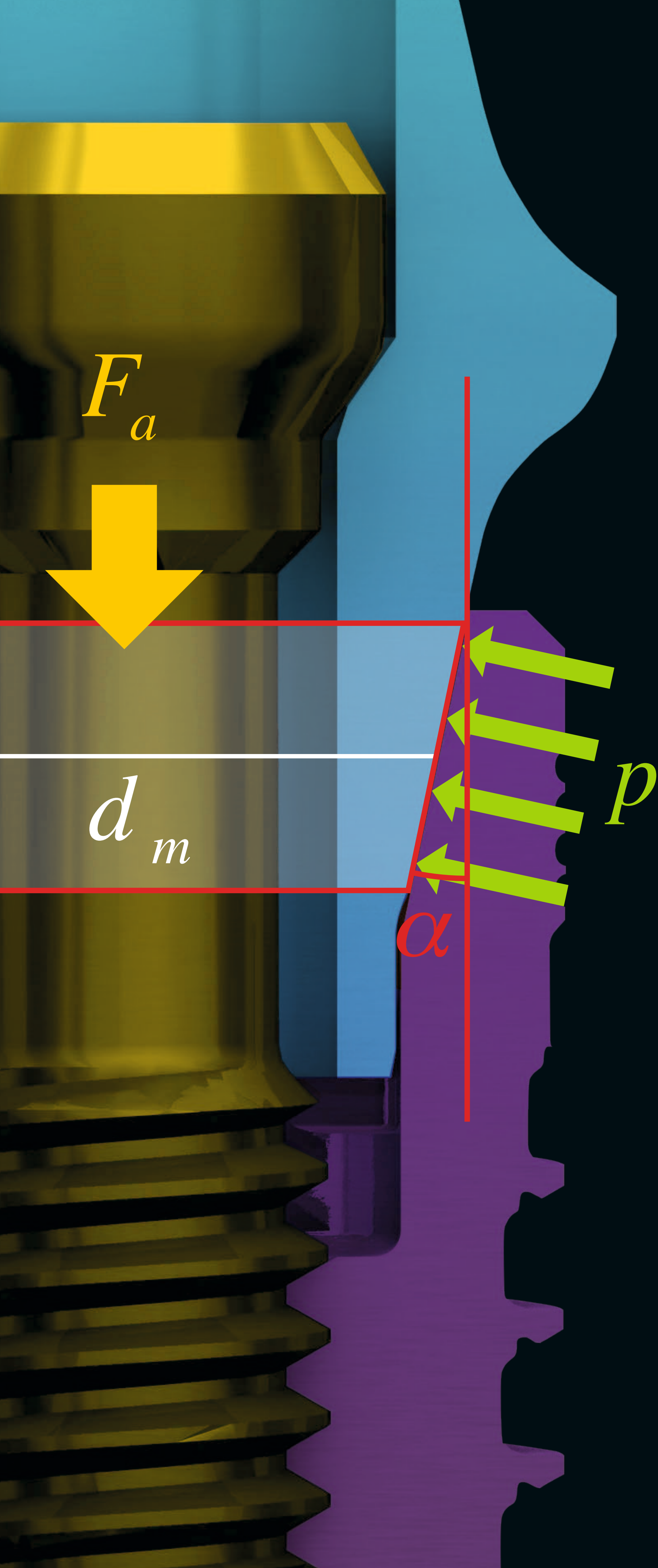


Individualized
CAD/CAM
restorations

Science First

Volume 3, Issue 1
2015

Cover picture: 3D rendering showing a precise fit between NobelProcera Abutment, NobelReplace Conical Connection implant and clinical screw. Selecting the matching abutment and using the dedicated clinical screw is crucial for system performance, since any small misfit can lead to extreme load and stress conditions and may result in system failure.

Contents

Patients want their teeth restored

This year we're celebrating 50 years since Professor Per-Ingvar Brånemark treated his first patient, Gösta Larsson, with dental implants. However, as much as we all have learned about the benefits of implant dentistry, it is still rare to hear a patient ask for an implant. Patients don't want implants, they want their teeth restored – and with their teeth the ability to eat, speak and laugh normally again. They want to enjoy a lifelong solution to oral function just like Gösta did. At his passing in 2006, he still had all his implants in place.

At Nobel Biocare, we are aware that the implant is just one part of the total solution you provide for your patients. That's why we are not just the pioneer of the industrial production of dental implants, but also of individualized CAD/CAM restorations. Together with Dr. Matts Andersson in the 1980s, we were the first to offer fully automated industrial manufacturing of prosthetic components. Since then, we have developed a comprehensive system of individualized CAD/CAM solutions, and patients all over the world have benefited from the more than eleven million units that we have produced.

In this issue of Science First, we present to you the scientific evidence on our individualized CAD/CAM restorations. You can be sure that our NobelProcera and Procera solutions have proven themselves in clinical life. They demonstrate superior precision of fit and excellent long-term performance. We also present clinical data that suggest that screw-retained restorations can be a better option than cement-retained when it comes to hard and soft tissue responses. And that excess cement should be avoided by all means, as it is a proven underlying cause of peri-implantitis.

Today, we are witnessing a technological revolution in treatment planning, surgery and CAD/CAM restorations – all for the benefit of you and your patients. At Nobel Biocare, we are proud to play a leading role in this movement. The future we envision: Each patient will be treated as an individual, to the highest standards of care, and paradoxically, more efficiently and affordably. While it starts with an implant, it must end with a patient's smile.

«Nobel Biocare is helping you to treat more patients better than anyone else in the industry."»

Richard Laube, CEO Nobel Biocare

The whole is greater than the sum of its parts

Selecting the best implant-supported restorative solution for their patients is a key challenge for clinicians. For every restoration type there is a variety of manufacturers providing all types of components. Then there are the options offered by conventional casting, too. The resulting plethora of restorative solutions demands that every clinician navigates these options to meet the requirements of long-term performance, clinical safety, cost efficiency and patient satisfaction.

Designed and tested as part of a system

A key aspect of performance assessment is that a system is only as strong as its weakest link, and that the performance of any component depends not only on the component itself, but also on its interactions within the system. Consequently, the appropriate test of any component is as a part of that system. For this reason, Nobel Biocare conducts testing and research not only on separate components such as implants, abutments and screws, but always on the entire system, too. Nobel Biocare investigates systems from their design to the end user including assessment of: engineering and manufacturing processes, clinical research, quality assurance, and post-market surveillance. Only with this approach can the system function safely and reliably for many years.

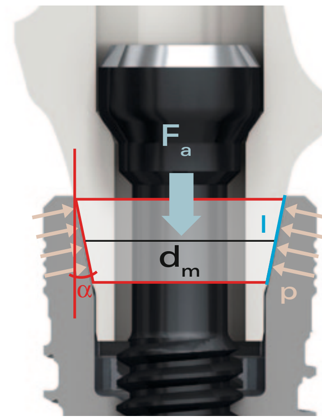
Understanding the parameters that influence long-term performance

Both theory (e.g. finite element analysis) and biomechanical testing indicate that several parameters can impact the performance of an implant system. These parameters include joint compression (the force that acts at the implant-abutment interface under loading conditions), preload (the tensile force keeping the pieces together) and friction coefficient (which depends on the surface materials that are in contact). In addition, there's the force that the patient exerts on the system by chewing, as well as the length of the contact between the abutment and the implant. Plus, in a conical connection implant, the angle of the abutment within the implant cone. A small change in any of these parameters, even one not visible to the eye, can lead to extreme load and stress conditions that result in system failure.

Precise fit maintains joint stability

The interface between implant and abutment is critical for joint stability. Manual adjustment of a cast or use of a substitute abutment can alter the contact angle and contact length. This can result in an undefined contact situation that could bring unknown risks to the patient. Consequently, selecting the matching abutment is crucial for system performance, as it not only affects the fit of the restoration on the implant itself, but may also impact performance-relevant parameters.[1]

Precise fit ensures long-term performance



$$p=\frac{F_a * \cos(\rho) * \cos(\frac{\alpha}{2})}{d_m * \pi * l * \sin(\rho+\frac{\alpha}{2})}$$

Joint compression (p) depends on a number of variables such as preload (tensile force F_a), friction angle (α) and contact length (l). Small changes in any of these parameters can lead to extreme load and stress conditions, which can cause implants to fracture.

Preload, the force that holds the components together

Preload is defined as the tensile force created in the clinical screw as the result of screw tightening. It is generated by application of torque to the screw, although only a fraction of the torque force is stored as preload, while a much larger percentage is spent on overcoming friction. To account for this major loss of torque, and to ensure that the system is sufficiently held together, the screw has to be inserted at the recommended torque. Fully manual screw insertion is likely to result in lower torque and, consequently, suboptimal preload. Insufficient preload leads to increased relative motion between the system components, which is a causative factor of screw loosening or even component failures.[2] Conversely, preload values that are too high can result in fracture of the componentry.

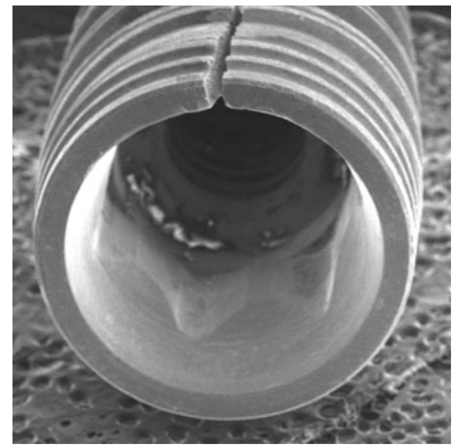
Optimized to the last detail – why the clinical screw matters

Nobel Biocare abutments are delivered with a dedicated clinical screw that has been optimized for the implant-abutment system that it's a part of. Depending on the abutment, connection type and platform size, screws come with or without a surface coating. The absence or presence of the coating and the coating type all impact the preload. For example, diamond-like carbon (DLC), a coating for screws marketed under the brand TorqTite, shows higher preload values compared with screws that have a standard titanium surface ($P<0.001$).[3] At Nobel Biocare the selection of the appropriate screw type is individual for each and every implant-abutment connection, ensuring a tight and stable fit for long-term performance.

Substitutes can put patients at risk

The use of substitute components means that the parameters governing system performance are no longer controlled. In the example of maximum joint compression, which defines the load that the implant collar can bear, a substitute may result in a force that is higher than the allowed maximum, causing the implant to fracture. To avoid this, the peak forces have to be distributed in a controlled way. This can only be achieved by using high-quality and precision-manufactured components that have been designed and tested for the system they are a part of.

Mismatching components can have severe consequences



Imprecise fit leads to uncontrolled peak forces, which may result in implant fracture.

History of NobelProcera®

In 1983, Dr. Matts Andersson first presented his groundbreaking innovation: fully automated industrial CAD/CAM* dental prosthetic production. Today, NobelProcera continues to lead the field as it delivers restorations of outstanding quality. Patients all over the world have benefited from the more than eleven million individualized units that have been delivered since the fabrication of the first coping over thirty years ago.

The roaring 80s of implant dentistry

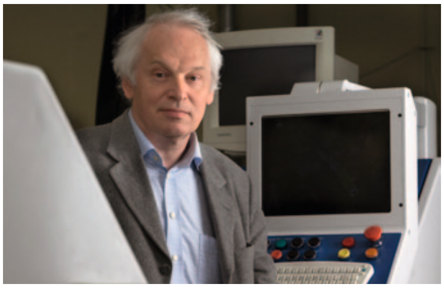
The 1980s were a historic period for implant-based oral rehabilitation. The publication of Professor Per-Ingvar Brånemark's ten year follow-up clinical data in 1982 led to global acceptance of dental implants as a treatment method.[4] In 1983, Professor Matts Andersson developed the Procera method of repeatable high-precision manufacturing for individualized dental restorations, beginning with titanium crowns. Nobelpharma, which would later become Nobel Biocare, saw the potential in Procera and acquired the technology in 1988. The breakthrough came with the production of all-ceramic crowns in 1989. Later, bridges, abutments and implant bridges in both titanium and ceramic followed.

From Procera to NobelProcera

In 2009, Procera was relaunched as NobelProcera. This saw the introduction of a new scanner offering unique optical scanning through conoscopic holography, easy-to-use software and advanced centralized manufacturing. At the same time, fixed and fixed-removable overdenture bars were introduced. Today, NobelProcera offers the full range of screw- and cement-retained solutions – from single-unit to full-arch restorations, both for Nobel Biocare and other major implant systems.

Precision-manufacturing at its best

NobelProcera approaches the development of new products with advanced engineering, thorough verification, meticulous validation and specialized manufacturing techniques and tooling. The result: consistent precision of fit and exceptional product quality. All NobelProcera restorations are developed and produced according to the Medical Devices Quality Management System ISO 13485:2003. This means that all processes are regularly audited by the British Standards Institution (BSI), a notified body conducting a conformity assessment under the relevant EU Directives, and inspected by competent authorities such as the US Food and Drug Administration (FDA). This has established confidence that clinicians and patients always receive the best quality products.



In 1983, Professor Andersson developed the Procera method of repeatable high-precision manufacturing for dental restorations.

The first titanium coping was fabricated with the help of ordinary machines that are available in a toolmaker's workshop.

Thorough quality control ensures that NobelProcera restorations are ready to use (production plant in Chiba, Japan).

* Computer-aided design / computer-aided manufacturing.

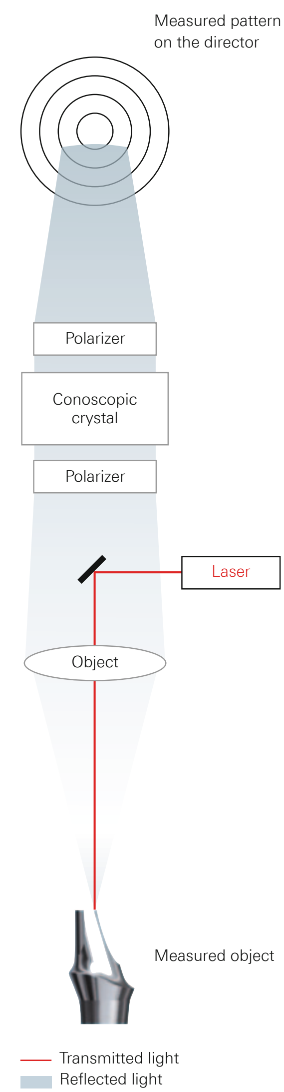
Advantages of CAD/CAM dentistry

Nobel Biocare efficiently produces precise, durable and esthetic tooth- and implant-supported CAD/CAM prosthetics. Computer-aided design and manufacturing ensures precision of fit, while milling enables the use of high-strength, durable, and biocompatible materials. In addition, using CAD/CAM protocols reduces manual labor and removes the risks associated with the casting technique.

Accurate scanning technology

Highly accurate acquisition and digital representation of oral structures, such as prepared teeth or inserted implants, is paramount if a CAD/CAM restoration is to fit precisely. The laboratory-based scanners from Nobel Biocare have evolved from the Procera touch probe scanner used for digitizing stone casts to the current NobelProcera scanner that uses conoscopic holography. The latter allows measurements of steep angles and deep cavities. Several studies confirm the high accuracy and repeatability of surface scanning using both of these scanners. Persson and colleagues compared the two scanning devices and concluded that their "repeatability is comparable and accuracy sufficient to serve as input in a manufacturing system for fixed dental prostheses."[5] Another study shows that the measurement deviations upon acquisition with either device are 11 µm, and fall to 4 µm with repeated scanning.[6] Using gap measurement as a read-out of accuracy for 10-unit titanium and zirconia frameworks, an *in vitro* investigation demonstrates the high accuracy of both laser and tactile scanners, reporting median vertical gaps of 14 µm and 18 µm, respectively. This strongly contrasts with the gap of 236 µm measured in this study for conventional casts.[7] Based on these results the authors conclude that the "misfit of the cast alloy frameworks is clinically inacceptable", while the laser and tactile scanners "facilitate production of highly accurate reconstructions." Further studies are required to confirm the predicted superiority of holographic scanners over tactile technology in relation to challenging situations involving deep crevasses and steep angles.

Conoscopic holography – working principle

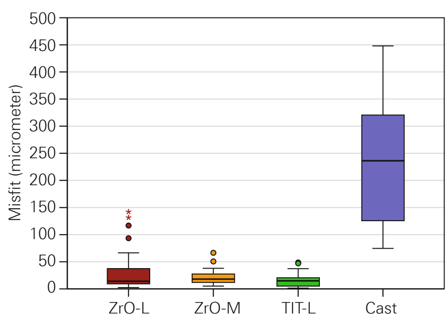


Conoscopic holography is advantageous compared with other optical scanner techniques, such as triangulation, in that the projected and reflected beams travel the same linear pathway to and from the scanned object. This "co-linearity" allows measurements of steep angles and deep cavities, such as those found in dental impressions.

Superior precision of fit

Nobel Biocare can consistently deliver Procera and NobelProcera restorations with a precision of fit superior to that of conventional casts or products milled chairside. In *in vitro* studies, both zirconia and titanium frameworks show median marginal gaps at least ten times smaller than those of cobalt chromium cast products and at least five times smaller than gold cast products.[7,8] Nobel Biocare titanium frameworks have also demonstrated a better passive and non-passive fit and lower strain when compared with conventional castings.[9] Similarly high accuracy has been reported for Nobel Biocare restorations on teeth in a study comparing mean marginal gaps between zirconia ceramic crowns produced by different CAD/CAM systems. The authors of the study conclude that "of the systems tested, the highest marginal accuracy was achieved with the Procera system."[10]

Ten times higher precision of fit



Nobel Biocare CAD/CAM systems offer reconstructions with a precision of fit over ten times higher than those of conventional cast frameworks. The boxplot shows the vertical micro gap for a NobelProcera zirconium dioxide framework fabricated using a laser scanner (ZrO-L), a Procera zirconium dioxide framework fabricated using a touch probe scanner (ZrO-M), a NobelProcera titanium framework fabricated using a laser scanner (TIT-L), and a CoCrW-alloy cast framework.[7]

From single-unit to full-arch restorations – the full-range of screw- and cement-retained CAD/CAM solutions.

Excellent strength *in vitro*

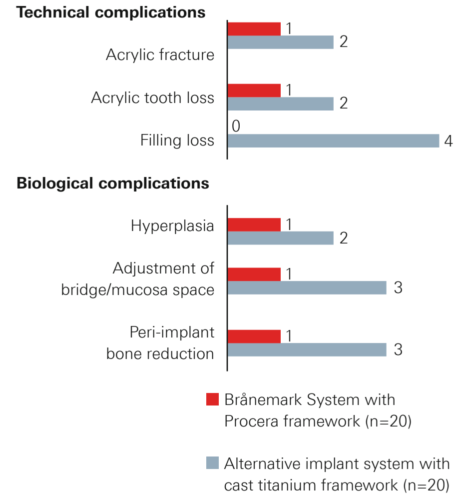
CAD/CAM technology has introduced individualized prosthetics made from materials such as titanium or zirconia, the use of which is limited in traditional laboratory-based workflows. Titanium was the first raw material used in the Procera manufacturing process. Since its market entry in 1984, it has remained the gold standard due to high strength and biocompatibility.[11] Over the last few years, an ever-increasing demand for esthetic properties has paved the way for ceramics such as zirconia, which offers both durability and tooth-like color.[12] A number of independent investigations have demonstrated the excellent raw material strength of titanium and zirconia used by the Nobel Biocare CAD/CAM technology.[13–25] Although considerable variations in fracture load can be observed between the different studies, comparative studies reveal that Nobel Biocare materials have an equivalent or superior strength to that of conventional cast materials.[21,23]

Nobel Biocare restorations maintain outstanding strength after exposure to fatigue stress in an artificial oral environment. Att and colleagues performed a series of *in vitro* tests aimed at evaluating fracture load after thermo-mechanical cycling set to mimic five years of function. The two studies demonstrate that all restorations, including titanium and zirconia, "exceeded the minimum limits of the fracture resistance for anterior restorations."[15,16]

Exceptional durability in a clinical setting

As expected, use of stronger materials and individualized design has a marked positive influence on the strength and durability of CAD/CAM restorations in the clinical setting. Improved strength and durability have been reported for various Nobel Biocare frameworks, including implant bridges and implant bars. In a comparison of 10-unit titanium frameworks with gold alloy cast, the 5-year prosthesis survival rate was 100.0% vs. 97.1%, respectively.[26] In addition, patients with Nobel Biocare restorations needed fewer appointments and experienced significantly fewer phonetic problems, fewer fistulas, fewer veneer fractures and no implant failures. Plus, a lower number of patients had their prostheses temporarily removed for adjustments.[26] Similar results have been demonstrated in a study comparing conventional and Nobel Biocare CAD/CAM implant bar-retained overdentures, where CAD/CAM restorations experienced a significant reduction in technical complications.[27,28] Fewer complications during the follow-up period have also been reported by Moberg and colleagues. They investigated Procera titanium frameworks supported by Nobel Biocare implants in comparison with conventional cast titanium frameworks supported by an alternative implant system.[29]

Nobel Biocare CAD/CAM titanium frameworks are associated with fewer technical and biological complications



Complications recorded during a 3-year follow-up of a randomized prospective study with 40 edentulous patients treated with either Nobel Biocare implants and Procera frameworks or an alternative implant system with conventional titanium cast frameworks.[29]

Biocompatibility

All Nobel Biocare medical devices are made from biocompatible materials. Unalloyed grade 2 titanium and the grade 5 alloyed titanium (Ti-6Al-4V) have both shown resistance to corrosion and a limited ion release in response to contact with a live environment. This results in low ion leakage and favorable tissue response including osseointegration.[11,30] Similarly, zirconia has shown biocompatibility *in vitro* and *in vivo*.[12,30]

Biocompatibility of restorative materials plays an important role not only in osseointegration, but also with respect to appropriate soft tissue attachment. It also influences the adhesion of bacteria. Mustafa and colleagues report that the adhesion and activity of human gingival fibroblasts is greater on industrially manufactured zirconia in comparison with polished and veneered structures.[31]

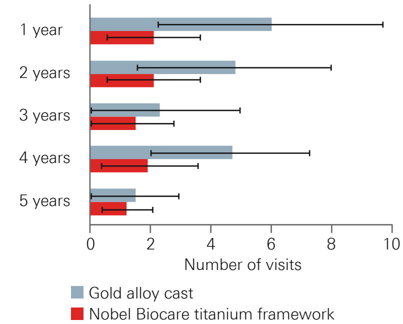
Bacterial adhesion is believed to be part of the first step both in biofilm formation and in initiation of an inflammatory response that could possibly lead to bone resorption and implant failure.[32] *In vitro* tests demonstrated that the numbers of bacteria adhering to saliva- or saliva-plus-serum-covered surfaces of titanium, zirconia and hydroxyapatite (an enamel surrogate) are comparable. This led the authors to conclude that zirconia is "suitable material for manufacturing implant abutments with biological properties similar to titanium."[33]

The results of clinical studies support the *in vitro* findings on the biocompatibility of CAD/CAM materials. A report of fifty clinical cases with a simplified technique for reconstructing emergence profiles during implant restoration using Nobel Biocare Abutments in titanium and zirconia shows that, when these abutments are used at the provisional crown stage, the restorations exhibit excellent esthetics and healthy gingival tissues.[34]

Less chair time and fewer clinical visits

Use of CAD/CAM technology has led to a significant shortening of chair time during the prosthetic procedure and a significant reduction in the number of follow-up appointments. In a retrospective study comparing two patient cohorts, one with gold alloy cast frameworks and the other with Nobel Biocare CAD/CAM titanium restorations, the authors demonstrate that patients undergoing conventional treatment had to attend more clinical appointments, and that the mean time for completion of their permanent prosthesis was almost 60% longer.[26] The authors largely attribute these changes to the improved fit associated with the computer-aided design and production, as well as to the high durability of the materials.

Fewer follow-up visits



Mean number of clinical visits per patient during the follow-up period. Nobel Biocare CAD/CAM titanium frameworks are associated with fewer follow-up visits due to higher precision of fit and stronger materials.[26]

Nobel Biocare CAD/CAM abutments – scientific evidence

Nobel Biocare CAD/CAM abutments are individualized solutions that combine long-term clinical stability with high esthetic results. This is due to their wide versatility, homogenous and biocompatible materials, and anatomic design.

Clinical studies with up to 5-year follow-up confirm excellent performance of Nobel Biocare CAD/CAM abutments with consistently high survival rates: out of over 1000 Procera and NobelProcera Abutments placed in more than 800 patients, only two were reported to have fractures and needed replacement.*

Key findings of the clinical studies are:
- Excellent abutment survival with follow-up up to 5 years: 12 studies with 100% and one study with 99% survival (references see table).
- Stable bone levels in studies with 5 years of follow-up.[35,36]
- Low levels of peri-implant pathology[40,48] and low bleeding on probing[36,40,43,48] indicating healthy soft tissue.
- Low complication rates of 5% and 12.5% in the two 5-year follow-up studies by Calandriello and Zembic, respectively.[35,36]
- Excellent esthetic results[38-40] and high patient satisfaction.[38-40,42,45,49]
- Successful at various locations and loading protocols (see extended table following this chapter).
- Wide versatility: excellent clinical outcomes for Nobel Biocare CAD/CAM abutments on third-party implants.[47,50]

Comparative studies reveal comparable outcomes for titanium and zirconia abutments

Zirconia abutments offer an attractive alternative to titanium. They provide better esthetic results due to lesser mucosal discoloration[51] and lower bacterial adhesion.[52] Zembic et al. conducted a randomized controlled clinical trial comparing the outcomes of NobelProcera titanium vs. zirconia abutments to evaluate their performance in supporting single-implant crowns in canine and posterior regions.[36] In the 5-year follow-up, the authors report no screw loosening or abutment or crown failures for either tested group. Similarly, there were no differences between zirconia and titanium abutments with regard to biological outcomes including mean pocket probing depth (3.3 mm ±0.6 mm for zirconia vs. 3.6 mm ±1.1 mm for titanium at 5 years), bleeding on probing average per 4 sites probed, or hard tissue response as determined by mean marginal bone levels. Interestingly, the authors report a trend of less plaque at reconstructions on zirconia abutments than on titanium abutments (mean plaque control record was 0.1 ±0.3 for zirconia vs. 0.3 ±0.2 for titanium at 5 years, P=0.0712). In conclusion, the authors state that "there were no statistically or clinically relevant differences between the 5-year survival rates, and the technical and biological complication rates of zirconia and titanium abutments in posterior regions". And that these "positive results warrant the use of zirconia implant abutments even in posterior regions."

Consistently high survival rate of Nobel Biocare CAD/CAM abutments

Study	Study follow-up	Material	Survival
Follow-up time 5 years			
Calandriello 2011[35]	5 years	nr	100%
Zembic 2013[36]	5 years	Zr, Ti	100%
Follow-up time >1 to <5 years			
den Hartog 2011[37]	18 months	Zr, Ti	100%
den Hartog 2011[39]	18 months	Zr	100%
Ekfeldt 2011[40]	3–5 years	Zr	99%
Pozzi 2012[41]	43.3 months	Zr, Ti	100%
Rao 2007[42]	1–3 years	nr	100%
Follow-up time 1 year			
Kutkut 2013[34]	1 year	Zr, Ti	100%
Pozzi 2014[43]	1 year	Ti	100%
Raghoebar 2009[44]	1 year	Zr	100%
Tymstra 2011[45]	1 year	Zr	100%
Urban 2012[46]	1 year	Ti	100%
Procera Abutments on third-party implants			
Vigolo 2006[47]	4 years	Ti	100%

Zr: zirconia
Ti: titanium
nr: not reported

List includes all studies with Nobel Biocare CAD/CAM abutments reporting abutment survival or where abutment survival could be calculated. The indicated follow-up time describes the study duration and thus may be longer than the abutment follow-up.

* This is based on events reported in all studies listed in the extended table at the end of this chapter.

Excellent functional and esthetic outcomes

Another clinical study with Nobel Biocare CAD/CAM abutments in zirconia used for single-tooth restorations, mostly in the anterior maxilla, reports low rates of both technical and biological complications at 1-year follow-up.[40] 25 patients with 40 abutments underwent an evaluation with a longer follow-up of 3–5 years, which confirmed the good performance of zirconia abutments. The peri-implant bone level on all measurable implants was 0.16 mm ±0.72 mm (0.29 mm ±0.87 mm on randomly selected 25 implants). The mean bleeding on probing was slightly higher around the implant-supported restorations than at the mesial, but not the distal, neighboring teeth (0.18 ±0.2 vs. 0.07 ±0.11, *P*=0.0199; and vs. 0.14 ±0.27, *P*=0.5545). The esthetic outcomes were assessed as excellent (73%) or good (27%). The authors conclude that "zirconia abutments for single-implant crowns seem to demonstrate good short-term technical and biological results."

Cement- and screw-retained solutions

Clinical studies confirm excellent outcomes for zirconia and titanium abutments with both cement- and screw-retention systems. A recent report from a randomized clinical trial with single-tooth implants in the anterior jaw includes 38 screw-retained and 53 cement-retained restorations. It reports a 100% abutment and restoration survival rate as well as good performance in terms of function and esthetics. In addition, the study shows high patient satisfaction (score 9.0 ±1.0 out of maximum 10) after 18 months of follow-up.[37,38]

One-piece solution: screw-retained crowns for direct veneering

Several clinical studies used screw-retained crowns for direct veneering. They demonstrate promising clinical outcomes in short-term follow-up reports.[37-40,45,49] Ekfeldt and colleagues conducted a retrospective evaluation of the records of 130 patients with 185 single-tooth implant restorations, 90 of which had the veneering porcelain baked directly to the zirconia abutment. At the 1-year follow-up, implant and abutment survival rates were both 99%, and the rates of complications were low. The authors conclude that "there were no significant differences in changes for any of the soft tissue registrations or the peri-implant marginal bone level" between the conventional two-piece abutment-crown restoration and the one-piece solution.[40]

Excellent esthetic results: screw-retained crowns for direct veneering[40]

A Agenesis of tooth 22 and small peg-shaped tooth 12.
B Zirconia abutment with porcelain baked to the abutment; palatal view.
C Front view at 1-year examination: a single-implant restoration region 22, a ceramic veneer on tooth 12.
D Radiograph taken at the insertion of the restoration.

Healthy soft tissue

Custom abutments offer an individualized contour and emergence profile and are able to provide good soft tissue support. Clinical studies that evaluate soft tissue outcomes with NobelProcera and Procera Abutments confirm these proposed advantages of CAD/CAM abutments.

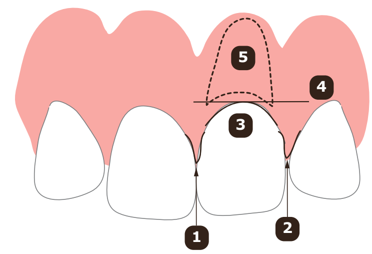
- In three studies reporting plaque accumulation, 236 out of the summed 242 investigated sites had no visible plaque.[37,39,43]
- Esthetic analysis was conducted in three studies, with pink esthetic score (PES)[53] mean values ranging from 6.3 ±1.7 to 7.1 ±1.5 (where 0 is the minimum, and 10 is the maximum and denotes healthy soft tissue). Satisfactory ICAI (implant crown aesthetic index[54]) mucosa was reported in three studies and ranged from 56.6% to 100%.[38–40]
- In all studies using Nobel Biocare CAD/CAM abutments (18 studies, 1146 implants, 1061 abutments), peri-implantitis and peri-implant mucositis, as defined by authors, is reported in 3[36,55] and in 11 patients,[40,48] respectively.
- Bleeding on probing ranged from 0 to 1.4 ±0.75[36,40,43,48] and pocket probing depth ranged from 2.2 mm ±0.84 mm to 5.3 mm ±1.5 mm.[36,37,39,45–49]

High patient satisfaction

Excellent clinical outcomes combined with good esthetic results lead to high patient satisfaction, as evidenced by the studies with Nobel Biocare CAD/CAM abutments that assess patient responses.

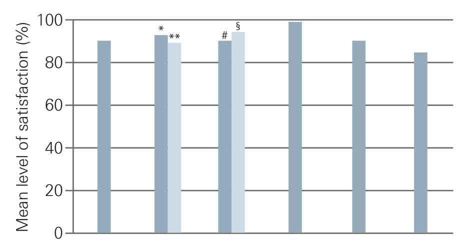
- Two randomized clinical trials comparing different implant designs using titanium and zirconia abutments in the esthetic zone of 133 patients report high satisfaction of 84.5 out of 100 and 9.0 out of 10 on two visual analog scales.[38,49]
- Another randomized clinical trial comparing different loading protocols using zirconia abutments reports high patient satisfaction of 92.7% (immediate loading) and 89.0% (delayed loading) after 18 months of follow-up.[39]
- A clinical 3- to 5-year follow-up of 25 patients with 40 single-tooth restorations with zirconia abutments reports esthetic patient satisfaction of 90% (median 100%) and functional patient satisfaction of 94% (median 100%).[40]
- A pilot study with 10 patients who were missing two adjacent teeth in the maxillary esthetic zone reports very high patient satisfaction with an average score of 9.0 (out of 10) on a visual analog scale.[45]
- A prospective study reports that the 46 patients found the esthetic and functional results excellent (95.6%) or good (4.3%). The authors state that "a general impression of satisfaction of the patients was observed, as they expressed amazement over the absence of symptoms."[42]

Definition of the esthetic assessment using the pink esthetic score (PES)[53]



PES evaluates five variables: mesial papilla (1), distal papilla (2), curvature of facial mucosa (3), level of facial mucosa (4), and root convexity/soft tissue color and texture (5). During an assessment each variable is assigned a score of 0, 1, or 2, with 0 being absent or having major discrepancy, 1 being incomplete or having minor discrepancy, and 2 being complete or having no discrepancy. Under optimum conditions all these scores add up to 10. The threshold of clinical acceptability is set at 6.[53]

High patient satisfaction



Study	den Hartog[38]	den Hartog[37]	Ekfeldt[40]	Rao[42]	Tymstra[45]	Tymstra[49]
Patients	93	62	25	46	10	40
Material	Zi, Ti	Zi	Zi	nr	Zi	Zi, Ti

* Immediate loading
** Delayed loading
# Esthetic satisfaction
§ Functional satisfaction
Zi: zirconia
Ti: titanium
nr: not reported

Patients are highly satisfied with the protocols involving Nobel Biocare CAD/CAM abutments. Different questionnaires may have been used by different studies.

Engineered to be effective

Key findings from the *in vitro* experiments on Nobel Biocare CAD/CAM abutments assessing strength, durability and consistent precision of fit:

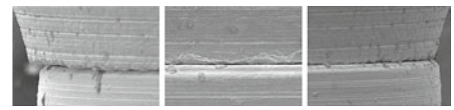
- Nobel Biocare abutments show comparable or superior fracture load and bending moments in nine *in vitro* studies with various protocols. These include after aging and comparisons with stock abutments.[56–65]
- Detorque values of zirconia abutments do not change with increasing loading cycles. This suggests high system stability and resistance to screw loosening.[66]
- Rotational freedom between implant and abutment ranges from 2.01° to 4.13°,[59,67–69] with all values falling below the threshold of 5°, excess of which is associated with screw loosening.[70]
- Mean micro gaps between Nobel Biocare CAD/CAM abutments and supporting implants range from 0.06 µm to 10.5 µm.[67,71–75]

Points to consider when working with Nobel Biocare CAD/CAM abutments

- Fracture load of zirconia abutments is not affected by manual grinding as long as the appropriate guidelines are followed (stress-free preparation with water cooling and using fine-grained cutting diamonds).[57] Manual adjustment of the abutment at the implant-abutment interface should be avoided, as this can lead to misfit. This problem was experienced by Gigandet and colleagues who had manually adjusted the Procera Abutment and consequently could not investigate its rotational play.[59]
- Metallic inserts in the zirconia abutments increase their strength.[64]
- As expected due to material strength characteristics, titanium abutments are stronger than zirconia abutments in *in vitro* testing (fracture load). However, both meet the strength requirements for clinical use.[62,65]
- To minimize potential bacterial leakage and ensure long-term stability of the prosthesis, abutments should be tightened to manufacturer-recommended torque levels.[1,74]
- For proper seating of the screw head, use the original screws provided with the Nobel Biocare abutments.[76]
- Using abutments on off-label implants can result in a significant vertical misfit.[72]

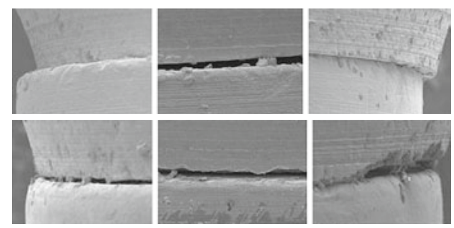
Original Nobel Biocare CAD/CAM abutments on original Nobel Biocare implants for best precision of fit

Original on original



Procera Abutment on Nobel Biocare implant: gaps are distributed uniformly among all measured sites. No horizontal discrepancies can be observed.

Off-label use of Nobel Biocare CAD/CAM abutments



Procera Abutments on off-label implants. Top photomicrographs show a greater misfit in the central area compared with the left and right edge, where a horizontal mismatch is clearly visible. Bottom photomicrographs demonstrate a non-uniformly distributed microgap.[72]

Nobel Biocare CAD/CAM abutments on third-party implants

Nobel Biocare CAD/CAM abutments on third-party implants are engineered to provide a precise fit. The outstanding quality and excellent performance of these abutments is confirmed by both *in vitro* testing and clinical investigations.

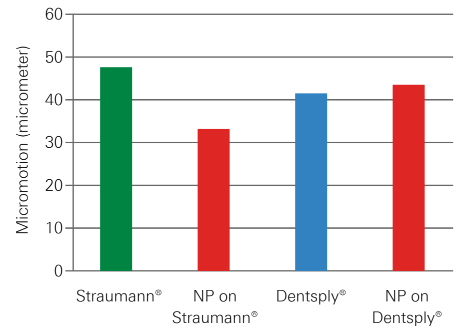
Engineered to fit

Excessive micromotion at the implant-abutment interface can lead to a variety of technical and biological problems and result in prosthesis and implant failure. As such, a good implant-abutment connection design that limits micromotion is likely to improve the performance of the entire restoration. Nobel Biocare CAD/CAM abutments on third-party implants are engineered to provide a precise fit, as demonstrated by a recent *in vitro* report that measured micromotion generated between several implants and their different abutments. In this study, NobelProcera Abutments on Dentsply® and Straumann® implants led to comparable or even lower micromotion when compared with original abutments on the same implants.[77]

Excellent clinical results

Results from clinical studies confirm the excellent performance of Nobel Biocare CAD/CAM abutments on third-party implants. In a 4-year follow-up study, 40 Biomet 3i® implants were restored with 20 Procera Abutments in titanium and 20 Biomet 3i® gold alloy abutments. No patient reported any prosthetic complications such as loosening of the abutment screw, fracture of the porcelain, or loosening of provisionally cemented final crowns. Furthermore, the survival rate of Procera Abutments was 100% with no difference between the two abutment groups.[47] Good clinical results for Nobel Biocare abutments in terms of mean marginal bone levels were confirmed by clinical case series on Astra Tech® implants.[50]

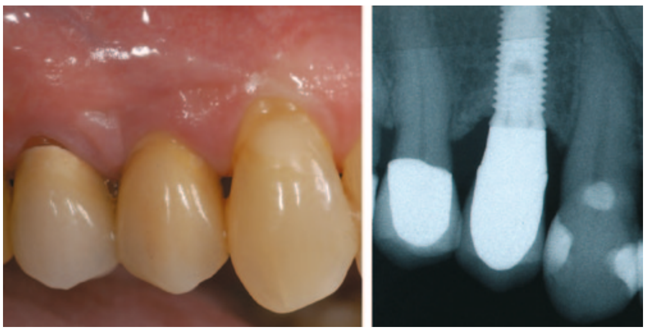
Low micromotion on third-party implants



NobelProcera Abutments (NP) have lower or comparable micromotion on third-party implants when compared with original abutments.[77]

Five-year results of a randomized controlled clinical trial comparing zirconia and titanium abutments supporting single-implant crowns in canine and posterior regions

Zembic A, Bosch A, Jung RE, Hammerle CH, Sailer I
Clin Oral Implants Res. 2013;24:384-390



Clinical and radiographical 5-year follow-up of an all-ceramic crown (ACC) on a zirconia abutment in region 14. Apparent buccal recessions on both neighboring teeth.

Clinical and radiographical 5-year follow-up of a metal-ceramic crown (MCC) on a titanium abutment in region 24.

Original abstract

Objectives: To test the survival rates, and the technical and biological complication rates of customized zirconia and titanium abutments 5 years after crown insertion.

Materials and methods: Twenty-two patients with 40 single implants in maxillary and mandibular canine and posterior regions were included. The implant sites were randomly assigned to zirconia abutments supporting all-ceramic crowns or titanium abutments supporting metal-ceramic crowns. Clinical examinations were performed at baseline, and at 6, 12, 36 and 60 months of follow-up. The abutments and reconstructions were examined for technical and/or biological complications. Probing pocket depth (PPD), plaque control record (PCR) and Bleeding on Probing (BOP) were assessed at abutments (test) and analogous contralateral teeth (control). Radiographs of the implants revealed the bone level (BL) on mesial (mBL) and distal sides (dBL). Data were statistically analyzed with nonparametric mixed models provided by Brunner and Langer and STATA ($P < 0.05$).

Results: Eighteen patients with 18 zirconia and 10 titanium abutments were available at a mean follow-up of 5.6 years (range 4.5–6.3 years). No abutment fracture or loss of a reconstruction occurred. Hence, the survival rate was 100% for both. Survival of implants supporting zirconia abutments was 88.9% and 90% for implants supporting titanium abutments. Chipping of the veneering ceramic occurred at three metal-ceramic crowns supported by titanium abutments. No significant differences were found at the zirconia and titanium abutments for PPD (mean PPD ZrO_2 3.3 ± 0.6 mm, mPPD Ti 3.6 ± 1.1 mm), PCR (mPCR ZrO_2 0.1 ± 0.3, mPCR Ti 0.3 ± 0.2) and BOP (mBOP ZrO_2 0.5 ± 0.3, mBOP Ti 0.6 ± 0.3). Moreover, the BL was similar at implants supporting zirconia and titanium abutments (mBL ZrO_2 1.8 ± 0.5, dBL ZrO_2 2.0 ± 0.8; mBL Ti 2.0 ± 0.8, dBL Ti 1.9 ± 0.8).

Conclusions: There were no statistically or clinically relevant differences between the 5-year survival rates, and the technical and biological complication rates of zirconia and titanium abutments in posterior regions.

Nobel Biocare CAD/CAM abutments – overview of studies

The following overview groups clinical studies with NobelProcera and Procera Abutments according to follow-up time. Studies on third-party implants are separated. Within each group, the studies are listed alphabetically.

Only peer-reviewed clinical studies are listed. Abstracts, reviews, single case reports, technique descriptions, and animal and *in vitro* tests are excluded.

For more information on these studies visit PubMed at www.pubmed.gov

Reference	Follow-up time	Implant type	Study type	Indication/study focus	Number of patients	Number of implants	CSR implants %*	Number of abutments	Abutment material	Survival abutments %
Study follow-up time >5 years										
Calandriello R, Tomatis M (2011). Clin Implant Dent Relat Res 13: 311-318.	5 years	Brånemark System Mk III	Prospective Multicenter Single arm	Single lower molars Immediate loading	33	40	95	40	nr	100
Zembic A, Bosch A, Jung RE, Hammerle CH, Sailer I (2013). Clin Oral Implants Res 24: 384-390. *Zembic A, Sailer I, Jung RE, Hammerle CH (2009). Clin Oral Implants Res 20: 802-808.* *Sailer I, Zembic A, Jung RE, Siegenthaler D, Holderegger C, Hammerle CH (2009). Clin Oral Implants Res 20: 219-225.*	5 years	Brånemark System	Prospective Monocenter Randomized controlled	Canine and posterior maxilla and mandible Single tooth Delayed loading	22	40	89.3	40	Zirconia and titanium	100
Study follow-up time >1 to <5 years										
Calandriello R, Tomatis M (2005). Clin Implant Dent Relat Res 7 Suppl 1: S1-12	1–4 years	Brånemark System Mk IV Replace Select	Prospective Monocenter Single arm	Atrophic posterior maxilla Immediate/early loading Axial and tilted implants Flap and flapless surgery Partial and full-arch prosthesis	18	60	96.7	19	Titanium	nr
den Hartog L, Meijer HJ, Stegenga B, Tymstra N, Vissink A, Raghoebar GM (2011). Clin Oral Implants Res 22: 1289-1297. *den Hartog L, Raghoebar GM, Slater JJ, Stellingsma K, Vissink A, Meijer HJ (2013). Clin Implant Dent Relat Res 15: 311-321.*	18 months	NobelPerfect NobelReplace and Replace Select Tapered	Prospective Monocenter Randomized controlled	Single anterior crowns in the maxilla Healed sites 2-stage surgery Minimally invasive Comparison of neck design	93	93	98.9	93	Zirconia and titanium	100
den Hartog L, Raghoebar GM, Stellingsma K, Vissink A, Meijer HJ (2011). J Clin Periodontol 38: 186-194.	18 months	NobelReplace Tapered	Prospective Monocenter Randomized controlled	Single anterior crowns in the maxilla Healed sites Immediate vs delayed loading 2-stage vs. 1-stage surgery Minimally invasive	62	62	98.4	62	Zirconia	100
Ekfeldt A, Furst B, Carlsson GE (2011). Clin Oral Implants Res 22: 1308-1314.	3–5 years	Brånemark System Mk III and IV Replace Select	Retrospective (part 1) and cross-sectional subgroup (part 2) Monocenter	Maxilla and mandible Early and delayed loading Soft tissue 2-stage and 1-stage surgery Directly veneered abutments and crowns	130	187	99	185	Zirconia	99
Meloni SM, De Riu G, Pisano M, De Riu N, Tullio A (2012). Eur J Oral Implantol 5: 345-353.	1.5 years	NobelReplace Tapered	Prospective Monocenter Randomized controlled Split mouth	Bilaterally missing first mandibular molars Immediate vs delayed loading Healed sites	20	40	100	40	Zirconia and titanium	nr

Reference	Follow-up time	Implant type	Study type	Indication/study focus	Number of patients	Number of implants	CSR implants %*	Number of abutments	Abutment material	Survival abutments %
Pozzi A, Sannino G, Barlattani A (2012). J Prosthet Dent 108: 286-297.	43.3 months (mean, range 36–54 months)	NobelSpeedy	Prospective Monocenter Single arm	Atrophic posterior maxilla Partial prosthesis Immediate loading Axial and tilted implants Extraction and healed sites Minimally invasive NobelGuide	27	81	96.3	81	Zirconia and titanium	100
Rao W, Benzi R (2007). J Prosthet Dent 97: S3-S14.	1–3 years	Replace Select Tapered	Prospective Monocenter Single arm	Molar single crowns in the mandible Immediate loading Minimally invasive Flapless surgery NobelGuide	46	51	100	51	nr	100
Study follow-up time 1 year										
Kutkut A, Abu-Hammad O, Mitchell R (epub ahead 2013). Journal of Oral Implantology.	1 year	nr	Monocenter Single arm Consecutive case series	Single tooth Esthetics and soft tissue Delayed loading	50	50	100	50	Zirconia and titanium	100
Pozzi A, Agliardi E, Tallarico M, Barlattani A (epub ahead 2012). Clin Implant Dent Relat Res.	1 year	NobelActive NobelSpeedy Groovy	Prospective Randomized controlled Split mouth	Partially edentulous Soft tissue health Delayed loading	34	88	100	88	Titanium	100
Raghoebar GM, Slater JJ, Hartog L, Meijer HJ, Vissink A (2009). Int J Oral Maxillofac Surg 38: 736-743.	1 year	NobelReplace	Prospective Monocenter Single arm	Single tooth Healed sites Connective tissue grafting 2-stage surgery Delayed loading	45	45	100	45	Zirconia	100
Tallarico M, Vaccarella A, Marzi GC (2011). Eur J Oral Implantol 4: 13-20.	1 year	Brånemark System Mk III NobelSpeedy Groovy	Prospective Monocenter Randomized controlled	Mandible and maxilla Single crowns and fixed partial dentures 1-stage vs 2-stage surgery Delayed loading	47	89	97.8	60	Titanium	nr
Tymstra N, Raghoebar GM, Vissink A, Den Hartog L, Stellingsma K, Meijer HJ (2011). J Clin Periodontol 38: 74-85.	1 year	NobelPerfect NobelReplace	Prospective Monocenter Randomized controlled	Anterior maxilla Comparison of implant designs 2-stage surgery Delayed loading	40	80	100	80	Zirconia and titanium	nr
Tymstra N, Raghoebar GM, Vissink A, Meijer HJ (2011). Clin Oral Implants Res 22: 207-213.	1 year	NobelReplace Tapered	Prospective Monocenter Randomized controlled	Anterior maxilla Comparison of 2 implants vs. 1 implant and cantilever 2-stage surgery Delayed loading	10	15	100	15	Zirconia	100
Urban T, Kostopoulos L, Wenzel A (2012). Clin Oral Implants Res 23: 1389-1397.	1 year	Brånemark System Mk III	Prospective Randomized controlled	Single molar crowns Immediate placement Bone grafting 2-stage surgery	92	92	83.7	77	Titanium	100
Nobel Biocare abutments on third-party implant systems										
Khzam N, Mattheos N, Roberts D, Bruce WL, Ivanovski S (epub ahead 2014). Journal of Esthetic and Restorative Dentistry	12–37 months	Astra Tech	Case series	Extraction sites Immediate loading Single tooth Soft tissue Flapless surgery	13	15	100	15	Zirconia	nr
Vigolo P, Givani A, Majzoub Z, Cordioli G (2006). J Prosthodont 15: 250-256.	4 years	Biomet 3i	Prospective Monocenter Randomized controlled Split mouth	Single crown Bilateral edentulous sites Gold alloy vs titanium abutments 2-stage surgery	20	20	100	20	Titanium	100

nr: not reported
* If the CSR is not reported separately in the study, the percentage of surviving implants was calculated.

Nobel Biocare CAD/CAM implant bridges – scientific evidence

Nobel Biocare implant-retained bridges offer optimum flexibility with documented long-term clinical success. Use of titanium or zirconia instead of conventional casting alloys introduces materials of higher strength and biocompatibility, and leads to fewer biological and technical complications and a longer prosthetic survival. In addition, industrial manufacturing enables production of frameworks from single blocks. This avoids local weakening due to welding procedures.

Key findings of the clinical studies are: Nobel Biocare CAD/CAM implant bridges show excellent survival rates between 93% and 100% after up to 10 years, with most studies demonstrating 100% survival (see extended table following this chapter). In addition, technical and biological complications are low:
- Only 1% to 3% of final restorations fractured as reported in six studies with up to 10 years of follow-up.[26,78,82–85] Fractures of provisional restorations occurred in 2% to 20% of restorations as reported in eleven studies with up to 5 years of follow-up.[82,83,85–93]
- Porcelain chipping, including minor events, is reported in eight studies (range 4% to 48% in up to 10 years of follow-up).[41,78,79,81,82,90,94,95]
- Peri-implantitis is reported in only two studies, occurring in 4 out of 81 patients (4.9%).[82,83]

Nobel Biocare CAD/CAM implant bridges also demonstrate high patient satisfaction with regard to function and esthetics:
- Esthetics, phonetics and mastication are assessed by three studies. According to the returned patient questionnaires, the respective outcomes were considered excellent or very good by 83%, 73%, and 91% of patients with edentulous mandibles, and 83.4%–87.5%, 87.5%–91.7%, and 75%–90.6% of patients with edentulous maxillae.[96–98]
- Two studies, with a total of 212 patients treated for maxillary or mandibular edentulism with the All-on-4® treatment concept and NobelProcera or Procera Implant Bridges, report no esthetic or functional (phonetic, masticatory, comfort, hygienic) complaints.[85,99]
- One study evaluating patient satisfaction on a visual analog scale (VAS) reports an esthetic VAS score of 98.1% and a functional VAS score of 95.5% after 3 years of function.[81]

Excellent precision of fit

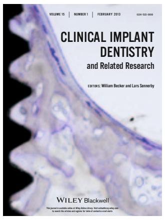
Three-dimensional evaluation of passive fit, made possible by using industrial non-contact scanners, reveals that NobelProcera Implant Bridges provide superior precision of fit when compared with conventional cast restorations ($P < 0.001$).[100] A fit assessment of contacting surfaces indicates shrinkage towards the pontic site in conventional casts, whereas NobelProcera restorations show equal circumferential fit. Interestingly, these differences between manufacturing techniques were not found when the total surface areas were analyzed, which emphasizes the need for a detailed analysis of component congruence.

High survival of Nobel Biocare CAD/CAM implant bridges in long-term clinical follow-up

Study	Study follow-up	Material	Survival
Ortorp 2012[78]	10 years	Ti	95.6%
Jemt 2011[26]	5 years	Ti	100%
Malo 2011[79]	5 years	Ti+ Zi (crowns only)	98.6%
Pettersson 2013[80]	5 years	Ti+ Zi (crowns only)	100%
Pozzi 2013[81]	5 years	Zi	100%

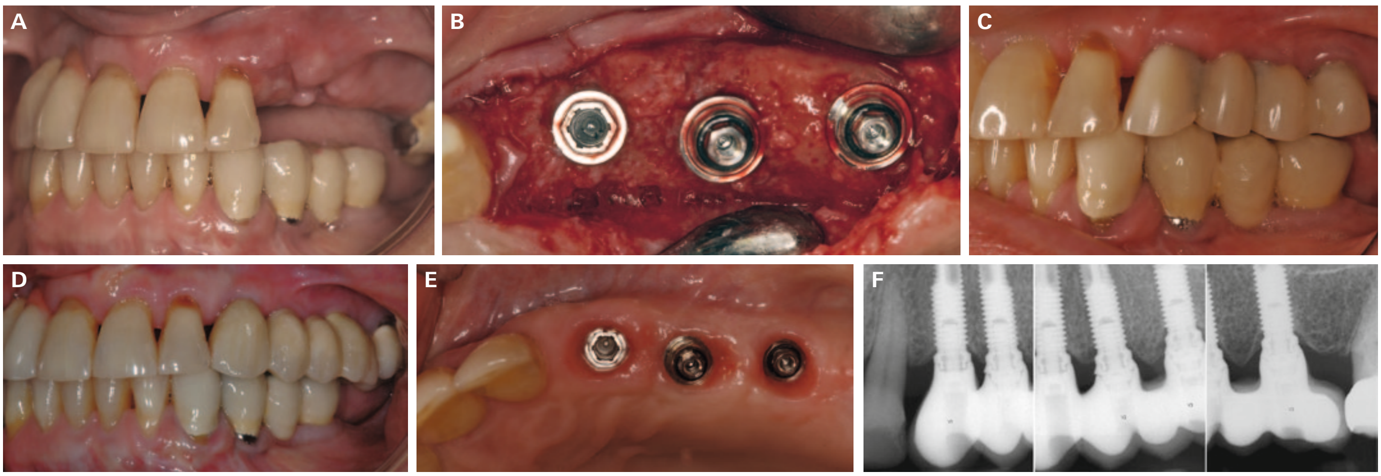
Zr: zirconia
Ti: titanium

List includes all studies on NobelProcera and Procera Implant Bridges with a minimum of 5 years' follow-up and reporting restoration survival rates.



Immediately Loaded Implants with or without Abutments Supporting Fixed Partial Dentures: 1-Year Results from a Prospective, Randomized, Clinical Trial

Göthberg C, André U, Gröndahl K, Ljungquist B, Thomsen P, Slotte C,
Clin Implant Dent Relat Res. Epub ahead 2013



Clinical and radiographic images from a representative test patient. A. Preoperative view. B. Three implants placed in the left maxilla. C. Temporary fixed prosthesis placed 2 days after surgery. D. Permanent fixed prosthesis placed 6 months after surgery. E. Soft tissue appearance at 1-year follow-up. F. Intra-oral radiographs at 1-year follow-up (composite image)

Original abstract

Purpose: To evaluate 1-year implant survival and marginal bone loss around implants that support fixed partial dentures loaded immediately or after 3 months, and effects from abutment usage.

Materials and methods: In this 2005 to 2009 randomized, parallel-group, clinical trial, 50 partially edentulous patients each received three Brånemark TiUnite implants (Nobel Biocare, Göteborg, Sweden), mostly in the posterior maxilla. Two implants were fitted with abutments: a TiUnite surface and a machine-milled surface; the suprastructure was attached directly at implant level for the third implant. After randomized allocation, implants were immediately loaded with a fixed temporary bridge (test group) or left unloaded for 3 months (control group). A permanent fixed suprastructure replaced the temporary bridge after 6 months (test). Hard and soft tissues were examined during pretreatment and surgery plus 2 days, 14 days, 4 weeks, 3 months, and 1 year after surgery.

Results: After 1 year, four implants were lost in the test and two in the control groups (1-year survival rates of 94.9% [test] and 97.2% [control], with no significant intergroup difference). Resonance frequency analysis values indicated a similar pattern in both groups, with implant stability quotient (ISQ) reduction between 2 and 4 weeks. The test group had a significantly lower ISQ than the control group at these appointments. After 1 year, marginal bone losses around the implants were, on average, 1.32 mm (test, standard error of the mean [SEM] 0.08) and 1.24 mm (control, SEM 0.08), with no significant intergroup difference. Significantly larger marginal bone loss was observed at implants without abutment compared with implants with abutment.

Conclusions: For both groups, this study showed similar implant survival rates and marginal bone loss. Larger bone loss was found at implants loaded without attached abutments.

Nobel Biocare CAD/CAM implant bridges – overview of studies

The following overview groups clinical studies with NobelProcera and Procera Implant Bridges according to follow-up time. Within each group, the studies are listed alphabetically.

Only peer-reviewed clinical studies are listed. Abstracts, reviews, single case reports, technique descriptions, and animal and *in vitro* tests are excluded.

For more information on these studies visit PubMed at www.pubmed.gov

Reference	Follow-up time	Restoration and implant type	Study type	Indication/study focus	Number of patients/ implants	Number of restorations or abutments	Restoration material	Survival rate restoration / implants %*
Study follow-up time at least 5 years								
Jemt T, Stenport V (2011). Int J Prosthodont 24: 356-362. *Jemt T, Stenport V, Friberg B (2011). Int J Prosthodont 24: 345-355.*	5 years	Procera 10-units Brånemark System	Retrospective 2 cohorts Monocenter	Gold alloy vs Procera Maxilla Healed sites 2-stage surgery Delayed loading	109 / 670	109	Titanium Veneering: resin teeth	100 / 97.3
Malo P, Nobre M, Lopes A (2011). Eur J Oral Implantol 4: 227-243.	5 years	Procera full-arch Multi-unit Abutments Brånemark System Mk III and Mk IV NobelSpeedy Groovy	Retrospective Monocenter Single arm	Fully edentulous maxilla All-on-4® Immediate loading Minimally invasive	221 / 995	221	Titanium Veneering: acrylic or Procera Crown Zirconia with NobelRondo	98.6 / 95.8
Örtorp A, Jemt T (2012). Clin Implant Dent Relat Res 14: 88-99. *Örtorp A, Jemt T (2004). Clin Implant Dent Relat Res 6: 199-209.* *Örtorp A, Jemt T (2002). Clin Implant Dent Relat Res 4: 104-109.* *Örtorp A, Jemt T (2000). Clin Implant Dent Relat Res 2: 2-9.*	10 years	Procera full-arch Abutments: standard, EsthetiCone, angulated Brånemark System Mk II	Prospective Monocenter Comparative	Edentulous maxilla and mandible Delayed loading Comparison of frameworks	65 / 367	67	Titanium Veneering: resin teeth	10 years: 95.6 / 95.0 5 years: 98.3 / 95.0 3 years: 98.3 / 95.3 1 year: 100 / 97.8
Pettersson P, Sennerby L (epub ahead 2013). Clin Implant Dent Relat Res	5 years	Procera partial and full-arch Procera copings Esthetic and angulated abutments Replace Select Tapered	Retrospective Monocenter Single arm	Fully and partially edentulous Healed and extraction sites Immediate and delayed loading	88 / 271	121	Titanium Zirconia (crowns only)	100 / 99.6
Pozzi A, Tallarico M, Barlattani A (epub ahead 2013). Journal of Oral Implantology.	5 years	NobelProcera full-arch Non-engaging abutments NobelSpeedy Groovy NobelSpeedy Replace NobelActive	Prospective Monocenter Single arm	Edentulous Flapless and mini-flap NobelGuide Immediate loading	16 / 132	18	Zirconia IPS e.max crowns	100 / 100
Sanna AM, Molly L, van Steenberghe D (2007). J Prosthet Dent 97: 331-339.	5 years	Procera full-arch Guided abutments Brånemark System TiUnite	Retrospective Monocenter Single arm	Edentulous Flapless NobelGuide Immediate loading	30 / 212	30	Titanium Veneering: resin	nr / 91.5

Reference	Follow-up time	Restoration and implant type	Study type	Indication/study focus	Number of patients/ implants	Number of restorations or abutments	Restoration material	Survival rate restoration / implants %*
Study follow-up time at least 3 years and < 5 years								
Agliardi EL, Pozzi A, Stappert CF, Benzi R, Romeo D, Gherlone E (epub ahead 2012). Clin Implant Dent Relat Res.	55.53 months (36–78)	Procera full-arch Multi-unit Abutments NobelSpeedy Groovy Brånemark System Mk IV	Prospective Monocenter Single arm	Edentulous maxilla Axial and tilted implants Extraction and healed sites Immediate Function Minimal invasive	32 / 192	48	Titanium	100 / 99.0
Calandriello R, Tomatis M (2005). Clin Implant Dent Relat Res 7 Suppl 1: S1-12.	1–4 years	Procera partial and full-arch, and others Angulated and Procera abutments Brånemark System Mk IV Replace Select	Prospective Monocenter Single arm	Atrophic posterior maxilla Immediate/early function Axial and tilted implants Flap and flapless	18 / 60	19	Titanium	100 / 96.7
Cavalli N, Barbaro B, Spasari D, Azzola F, Ciatti A, Francetti L (epub ahead 2012). Int J Dent.	38.8 months (12–73)	Procera full-arch Multi-unit Abutments NobelSpeedy Groovy Brånemark System Mk IV	Retrospective Monocenter Single arm	Edentulous maxilla All-on-4® Immediate loading	34 / 136	34	Titanium	100 / 100
Francetti L, Romeo D, Corbella S, Taschieri S, Del Fabbro M (2012). Clin Implant Dent Relat Res 14: 646-654.	52.8 (mandible), 33.8 (maxilla) months (22–66)	Procera full-arch Multi-unit Abutments NobelSpeedy Groovy Brånemark System Mk IV	Prospective Two centers Single arm	Edentulous maxilla and mandible All-on-4® Immediate loading Minimal invasive Soft tissue health Healed and extraction sites	47 / 196	49	nr	100 / 100
Malo P, de Araujo Nobre M, Lopes A, Ferro A, Moss S (epub ahead 2013). Clin Implant Dent Relat Res.	0.5–7 years	NobelProcera full-arch Brånemark System Zygoma NobelSpeedy Groovy	Retrospective Monocenter Single arm	Edentulous atrophic maxilla Extra-maxillary technique All-on-4® Immediate loading	352 / 1542	352	Titanium Veneering: acrylic or all-ceramic crowns with NobelRondo	99.7 / 98.2
Malo P, de Araujo Nobre M, Lopes A, Francischone C, Rigolizzo M (2012). Clin Implant Dent Relat Res 14 Suppl 1: e139-150.	3–5 years	Procera full-arch Multi-unit Abutments Brånemark System Mk III and Mk IV NobelSpeedy Groovy	Retrospective Monocenter Single arm	Edentulous maxilla All-on-4® Immediate loading Minimally invasive	242 / 968	242	Titanium Veneering: acrylic or all-ceramic crowns with NobelRondo	100 / 98.0
Malo P, Nobre M, Lopes A (2013). Eur J Oral Implantol 6: 273-283.	3 years	NobelProcera full-arch NobelSpeedy Groovy NobelSpeedy Replace	Retrospective Monocenter Single arm	Edentulous atrophic maxilla All-on-4® Immediate loading	70 / 280	70	Titanium Veneering: acrylic or all-ceramic crowns with NobelRondo	100 / 98.2
Malo P, Nobre M, Lopes A, Francischone C, Rigolizzo M (2012). Eur J Oral Implantol 5: 37-46. *Malo P, Nobre Mde A, Lopes I (2008). J Prosthet Dent 100: 354-366.*	3 years 1 year	NobelProcera full-arch Multi-unit Abutments Brånemark System Zygoma and others	Retrospective Monocenter Single arm	Edentulous atrophic maxilla Extra-maxillary technique All-on-4® Immediate loading	39 / 169	39	Titanium Veneering: acrylic or all-ceramic crowns with NobelRondo	100 / 100
Moberg LE, Kondell PA, Sagulin GB, Bolin A, Heimdahl A, Gynther GW (2001). Clin Oral Implants Res 12: 450-461.	3 years	Procera full-arch and others Brånemark System and others	Prospective Monocenter Randomized controlled	Edentulous mandible 2-stage vs 1-stage Comparison of systems Delayed loading	20 / 102	20	Titanium	100 / 97.9

nr: not reported
* If the survival rate is not reported separately in the study, the percentage of surviving implants / restorations was calculated.

Reference	Follow-up time	Restoration and implant type	Study type	Indication/study focus	Number of patients/ implants	Number of restorations or abutments	Restoration material	Survival rate restoration / implants %*
Papaspyridakos P, Lal K (2013). Clin Oral Implants Res 24: 659-665.	3 years (2–4)	Procera full-arch Implant leve	Prospective Monocenter	Edentulous maxilla and mandible Flapless NobelGuide	14 / 103	16	Zirconia Veneering: porcelain	100 / 100
Pozzi A, Holst S, Fabbri G, Tallarico M (epub ahead 2013). Clin Implant Dent Relat Res.	42.3 months (3–5 years)	NobelProcera full-arch Non-engaging abutments NobelSpeedy Groovy NobelSpeedy Replace NobelActive NobelReplace Tapered	Retrospective Monocenter Single arm	Edentulous maxilla and mandible Soft tissue health Healed and extraction sites	22 / 170	26	Zirconia Veneering: Noritake Cerabien	100 / 100
Sjostrom M, Sennerby L, Nilson H, Lundgren S (2007). Clin Implant Dent Relat Res 9: 46-59.	3 years	Procera full-arch Standard and angulated abutments Brånemark System	Prospective Monocenter Single arm	Edentulous atrophic maxilla Bone grafting 2-stage surgery Delayed loading	25 / 192	25	Titanium	nr / 90.0
Study follow up time < 3 years								
Agliardi E, Clerico M, Ciancio P, Massironi D (2010). Quintessence Int 41: 285-293.	30.1 months (19–47)	Procera full-arch Multi-unit Abutments NobelSpeedy Groovy Brånemark System Mk IV	Prospective Single cohort Single arm	Edentulous atrophic mandible All-on-4® Immediate loading	24 / 96	24	Titanium	100 / 100
Agliardi E, Panigatti S, Clerico M, Villa C, Malo P (2010). Clin Oral Implants Res 21: 459-465.	26.9 months (4–59)	Procera full-arch Multi-unit Abutments NobelSpeedy Groovy Brånemark System Mk IV	Prospective Single cohort Single arm	Edentulous maxilla and mandible All-on-4® Immediate loading Soft tissue	173 / 692	154	nr	100 / 99.2
Agliardi EL, Francetti L, Romeo D, Del Fabbro M (2009). Int J Oral Maxillofac Implants 24: 887-895.	27.2 months (18–42)	Procera full-arch Multi-unit Abutments NobelSpeedy Groovy Brånemark System Mk IV	Prospective Single cohort Single arm	Edentulous maxilla Immediate loading Soft tissue Extraction and healed sites Straight and angulated implants	20 / 120	20	nr	100 / 100
Engquist B, Astrand P, Anzen B, Dahlgren S, Engquist E, Feldmann H, Karlsson U, Nord PG, Sahlholm S, Svardstrom P (2002). Clin Implant Dent Relat Res 4: 93-103. *Engquist B, Astrand P, Anzen B, Dahlgren S, Engquist E, Feldmann H, Karlsson U, Nord PG, Sahlholm S, Svardstrom P (2004). Clin Implant Dent Relat Res 6: 90-100.*	1 year	Procera full-arch Abutment and implant level Brånemark System	Prospective Bi-center Comparative	Edentulous mandible 4 implants per jaw Delayed vs early loading 1-stage vs 2-stage surgery	108 / 432	108	Titanium Veneering: acrylic	93.0 / 94.4
Francetti L, Agliardi E, Testori T, Romeo D, Taschieri S, Fabbro MD (2008). Clin Implant Dent Relat Res 10: 255-263.	22.4 months (6–43)	Procera full-arch Multi-unit Abutments NobelSpeedy Groovy Brånemark System Mk IV	Prospective Single cohort Single arm	Edentulous mandible All-on-4® Immediate loading Minimally invasive Soft tissue Healed and extraction site	62 / 248	62	nr	100 / 100
Friberg B, Jemt T (2010). Clin Implant Dent Relat Res 12 Suppl 1: e56-62.	1 year	Procera full-arch Brånemark System Mk III and Mk IV	Retrospective Monocenter Single arm	Edentulous mandible 4 implants per jaw 1-stage surgery Early loading	75 / 300	75	Titanium Veneering: resin	98.5 / 98.5
Fröberg KK, Lindh C, Ericsson I (2006). Clin Implant Dent Relat Res 8: 187-197.	18 months	Procera full-arch Brånemark System Mk III	Prospective Comparative Split mouth	Edentulous mandible Machined vs TiUnite Immediate loading	15 / 89	15	Titanium	100 / 100

Reference	Follow-up time	Restoration and implant type	Study type	Indication/study focus	Number of patients/ implants	Number of restorations or abutments	Restoration material	Survival rate restoration / implants %*
Galindo DF, Butura CC (2012). Int J Oral Maxillofac Implants 27: 628-633.	1 year	Procera full-arch Multi-unit Abutments NobelSpeedy Groovy NobelActive	Retrospective Single center Single arm	Edentulous mandible All-on-4® Immediate loading	183 / 732	183	Titanium	98.9 / 99.9
Gillot L, Noharet R, Cannas B (2010). Clin Implant Dent Relat Res 12 Suppl 1: e104-113.	12–51 months	Procera full-arch Guided and Multi-unit Abutments NobelSpeedy Groovy Brånemark System Mk IV	Retrospective Single cohort Single arm	Edentulous maxilla Immediate loading Minimally invasive NobelGuide	33 / 211	33	Titanium	100 / 98.1
Gothberg C, Andre U, Grondahl K, Ljungquist B, Thomsen P, Slotte C (epub ahead 2013). Clin Implant Dent Relat Res.	1 year	Procera 3–4 units Implant and Multi-unit Abutment level Brånemark System Mk III	Prospective Randomized controlled Monocenter	Partially edentulous Soft tissue Immediate vs. delayed loading	50 / 150	50	Titanium	nr / 97.3
Johansson B, Friberg B, Nilson H (2009). Clin Implant Dent Relat Res 11: 194-200.	1 year	Procera full-arch Guided abutments Brånemark System Mk III	Prospective Multicenter Single arm	Edentulous maxilla Immediate loading Minimally invasive NobelGuide Flapless	52 / 312	52	Titanium Veneering: acrylic	96.2 / 99.4
Katsoulis J, Brunner A, Mericske-Stern R (2011). Int J Oral Maxillofac Implants 26: 648-656.	2 years	Procera full-arch and others Implant level Replace Select Tapered	Prospective Comparative Monocenter	Edentulous maxilla Bar vs fixed framework Maintenance NobelGuide	25 / 124	25	Titanium Overdenture vs wrap-around	100 / 100
Kohal RJ, Patzelt SBM, Sahlin H, Butz F (2013). J Clin Periodontol 40: 553–562.	1 year	Procera 3 units Zirconia implants	Prospective Monocenter Single arm	Maxilla and mandible Anterior and posterior Healed and extraction sites	28 / 56	28	Zirconia Veneering: NobelRondo	100 / 98.2
Kronström M, Widbom T, Löfquist LE, Henningson C, Widbom C, Lundberg T (2003). J Prosthet Dent 89: 335-340.	1 year	Procera full-arch Brånemark System	Prospective Monocenter	Edentulous mandible 4 implants Early loading 1-stage surgery Healed sites	17 / 68	17	Titanium Veneering: resin teeth	94.1 / 93.0
Lindh T, Back T, Nystrom E, Gunne J (2001). Clin Oral Implants Res 12: 441-449	2 years	Procera Implant Bridge and copings Abutments: standard, EsthetiCone, angulated Brånemark System Mk II	Prospective Monocenter Comparative Split mouth	Posterior maxilla Fixed partial dentures Implant-supported vs mixed supported 2-stage surgery Delayed loading	26 / 95	52	Titanium Veneering: Procera Titanporslin	100 / 88.0
Malo P, de Araujo Nobre M, Lopes A, Rodrigues R (epub ahead 2013). Clin Implant Dent Relat Res.	0.5–2 years	NobelProcera full-arch Multi-unit Abutments Brånemark System Mk III and Mk IV NobelSpeedy Groovy	Prospective Monocenter Single arm	Edentulous maxilla and mandible Tilted implants Immediate loading	16 / 68	17	Titanium Veneering: acrylic or all-ceramic crowns with NobelRondo	100 / 100
Malo P, Nobre Mde A, Lopes A (2012). Int J Oral Maxillofac Implants 27: 1177-1190.	2 years (1–107 months)	Procera full-arch Multi-unit Abutments Brånemark System Mk III and Mk IV NobelSpeedy Groovy	Prospective Monocenter Single arm	Edentulous maxilla and mandible Immediate loading All-on-4®	142 / 227	142	Titanium Veneering: acrylic or crowns with NobelRondo	100 / 96.9
Meloni SM, De Riu G, Pisano M, Cattina G, Tullio A (2010). Eur J Oral Implantol 3: 245-251.	1.5 years	Procera full-arch NobelReplace Tapered	Prospective Monocenter Single arm	Edentulous maxilla Immediate loading Minimally invasive NobelGuide	15 / 90	15	Titanium or zirconia Veneering: ceramic or resin	100 / 97.8

nr: not reported
* If the survival rate is not reported separately in the study, the percentage of surviving implants / restorations was calculated.

Reference	Follow-up time	Restoration and implant type	Study type	Indication/study focus	Number of patients/ implants	Number of restorations or abutments	Restoration material	Survival rate restoration / implants %*
Olsson M, Urde G, Andersen JB, Sennerby L (2003). Clin Implant Dent Relat Res 5 Suppl 1: 81-87.	1 year	Procera full-arch Multi-unit Abutments Brånemark System Mk III Brånemark System Mk IV	Prospective case series	Edentulous maxilla Early loading	10 / 61	10	nr	100 / 93.4
Tallarico M, Vaccarella A, Marzi GC (2011). Eur J Oral Implantol 4: 13-20.	1 year	Procera Implant Bridge, Abutment and Crowns Brånemark System Mk III NobelSpeedy Groovy	Prospective Monocenter Randomized controlled	Maxilla and mandible Single crowns and partial fixed dentures 1- vs 2-stage surgery Delayed loading	47 / 89	60	Titanium Veneering: ceramic	100 / 97.8
Weinstein R, Agliardi E, Fabbro MD, Romeo D, Francetti L (2012). Clin Implant Dent Relat Res 14: 434-441.	30.1 months (20–40)	Procera 10 units Multi-unit Abutments Brånemark System Mk IV NobelSpeedy Groovy	Prospective Two centers Single arm	Edentulous mandible All-on-4® Immediate loading	20 / 80	20	nr	100 / 100

nr: not reported
* If the survival rate is not reported separately in the study, the percentage of surviving implants / restorations was calculated.

Nobel Biocare CAD/CAM implant bars – scientific evidence

Nobel Biocare CAD/CAM implant bars offer an important improvement in bar retention technology by allowing the use of high-quality materials together with the high accuracy of industrial manufacturing. Compared with gold bars, they provide a higher precision of fit and a striking improvement in performance for the patient.

Bar-retained overdentures

Bar retention, the option closest to a fixed prosthesis, provides edentulous patients with improved function, facial esthetics and comfort, as well as improved nutrition, psychosocial status and quality of life. However, gold bars, though currently considered standard in the industry due to several decades of clinical follow-up, are plagued by technical complications and lead to suboptimal survival rates of both implants and prostheses.

Key findings of clinical studies with Nobel Biocare CAD/CAM implant bars are:
– High survival rates of implants and restorations (100%).[27,101]
– Restorations are associated with stable peri-implant crestal bone levels.[28]
– Significantly fewer technical and biological complications in comparison with conventional cast frameworks.[27,28]
– High patient satisfaction.[27]

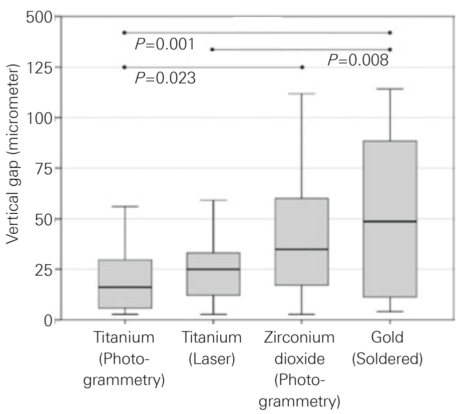
Better options for an individualized design

CAD/CAM technology allows the use of higher quality materials and increases the accuracy of the industrially manufactured components. In an *in vitro* comparison, the precision of fit of NobelProcera Implant Bars Overdenture was significantly higher than that observed with soldered gold bars.[102]

Significant improvement in quality of life

In a multicenter study, preliminary results on 14 patients from two centers evaluating NobelProcera Implant Bars Overdenture loaded with the final prosthesis no later than three months after implant placement show significant improvements in quality of life.[101] OHIP-21 scores improved both from pre-treatment assessment to prosthetic loading and at 6-month follow-up ($P<0.001$). The authors conclude that overdentures on milled titanium bars are a successful treatment.

High precision of fit with NobelProcera Implant Bars



Vertical micro gap measured *in vitro* for titanium bars produced with a photogrammetric and a laser scanner is lower than soldered gold bars or zirconium dioxide bars, indicating a high precision of fit of NobelProcera CAD/CAM design (titanium laser).[102]

High patient satisfaction

Individualized NobelProcera Implant Bar Overdenture on four implants after 6 months. In this study, patient satisfaction at 6 months after implant insertion (scale 1–10) was high for retention (9), speaking (8.6), esthetics (9) and overall (8.5).[101]

Courtesy of Dr. M. Stocchero, University of Padova, Italy

Low complication rates

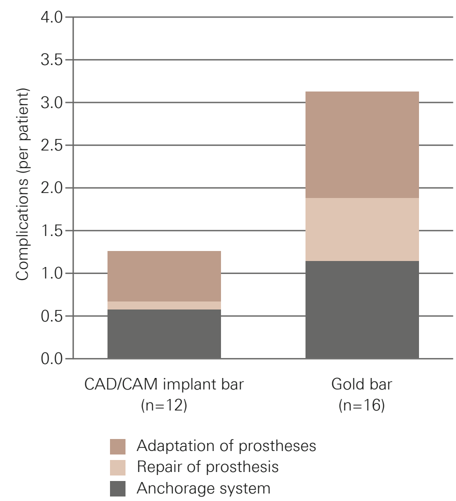
Unlike gold bars, Nobel Biocare CAD/CAM implant bars do not have solder joints and do not require high heat during the manufacturing process (high heat can reduce the technical performance of the material). Combined with higher precision, these characteristics lead to superior clinical performance. In a controlled clinical trial in patients with an edentulous maxilla, NobelProcera Implant Bars Overdenture experienced significantly fewer complications than gold bars.[27]

Another striking advantage of CAD/CAM implant bars as opposed to gold bars is that the patients experience a significantly lower rate of gingival hyperplasia (8% vs. 65% of patients).[27] This finding can most likely be attributed to the quality of the material and the individualized design. The authors conclude that CAD/CAM implant bars "had individual heights and followed the mucosal contour continuously in light contact, whereas the prefabricated gold bars were partly in contact with the mucosa and partly exhibited a gap of several millimeters, which might have favored tissue overgrowth."[27]

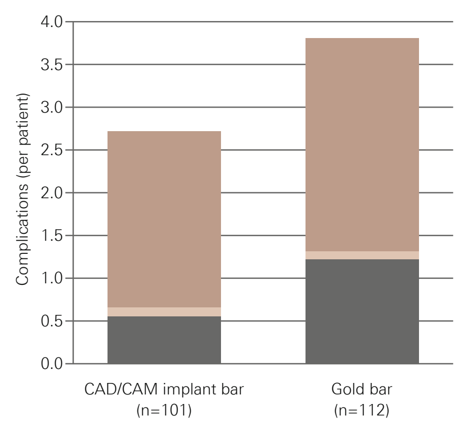
Nobel Biocare CAD/CAM implant bars also deliver superior performance in the mandible.[28] Analysis of data from 213 edentulous patients followed up over 3 to 4 years reveals that they have lower fracture rates of bar extensions and matrices when compared with standard gold bars (4.7% vs. 14.8%, $P<0.001$; and 1% vs. 13%, $P<0.001$, respectively).

Fewer technical complications

Maxilla, 2-years' follow-up[27]



Mandible, 3-4 years' follow-up[28]



For fixed-removable solutions in the edentulous mandible and maxilla, Nobel Biocare CAD/CAM implant bars significantly reduce technical complications.[27,28]

Nobel Biocare CAD/CAM implant bars – overview of studies

The following overview lists clinical studies with Nobel Biocare CAD/CAM implant bars.

Only peer-reviewed clinical studies are listed. Reviews, single case reports, technique descriptions, and animal and *in vitro* tests are excluded.

For more information on these studies visit PubMed at www.pubmed.gov

Reference	Follow-up time	Implant type	Study type	Indication/ study focus	Number of patients	Number of implants	CSR implants %*	Number of restorations	Material	Survival restorations %
Katsoulis J, Walchli J, Kobel S, Gholami H, Mericske-Stern R (epub ahead 2013). Clin Implant Dent Relat Res.	3–4 years	Replace Select Tapered	Prospective Comparative Monocenter	Different types of bars Edentulous mandible Maintenance NobelGuide	101	231	nr	101	Titanium	nr
Katsoulis J, Brunner A, Mericske-Stern R (2011). Int J Oral Maxillofac Implants 26: 648-656.	2 years	Replace Select Tapered	Prospective Comparative Monocenter	Bar vs. fixed framework Edentulous maxilla Maintenance NobelGuide	25	124	100	25	Titanium	100
Stoccher, M, Sivolell S, Lops D, Ricci S, Bressan E, Romeo E (2015). Annual Meeting of the Academy of Osseointegration, San Francisco USA.	6 months	NobelReplace Conical Connection	Prospective Multicenter Single arm	Quality of life Patient satisfaction	14	56	100	14	Titanium	100

nr: not reported
* If the survival rate is not reported separately in the study, the percentage of surviving implants was calculated.

Nobel Biocare CAD/CAM crowns and bridges – scientific evidence

Nobel Biocare CAD/CAM crowns and bridges are all made of biocompatible materials and are characterized by excellent esthetics and high precision of fit.

Excellent clinical performance

Numerous studies reveal the high clinical reliability and safety of Nobel Biocare CAD/CAM restorations on teeth and implants. A recent retrospective survey with up to 7.4 years of follow-up on the long-term survival of posterior zirconia and porcelain-fused-to-metal crowns on teeth in private practice demonstrates a 100% survival rate for Procera Crowns.[103] The same outstanding survival rate is reported for crowns on abutments.[35,37–39,42,49,55] Finally, a clinical study with Procera Crowns and Bridges on teeth (2–13 units) in titanium demonstrates a 5-year survival rate of 99.6% for single crowns and 97.8% for bridges.[104]

High resistance to fractures

An *in vitro* study, in which extracted human teeth were extra-orally prepared and restored to evaluate the resistance to load of casted metal-ceramic and veneered all-ceramic Procera Crowns, demonstrates no significant difference in fracture strength. This was independent of whether the crowns were made of zirconia, alumina, or porcelain-veneered gold platinum alloy. Importantly, all fractures after loading occurred within the teeth and not the restorations.[22] An investigation into the strength of abutment-supported zirconia crowns shows that even abutment-grinding adjustments do not affect their appropriate fatigue resistance.[105] Other *in vitro* studies of Procera Bridges demonstrate that after an aging protocol the veneered all-ceramic bridges have the potential to withstand physiological occlusal forces applied in the posterior region.[14,17]

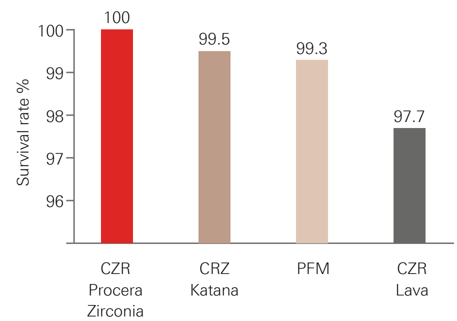
Predictable precision of fit

In vitro investigations demonstrate that Nobel Biocare CAD/CAM crowns and bridges are characterized by a high and predictable precision of fit. The mean marginal gap ranges are as follows: 30–83 µm for alumina crowns,[106–111] 8.7–44.2 µm for zirconia crowns,[10,112] 14–28 µm for titanium crowns,[113] 26–89 µm for zirconia bridges,[114,115] and 21.0–26.9 µm for titanium bridges.[116,117] This means all of the restorations demonstrate a clinically acceptable marginal gap size – suggested to be less than 120 µm.[118] Furthermore, a direct comparison reveals that the fit of Procera Crowns is significantly better than that of cast titanium, both before and after cementation. Importantly, cast titanium leads to marginal gap sizes over the clinically relevant limit of 120 µm (± 32 µm).[113]

Superior scanning and milling

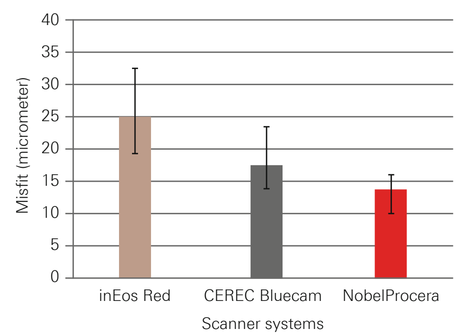
A study evaluating marginal fit of copings has shown the superiority of NobelProcera over two Sirona® systems (inEos Red and CEREC Bluecam) with regard to digital scanning, milling and the ability to read varying depths accurately.[128] Although all systems are considered clinically acceptable, NobelProcera shows better marginal fit with significantly lower marginal gap than the other two systems (P<0.0001).

Procera Crowns show excellent clinical performance



Probability of survival of veneered all-ceramic zirconia (CZR) and porcelain-fused-to-metal (PFM) crowns based on 7.4-year clinical follow-up.[103]

Superior marginal fit



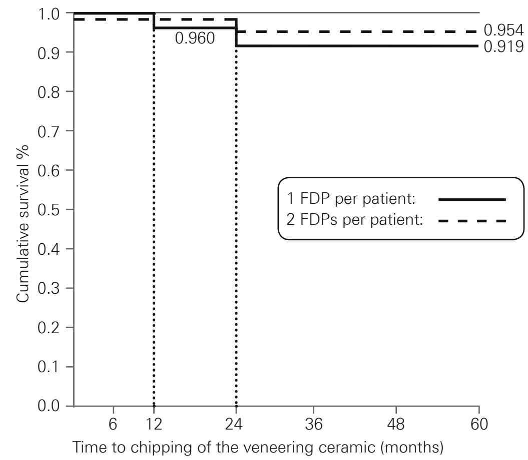
NobelProcera scanning and milling achieves a better marginal fit than the two tested Sirona® systems (P<0.0001).[128]

Significantly smaller marginal gaps were shown with all three designs tested:[128]
1 chamfer
2 chamfer with shallow depression in one aspect of finish line
3 chamfer with a deep depression

Five-year prospective clinical study of posterior three-unit zirconia-based fixed dental prostheses

Sorrentino R, De Simone G, Tete S, Russo S, Zarone F
Clin Oral Investig. 2012;16:977-985

Five-year recall evaluation of a zirconia FDP.



Kaplan-Meier graph of chipping of the veneering ceramic in relation to time. Two different survival curves are reported for patients wearing one and two FDPs, respectively. No framework fractures were detected while minor chippings of veneering ceramic were noticed in three [out of 48 included] FDPs.

Original abstract

This prospective clinical trial aimed at evaluating the clinical performance of three-unit posterior zirconia fixed dental prostheses (FDPs) after 5 years of clinical function. Thirty-seven patients received 48 three-unit zirconia-based FDPs. The restorations replaced either a premolar or a molar. Specific inclusion criteria were needed. Tooth preparation was standardized. Computer-aided design/computer-assisted manufacturing frameworks with a 9 mm^2 cross section of the connector and a 0.6 mm minimum thickness of the retainer were made. The restorations were luted with resin cement. The patients were recalled after 1, 6, 12, 24, 36, 48, and 60 months. The survival and success of the ceramics and zirconia were evaluated. The technical and aesthetic outcomes were examined using the United States Public Health Service criteria. The biologic outcomes were analyzed at abutment and contralateral teeth. Descriptive statistics were performed. All FDPs completed the study, resulting in 100% cumulative survival rate and 91.9% and 95.4% cumulative success rates for patients wearing one and two FDPs, respectively. No losses of retention were recorded. Forty-two restorations were rated alpha in all measured parameters. Minor chipping of the ceramics was detected in three restorations. No significant differences between the periodontal parameters of the test and control teeth were observed. Five-year clinical results proved that three-unit posterior zirconia-based FDPs were successful in the medium term for both function and aesthetic. Zirconia can be considered a promising substitute of metal frameworks for the fabrication of short-span posterior prostheses.

Cement vs. screw retention

Successful prosthetic retention needs to be stable, durable, meet occlusal requirements, support healthy hard and soft tissues, and provide excellent esthetics, especially in the anterior zone. Until recently neither cement nor screw retention were believed to meet all of these criteria. However, new clinical data suggest that, when it comes to hard and soft tissue response, screw retention is a superior option.

Comparable or better tissue response

Hard tissue response associated with screw retention is comparable or better than that associated with cement retention. In a pooled analysis of single-tooth restorations in the esthetic zone, the use of a cement-retained vs. a screw-retained provisional crown was strongly associated with marginal peri-implant bone loss of >0.50 mm at ≥1-year follow-up.[119] However, a clinically irrelevant difference at 4 years and no difference at 10 years have been reported in another study.[120]

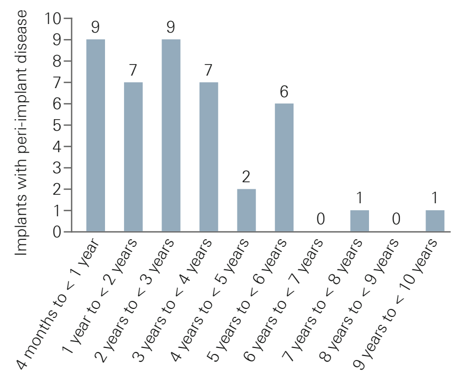
Soft tissue analysis using a modified plaque index and a sulcus bleeding index reveals that peri-implant soft tissues respond more favorably to screw-retained crowns when compared with cement-retained crowns.[121] One possible underlying reason for this result is excess cement, which has been indicated to account for over 80% of peri-implantitis cases.[122]

Fewer complications with screw-retained restorations

A systematic review shows that screw-retained solutions exhibit significantly fewer technical and biological complication rates based on calculations of estimated events per 100 life years:[123]

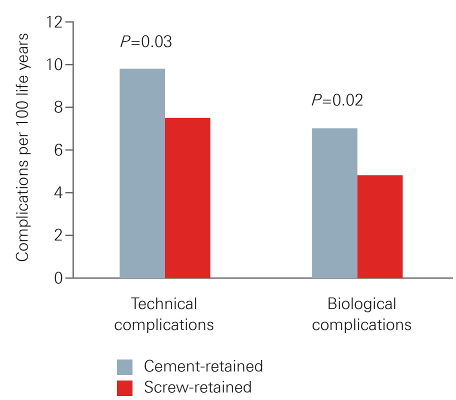
- Cement retention was associated with a 9x increase in loss of retention and almost 4x more frequent abutment loosening (both $P<0.01$).
- Fracture or chipping occurred more commonly (3.5 times) with screw retention ($P=0.02$).
- Event rates for loss of the access hole cover and screw loosening were 0.81 and 1.76 per 100 life years, respectively.

Excess cement is a causative factor in over 80% of cases of peri-implantitis



In a prospective clinical endoscopic study, peri-implant disease occurred as little as 4 months after implant placement, and up to 9 years afterwards. 81% of these cases were resolved after removal of excess cement.[122]

Screw retention is associated with fewer complications



A systematic review of publications reporting outcomes of screw- and cement-retained restorations reveals that screw-retained reconstructions exhibit fewer biological and technical complications.[123]

Lower failure rates with two-piece screw-retained restorations

Overall, the difference in survival between cement-retained and screw-retained restorations is not significant.[123,124] However, estimated failure rates per 100 life years associated with two-piece screw retention are significantly lower than for cement retention (P=0.00).[123]

When is cement retention recommended?

In view of recent data tying cement retention to an increased likelihood of peri-implantitis, the current consensus statement has limited the recommended use of cement to the following situations:[125]

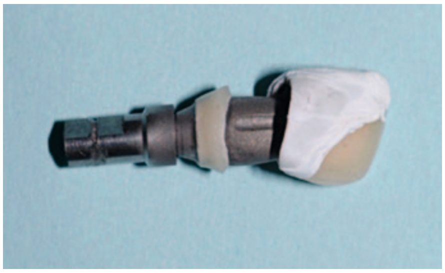
– For short-span prostheses with margins at or above tissue level. This is to simplify fabrication procedures.
– To enhance esthetics when the screw access passes transocclusally or in cases of malposition of the implant.
– When an intact occlusal surface is desirable.
– To reduce initial treatment costs.

Excess cement should be avoided

A survey of over 400 dentists shows that many of them place up to 20 times more cement than is required to secure the crown, while others fail to use the required minimum amount.[126] Such overload means up to 95% of the placed cement is extruded at the restorative margin. This margin is frequently found below the gum, making cement removal on implant-supported restorations virtually impossible. Wadhwani and Piñeyro describe a technique to minimize excess cement by creating a chair-side copy abutment that is used as a controlled applicator for the cement.[127]

Controlling the amount of cement

For the detailed procedure, see Wadhwani and Piñeyro (2009) [127]



Paint the internal surface of the crown with a suitable water-soluble lubricant and adapt PTFE tape (50 microns) to the inside of the crown using a dry brush, and further by gently placing the abutment.

Make a chair-side copy abutment (CCA) by filling the crown with a fast-setting impression or bite registration material and continue to overfill until a “handle” is produced.

After cleaning the crown, load it with cement and push the CCA into the crown, to extrude and remove any excess cement over 50 microns. Inspect the inside of the crown for an even cement layer, add a little extra to any “bare” areas, and seat the crown onto the abutment in the patient’s mouth. The same procedure can also be used for bridges.

NobelProcera ASC Abutment – versatility of screw retention combined with predictable abutment performance

The NobelProcera Angulated Screw Channel (ASC) Abutment positions the screw access hole at an angle of up to 25°. In the esthetic zone this means that the screw access channel can be more palatal to allow for optimized esthetics. For posterior restorations the access channel can be positioned more mesially to allow for easier handling. The NobelProcera ASC Abutment has been tested in biomechanical and 3D numerical fatigue-strength assays, where it demonstrated strength and performance equal or better than that of the NobelProcera Abutment with a straight screw access channel (data on file).

Excellent esthetic outcomes with the NobelProcera ASC Abutment

29-year old female patient with agenesis of both lateral superior incisors. Porcelain Maryland Bridges are affected by continuous decementation.

Try-in of two NobelProcera ASC Abutments supported by two NobelActive NP implants.

The angulated screw channel enables a palatally placed screw access hole to improve esthetics.

Esthetic result with two directly veneered NobelProcera ASC Abutments.

Courtesy of Dr. Juan Zufia and Santiago Dalmau, Spain

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Notes

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