. Bicortical anchorage was performed whenever possible.

The abutment choice was made according to the rehabilitation. For single teeth, Nobel Biocare multiunit or immediate healing abutments were used, depending on

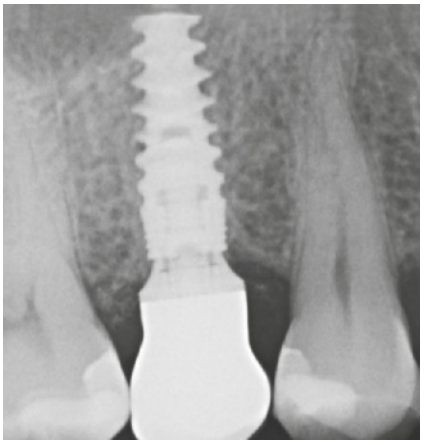


Fig 18-15 Periapical radiograph of an implant in the site of the maxillary right second premolar at 2 years of follow-up.

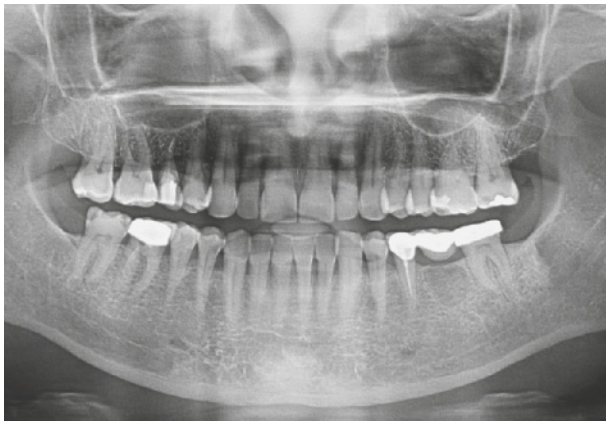


Fig 18-16 Preoperative panoramic radiograph.

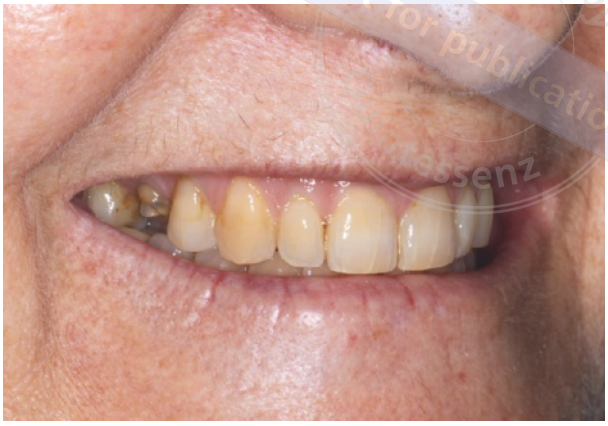
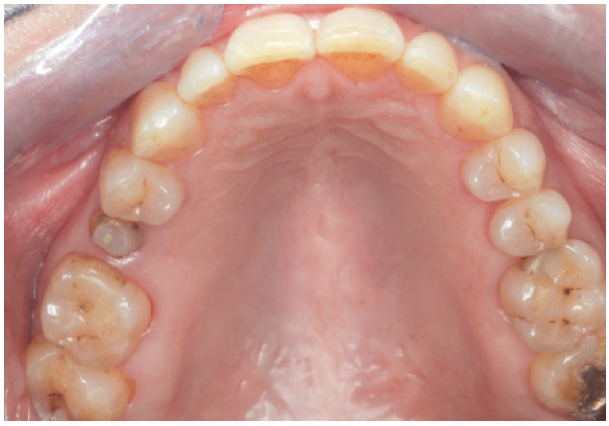
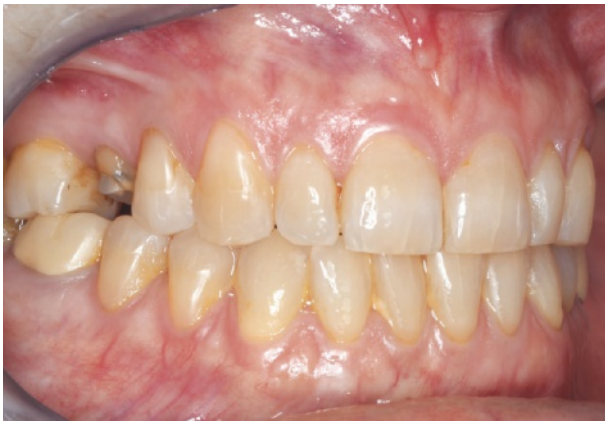


Fig 18-17 Extraoral preoperative lateral photograph of a compromised tooth in the site of the maxillary right second premolar.





Figs 18-18 and 18-19 Intraoral preoperative photographs of a compromised maxillary right second premolar.

whether the immediate prosthesis was screw-retained or cement-retained, respectively. For partial rehabilitations, Nobel Biocare multiunit abutments were used. A provisional acrylic resin crown or fixed dental prosthesis was manufactured and attached to the implants on the same day as surgery to offer immediate implant function (Figs 18-20 and 18-21). Final prostheses were delivered at 6 months and consisted of single-tooth ceramic crowns (Figs 18-22 to 18-24) or ceramic/metal–ceramic fixed partial dentures. Follow-ups were performed to assess clinical outcomes, with the final evaluation held at 24 months (Figs 18-25 to 18-27).

At 1 and 2 years of follow-up, cumulative implant survival rates of 96.6% and 99.2% were reported for the NobelActive and NobelParallel Conical Connection groups, respectively. The mean (95% confidence interval) MBL at 1 and 2 years, respectively, was 1.06 mm (0.77, 1.36) and 1.05 mm (0.78, 1.32) for the NobelActive group and 0.52 mm (0.42, 0.61)[47] and 0.50 mm (0.36, 0.64) for the NobelParallel Conical Connection group. MBL for the NobelActive group for the period between definitive crown placement and 1- and 2-year follow-ups, respectively, was –0.04 mm (–0.22, 0.21) and 0.10 mm (–0.22, 0.42). During the 2-year follow-up period, no biologic complications were registered for the NobelActive group. For the NobelParallel Conical Connection group, there was a 0.4% incidence of biologic complications at the implant level (one implant with a single-tooth restoration in the site of the mandibular right second premolar was infected).

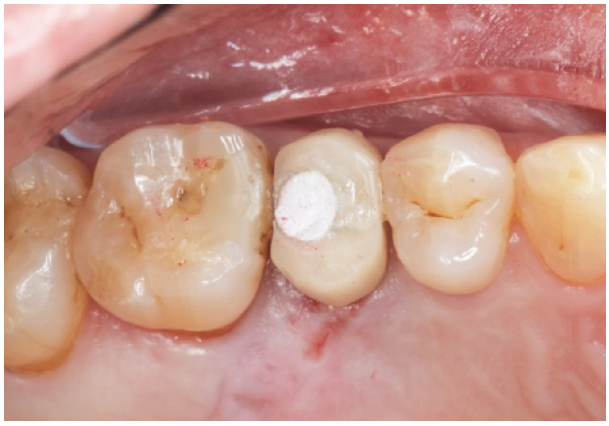


Fig 18-20 Intraoral occlusal photograph of a NobelParallel Conical Connection TiUltra implant in the site of the maxillary right second premolar with connection of a provisional crown on the day of surgery to achieve immediate function.

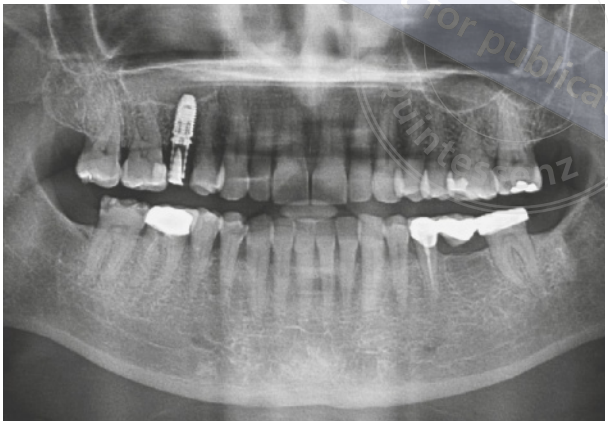


Fig 18-21 Postoperative panoramic radiograph.

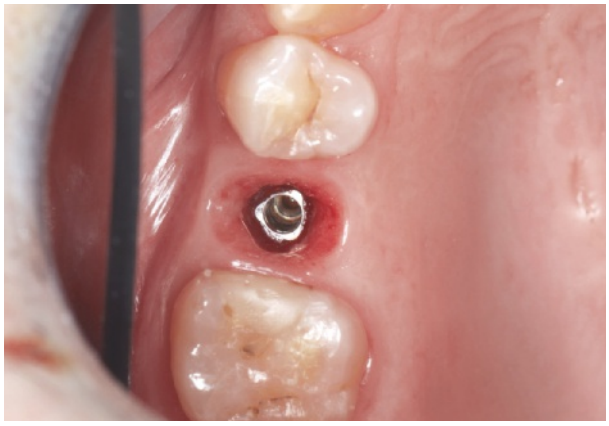


Fig 18-22 Intraoral occlusal photograph taken at the appointment for definitive prosthesis connection.

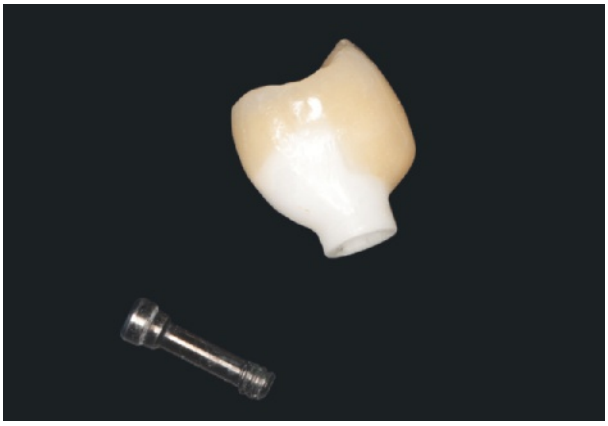


Fig 18-23 Definitive crown.

The survival outcomes reported for the NobelParallel Conical Connection TiUltra implants at 2 years of follow-up were compared with the outcomes reported in two previous publications from the same group of authors on implants with turned and anodized surfaces applied to single teeth[19] and partial rehabilitations.[20] The data was retrieved from each publication,[19,20] separated according to surface subgroup (machined and anodized), and evaluated over 2 years of follow-up. Evaluations revealed the highest survival rates for implants with ultra-hydrophilic multizone anodized surfaces (TiUltra), followed by implants with anodized surfaces (TiUnite), and finally implants with machined (turned) surfaces, for both single teeth and partial rehabilitations (Table 18-2).

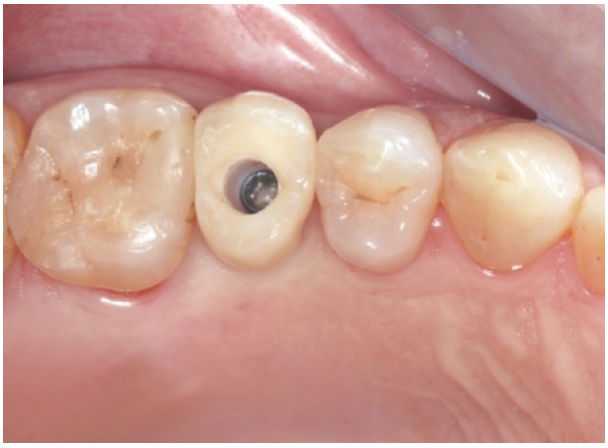
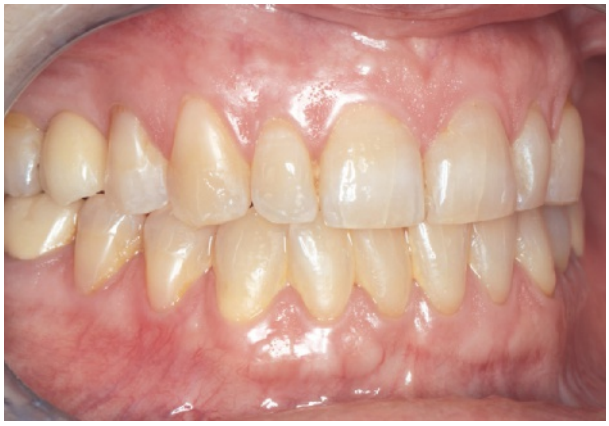
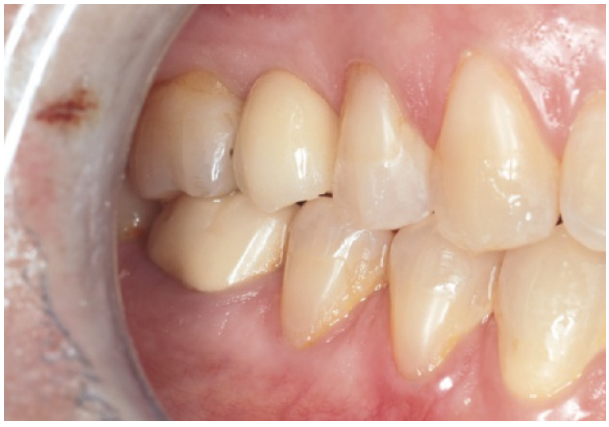


Fig 18-24 Intraoral occlusal photograph showing connection of the definitive prosthesis on the implant in the site of the maxillary right second premolar.





Figs 18-25 and 18-26 Intraoral lateral photographs showing the implant in the site of the maxillary right second premolar with the definitive prosthesis in occlusion.

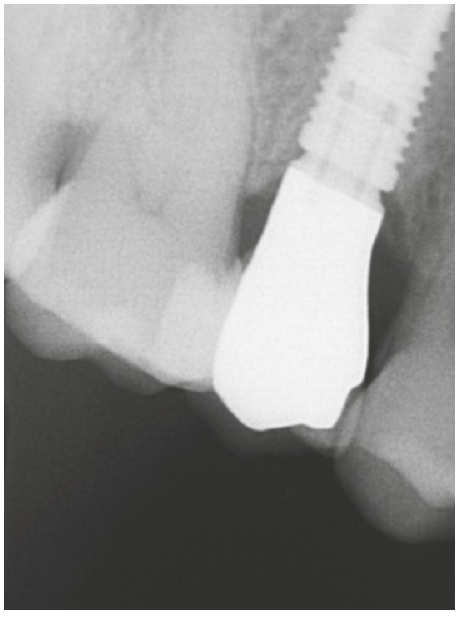


Fig 18-27 Periapical radiograph of the final restoration in the site of the maxillary right second premolar at 2 years of follow-up.

Considering biologic complications, the 0.4% incidence rate in the current evaluation of NobelParallel Conical Connection implants with ultra-hydrophilic multizone anodized surfaces (one implant in a single-tooth rehabilitation) compares favorably with previous publications from the same group on different surfaces. For single teeth, a 4.2% (25/594) overall incidence of biologic complications was previously reported (turned surfaces: 0.6% [1/170]); anodized surfaces: 5.7% [24/424]).[19] For partial rehabilitations, the current 0% incidence of biologic complications compares with the previously reported overall 0.6% incidence (turned surfaces: 0%; anodized surfaces: 0.8% [3/374]).[20]

TiUltra Ultra-Hydrophilic Multizone Anodized Implants for Full-Arch Implant-Supported Rehabilitations According to the All-on-4 Concept: Updated Data with 2 years of Follow-Up

The All-on-4 Concept consists of supporting a full-arch rehabilitation with four implants (two anterior implants placed axially and two posterior implants tilted distally up to 45 degrees).[16,48] Since the first publication from Maló, Rangert, and Nobre in 2003,[16] and with over 360 publications as of December 2024,[49] the All-on-4 Concept is probably the most thoroughly researched full-arch immediate function implant protocol in the history of dentistry. The All-on-4 Concept has accompanied the evolution of implant macro and micro design, with study samples using implants with exclusively turned surfaces (Nobel Biocare Mk III and Mk IV),[16] implants with turned surfaces and two different implants with anodized surfaces (Mk III, Mk IV, and Nobel Biocare NobelSpeedy),[48] and multiple implants with anodized surfaces (Mk III, Mk IV, NobelSpeedy, and NobelReplace).[22,23,50] Today, the long-term outcomes of the All-on-4 Concept have been validated for both arches, with studies reporting cumulative mandibular implant survival and success rates of 93% and 91.7%, respectively, for up to 18 years of follow-up[22] and cumulative maxillary implant survival and success rates of 94.7% and 93.9%, respectively, for up to 13 years of follow-up.[23]

The use of ultra-hydrophilic multizone anodized implants for full-arch implant-supported rehabilitations according to the All-on-4 Concept with 2 years of follow-up was evaluated using a sample of 43 patients (28 women and 15 men) with a mean age of 62 years (range: 36 to 79 years). A total of 172 implants with ultra-hydrophilic

Table 18-2 Cumulative implant survival rate distribution at 2-years of follow-up for different types of implant surfaces and rehabilitations

NobelParallel Conical Connection ultra-hydrophilic multizone anodized implants for single teeth					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	218	2	5	99.1%	99.1%
6 mo to 1 y	211	0	10	100%	99.1%
1 to 2 y	201	0	7	100%	99.1%
Dental implants with machined turned surface for single teeth*					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	170	3	0	98.2%	98.2%
6 mo to 1 y	167	2	0	98.8%	97.0%
1 to 2 y	165	4	0	97.6%	94.7%
Dental implants with anodized surfaces (TiUnite) for single teeth*					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	424	5	0	98.8%	98.8%
6 mo to 1 y	419	1	0	99.8%	98.6%
1 to 2 y	418	6	0	98.6%	97.2%
NobelParallel Conical Connection ultra-hydrophilic multizone anodized implants for partial rehabilitations					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	35	0	0	100%	100%
6 mo to 1 y	35	0	1	100%	100%
1 to 2 y	34	0	3	100%	100%
Dental implants with machined turned surfaces for partial rehabilitations†					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	107	4	0	96.3%	96.3%
6 mo to 1 y	103	0	0	100%	96.3%
1 to 2 y	103	0	0	100%	96.3%
Dental implants with anodized surfaces (TiUnite) for partial rehabilitations†					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	374	0	0	100%	100%
6 mo to 1 y	374	1	0	99.7%	99.7%
1 to 2 y	373	0	2	100%	99.7%

*Data retrieved from Maló et al19 (2015) with Mk II (n = 43), Mk III (n = 159), Mk IV (n = 98), NobelSpeedy (n = 255), NobelDirect (n = 12), NobelReplace (n = 26), and Nobel Biocare NobelPerfect (n = 1) implants.

†Data retrieved from Maló et al20 (2015) with Mk II (n = 27), Mk III (n = 146), Mk IV (n = 88), NobelSpeedy (n = 212), and NobelReplace (n = 8) implants.

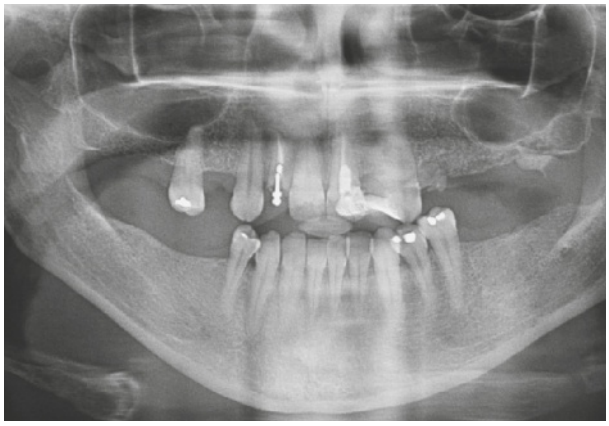


Fig 18-28 Preoperative panoramic radiograph.

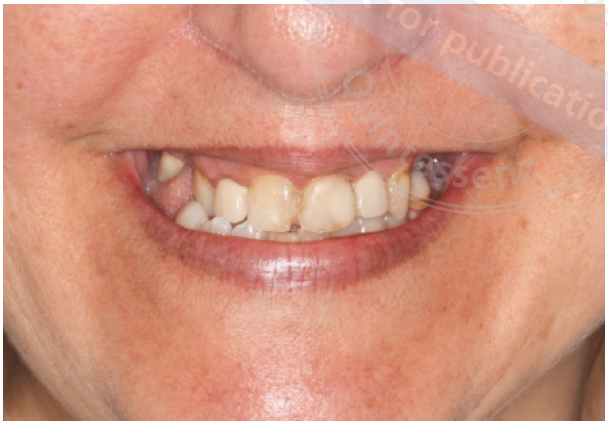


Fig 18-29 Preoperative view of the patient.

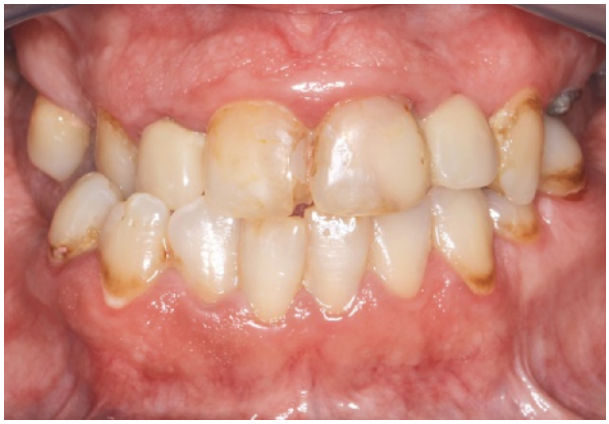


Fig 18-30 Preoperative intraoral view of a patient with periodontally compromised maxillary dentition requiring full-arch implant-supported rehabilitation.

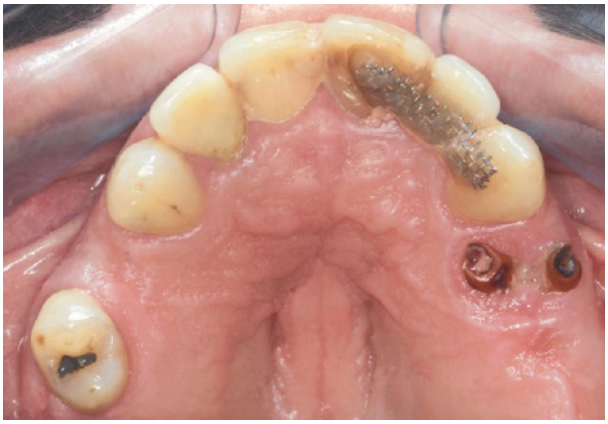


Fig 18-31 Preoperative occlusal view of the maxilla.

multizone anodized surfaces (NobelParallel Conical Connection TiUltra) were placed and connected to 172 multi-unit abutments (86 Multi-unit Xeal straight abutments and 86 Multi-unit 30-degree Xeal abutments).

With consideration for the rehabilitation protocol, study enrollment took place between February 2019 and July 2022, with a pretreatment examination performed on each subject via CBCT, panoramic radiography, and clinical photography (Figs 18-28 to 18-31). Sufficient bone was required for the placement of NobelParallel Conical Connection TiUltra implants with a minimum length of 10 mm.

The surgical protocol was initiated with a mucoperiosteal flap raised along the top of the ridge, with releasing incisions on the buccal aspect of the molar area (Fig 18-32). Implant placement was performed according to standard protocol, with underpreparation performed to achieve insertion torque in the range of 30 to 50 Ncm before final seating of the implants. Implants placed were 3.75 or 4.3 mm in width and between 10 and 18 mm in length (Fig 18-33). Implant platforms were placed with the goal of being flush with the bone crest, and bicortical anchorage was performed whenever possible. To facilitate placement and positioning of the posterior implants, a Nobel Biocare All-on-4 Guide was used (Fig 18-34). Implants were bilaterally positioned between the anterior walls of the maxillary sinus (between the mental nerve for mandibular rehabilitations), reaching angulations of 30 to 45 degrees in relation to the occlusal plane. Posterior implants typically emerged in the

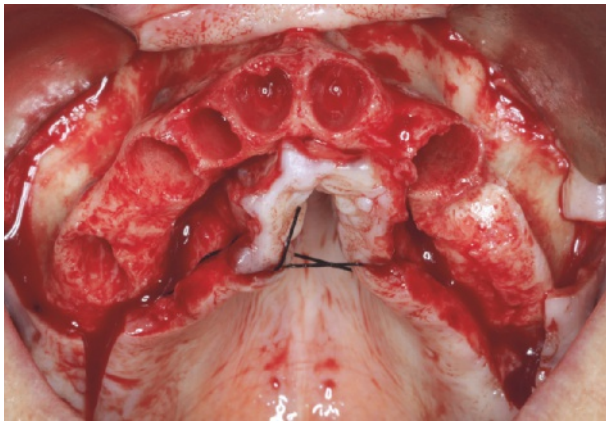


Fig 18-32 Intraoral view of the maxilla after tooth extraction and bone leveling.

Fig 18-33 The NobelParallel Conical Connection TiUltra implant used for the implant-supported full-arch rehabilitation.

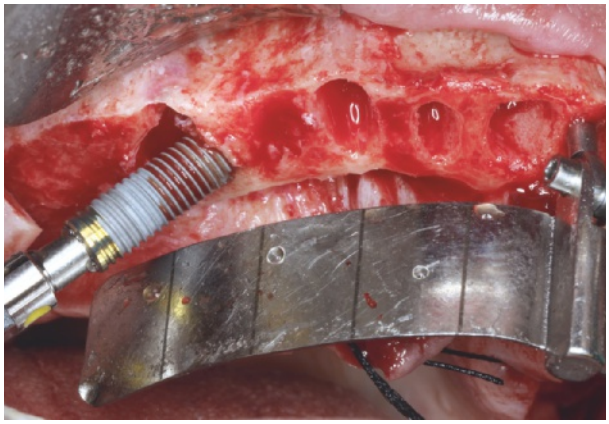


Fig 18-34 Placement of a posterior implant using distal tilting for full-arch implant-supported rehabilitation according to the All-on-4 Concept.

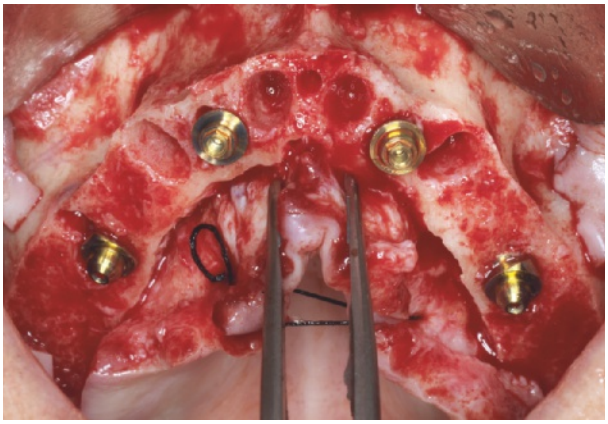


Fig 18-35 Intraoral view after insertion of four NobelParallel Conical Connection TiUltra implants according to the All-on-4 Concept, with the anterior implants connected to two Multi-unit Xeal abutments and the posterior implants connected to two Multi-unit Xeal 30-degree angulated abutments.

area of the second premolar, benefiting from distal tilting along the anterior sinus wall. Anterior implants were inserted in an axial position. When inserting the tilted implants, the bone crest was sometimes leveled first to ensure the implant platform was positioned at bone crest level, and after insertion, a bone mill was used to trim the excess bone and correctly position the angled abutments.

The abutments were connected to the implants (Multi-unit Xeal straight abutments for the anterior implants and Multi-unit Xeal 30-degree angulation abutments for the posterior implants; Figs 18-35 and 18-36). A high-density acrylic resin provisional prosthesis (PalaXpress Ultra, Kulzer) with acrylic resin crowns (Pala Premium teeth, Kulzer) and Nobel Biocare titanium cylinders was connected on the day of surgery to achieve immediate function (Figs 18-37 to 18-39).

Final prostheses were typically delivered 6 months after surgery and consisted of a Malo ceramic bridge with a titanium infrastructure (Nobel Procera, Nobel Biocare), acrylic resin artificial gingiva (PalaXpress Ultra, Kulzer), and all-ceramic alumina crowns (NobelRondo, Nobel Biocare) or a Malo acrylic bridge with a titanium infrastructure (Nobel Procera), acrylic resin artificial gingiva (PalaXpress Ultra), and acrylic resin crowns (Pala Premium teeth) (Figs 18-40 and 18-41). The patients were enrolled in an implant maintenance program and provided with oral hygiene instructions. Follow-up clinical examinations were performed to evaluate outcomes at 10 days and 2, 4, and 6 months after surgery, as well as thereafter

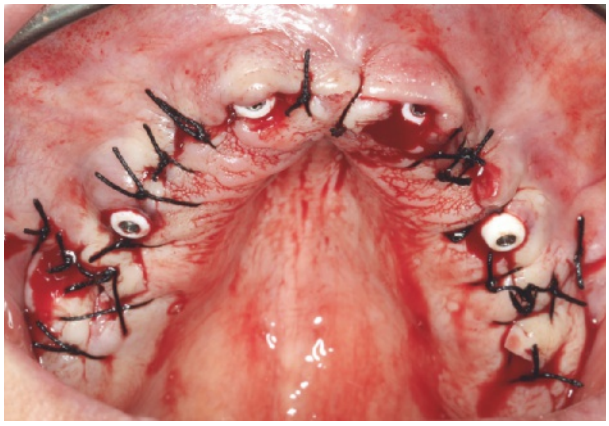


Fig 18-36 Intraoral view after suturing and with the healing abutments in place.

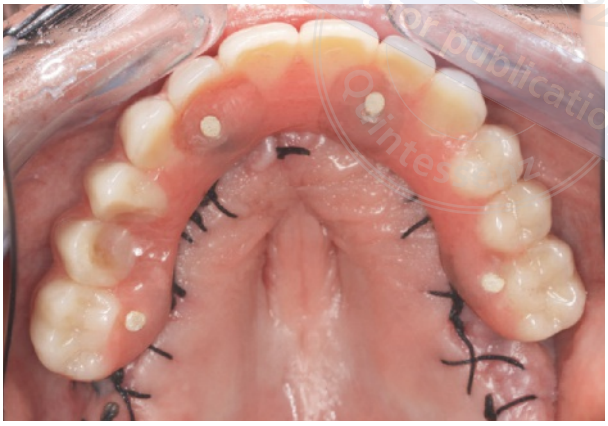


Fig 18-37 Intraoral occlusal view after connection of the full-arch immediate prosthesis on the same day of surgery to achieve immediate function.

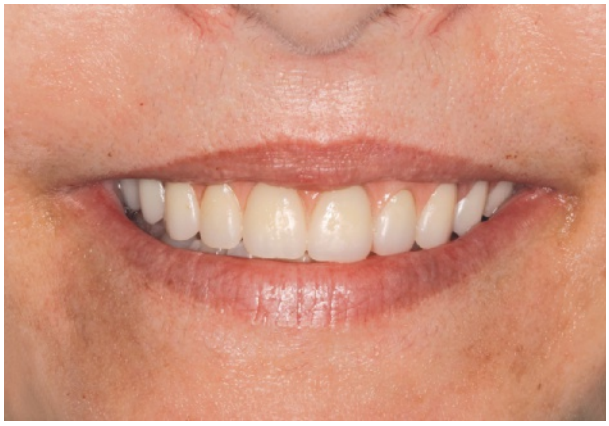


Fig 18-38 Extraoral view of the patient smiling with the full-arch immediate prosthesis.

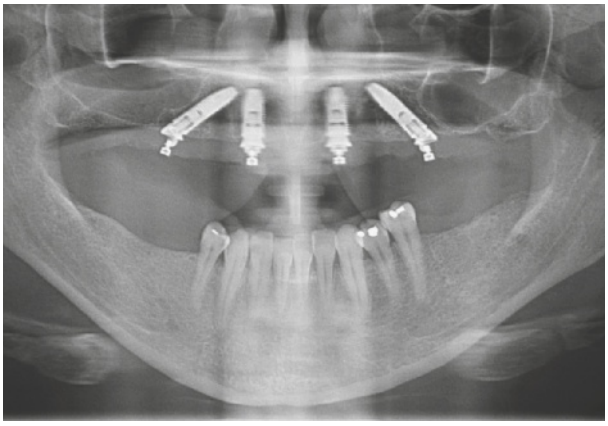


Fig 18-39 Postoperative panoramic radiograph.

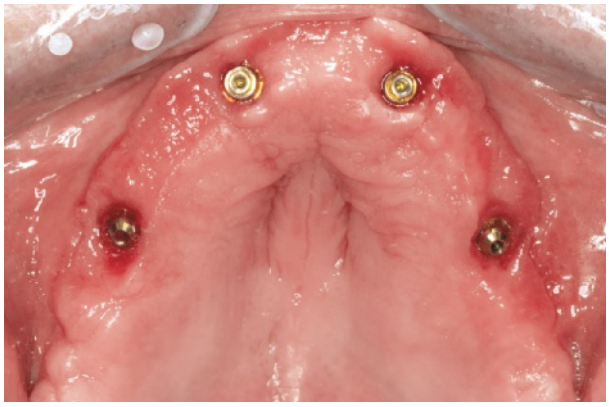


Fig 18-40 Intraoral occlusal view of the full-arch rehabilitation according to the All-on-4 Concept at the connection of the definitive prosthesis.

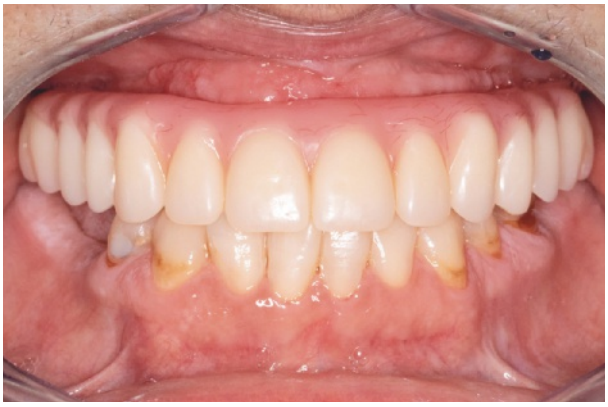


Fig 18-41 The full-arch implant-supported rehabilitation with connection of the definitive Malo acrylic bridge prosthesis.

Fig 18-42 Patient smiling at 2 years of follow-up.

every 6 months, with the final evaluation at 24 months (Figs 18-42 and 18-43).

At the 1- and 2-year follow-ups, a cumulative implant survival rate of 100% was reported for the NobelParallel Conical Connection implants with ultra-hydrophilic multizone anodized surfaces. The mean (95% confidence interval) MBL at 1 year was 0.39 mm (0.42, 0.61).[46]

The implant survival and biologic complications of the NobelParallel Conical Connection implants with ultra-hydrophilic multizone anodized surfaces at 2 years of follow-up and the mean MBL at 1 year of follow-up were compared to outcomes reported in other publications from the same group of authors for implants with turned and anodized surfaces used with the All-on-4 Concept.[16,22,23,48,51–53] After retrieving the data from the publications, it was separated according to implant surface (machined and anodized) while applying censoring to the data over 24 months of follow-up to analyze it statistically.

In the maxilla, a higher survival rate was reported for implants with ultra-hydrophilic multizone anodized surfaces (TiUltra) than for implants with anodized surfaces (TiUnite; no turned surface implants in the maxilla data; Table 18-3). In the mandible, implants with ultra-hydrophilic multizone anodized surfaces (TiUltra) were reported to have a higher survival rate, followed by implants with anodized surfaces (TiUnite), and finally implants with machined (turned) surfaces (see Table 18-3).

Table 18-3 Cumulative implant survival rate distribution at 2-years of follow-up for different types of implant surfaces and full-arch rehabilitations according to the All-on-4 Concept (maxilla and mandible)

NobelParallel Conical Connection ultra-hydrophilic multizone anodized implants for full-arch rehabilitations according to the All-on-4 Concept in the maxilla					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	80	0	0	100%	100%
6 mo to 1 y	80	0	8	100%	100%
1 to 2 y	72	0	0	100%	100%
Dental implants with anodized surfaces (TiUnite) for full-arch rehabilitations according to the All-on-4 Concept in the maxilla*					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	4,288	36	5	99.2%	99.2%
6 mo to 1 y	4,247	25	65	99.4%	98.6%
1 to 2 y	4,157	19	134	99.5%	98.1%
NobelParallel Conical Connection ultra-hydrophilic multizone anodized implants for full-arch rehabilitations according to the All-on-4 Concept in the mandible					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	92	0	0	100%	100%
6 mo to 1 y	92	0	0	100%	100%
1 to 2 y	92	0	0	100%	100%
Dental implants with machined turned surfaces for full-arch rehabilitations according to the All-on-4 Concept in the mandible†					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	219	4	0	98.2%	98.2%
6 mo to 1 y	215	0	8	100%	98.2%
1 to 2 y	207	1	4	99.5%	97.7%
Dental implants with anodized surfaces (TiUnite) for full-arch rehabilitations according to the All-on-4 Concept in the mandible†					
Time	No. of implants	No. of implant failures	No. of implants lost to follow-up	Implant survival rate	Cumulative implant survival rate
0 to 6 mo	1,665	3	0	99.8%	99.8%
6 mo to 1 y	1,662	0	36	100%	99.8%
1 to 2 y	1,626	4	40	99.8%	99.6%

*Data retrieved from Maló et al[23] (2019) with Mk III (n = 17), Mk IV (n = 92), and NobelSpeedy (n = 4,179) implants.

†Data retrieved from Maló et al[22] (2019) with Mk II (n = 38), Mk III (n = 661), Mk IV (n = 416), NobelSpeedy (n = 758), and NobelReplace (n = 11) implants.

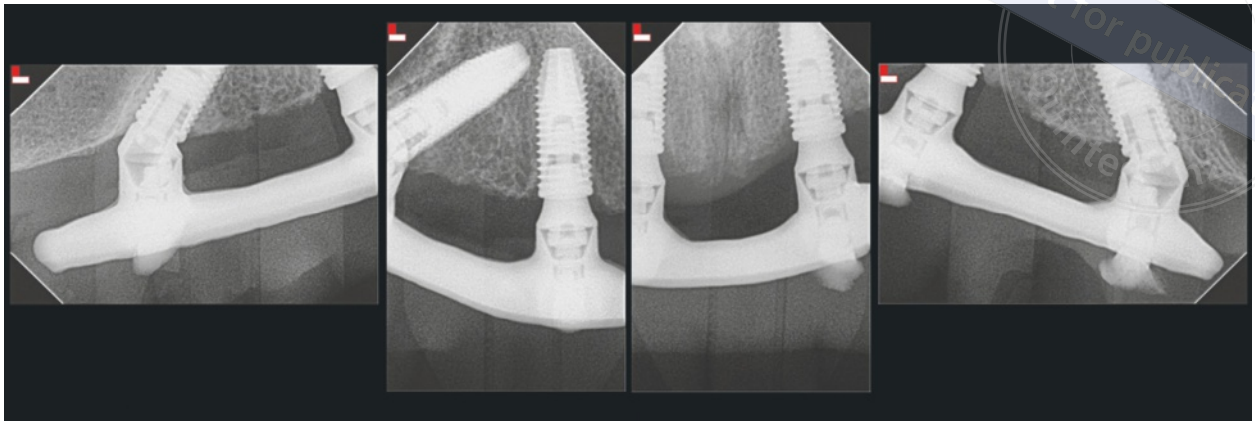


Fig 18-43 Periapical radiographs of the full-arch implant-supported rehabilitation at 2 years of follow-up.

Considering biologic complications, the current report on ultra-hydrophilic multizone anodized implant surfaces showed two maxillary implants with increased pockets in one patient (resolved via nonsurgical therapy). This represented an overall incidence of biologic complications of 1.2% at the implant level (2.5% incidence in the maxilla; 0% incidence in the mandible) after 2 years, comparing favorably with previous publications from the same group that reported an overall incidence of biologic complications of 3.5% in the maxilla[23] and 2.1% in the mandible[22] for the same follow-up time.

The MBL reported at 1 year for implants with ultra-hydrophilic multizone anodized surfaces (overall: 0.39 mm; maxilla: 0.51 mm; mandible: 0.29 mm)[46] also compares favorably with other publications from the same group for the maxilla (0.9 mm;[48] 1.2 mm;[51] 0.85 mm;[52] 1.30 mm[53]) and mandible (1.2 mm[16,51]).

Conclusion

In conclusion, the evolution of implant micro design has positively influenced success outcomes in implant dentistry. Considering the limitations of the few publications available and short follow-up times, it can be concluded that the use of dental implants with ultra-hydrophilic multizone anodized surfaces and abutments with ultra-hydrophilic anodized surfaces improves the short-term clinical outcomes of implant-supported rehabilitations, irrespective of the restoration type (single-tooth, partial, or full-arch according to the All-on-4 Concept). Nevertheless, it is necessary to further investigate the outcomes of ultra-hydrophilic surfaces in the long-term to obtain a clearer image of their value.

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