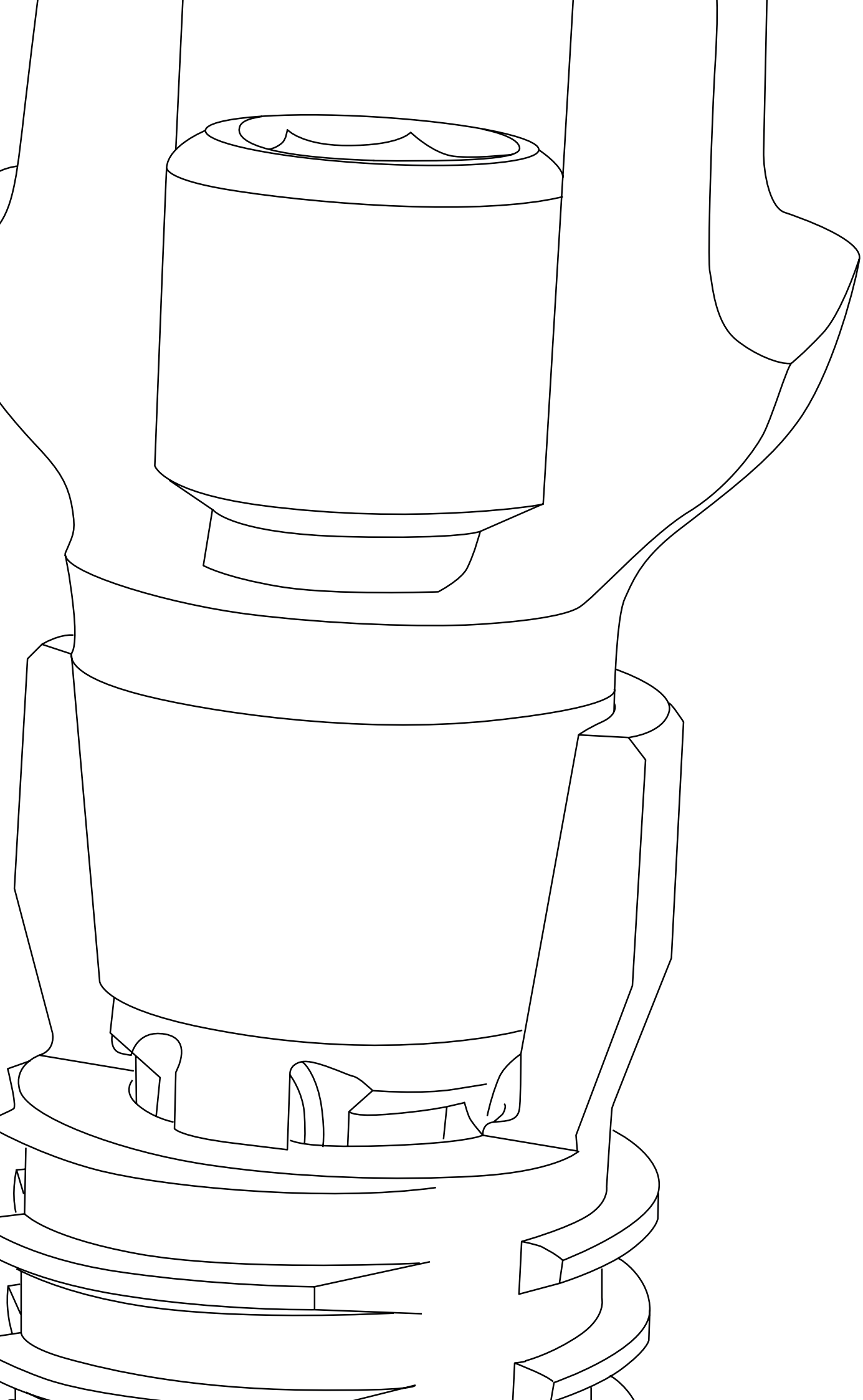
Clinical evidence and Science

Camlog Implant Systems

Inspiring excellence in oral reconstruction

biohorizons camlog



Science and Clinics and Industry

Albert Einstein once said, «All of science is nothing more than the refinement of everyday thinking» and this is what science is based on, answering questions of our daily life. For us today, as dental implant specialists, these questions ideally arise from our clinical routine.

Due to the increasing complexity of science, technologies and requirements for the regulatory approval of medical devices only a concerted approach of the scientist, the clinician and the entrepreneur will enhance the understanding of the parameters influencing the biologic integrity of dental implants. The clinician makes subjective observations leading to a question which science of course pursuits by applying knowledge and methods following a systematic methodology resulting in proven objective observations, the evidence. Ideally these objective observations are transformed into a technological advancement. This can just be the other way around, when technological advancement proofs to be successful in the clinicians´hands. The collection of publications from various prestigious scientists and clinicians predominantly sponsored by the Oral Reconstruction Foundation are displayed in this edition, they symbolize successful concerted activities advancing our knowledge in implantology.

*Courtesy of the Oral Reconstruction Foundation.

Prof. Dr. Katja Nelson
Faculty of Medicine
University of Freiburg

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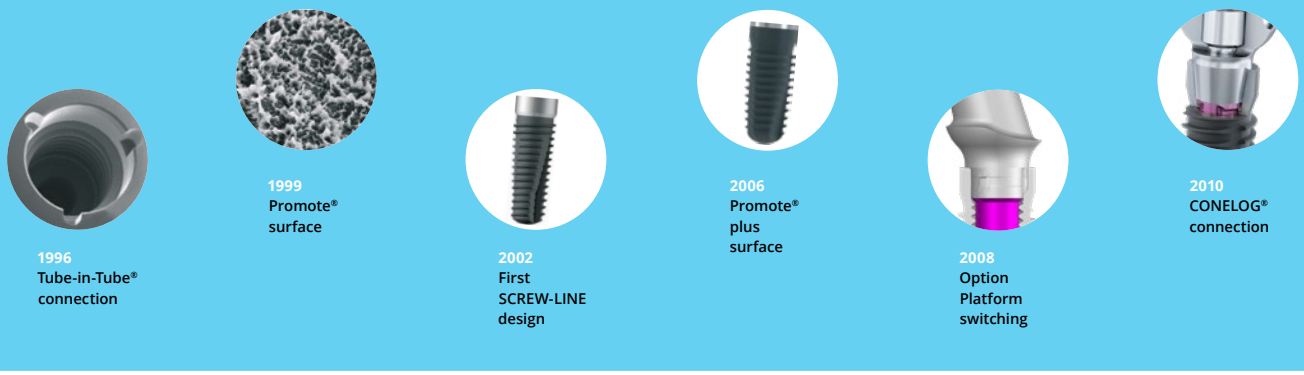


*Fig.1*_The development of the CAMLOG® and CONELOG® Implant Systems is based on solid foundation of scientific research

Importance of scientific documentation of implant systems

Pre-clinical and clinical studies and the knowledge gained from them help to understand the interface between the dental implant and the surrounding oral tissues as well as identifying areas where additional scientific research is required. Looking at the past development of dental implants and the history of publications, bone and soft tissue healing around dental implants varied greatly depending on the implant design, implant surface, and the surgical approach. Therefore, the importance of evidence-based implant systems is a prerequisite for predictable clinical outcomes in the practice. The overriding goal must be to maintain the implant longevity for the benefit of the patients.

From the beginning on, the Camlog company has set high standards in scientific documentation of all essential properties of their implant systems either independently by their Research and Development department or as a sponsor. Furthermore, their effort in supporting research projects in basic as well as in applied science was strengthened by the establishment of the Oral Reconstruction Foundation (www.orfoundation.org). A lot of topics like bone response to implant treatment, placement and loading time, implant and connection design, Platform-Switching concept, prosthetic treatment, and long-term success were covered in multiple publications and articles in highly ranked international scientific journals. Additionally, new scientific knowledge and findings were the basis of further developments of the CAMLOG® and CONELOG® Implant Systems.

The CAMLOG® and CONELOG® Implant Systems are state-of-the-art

The CAMLOG® Implant System with its butt-joint Tube-in-Tube® connection is one of the world's leading implant systems. Since its market introduction in 1999, millions of implants have successfully been inserted to restore the oral situation of the patients both aesthetically and functionally. Over the years, the features of the system have been continuously improved based on the scientific state-of-the-art (Fig. 1). The SCREW-LINE implant geometry came to market in 2002 and is very well scientifically documented. The CONELOG® Implant System, on the other side, offers a patented tapered implant-abutment connection, and features the same outer geometry except for the upper shoulder section as the CAMLOG® Implant System. In 2019, the PROGRESSIVE-LINE design was introduced for both implant systems and covers modern treatment options like immediacy, soft bone, and many more. This product line is currently part of many ongoing clinical investigations.

Other features common to both systems include the surface texture, the implant body and thread design, the surgical instruments, and prosthetic parts. Depending on the research question the clinical data obtained from one system could therefore be transferred to the other system.

This brochure gives an overview on numerous published scientific articles relating to the CAMLOG® and CONELOG® Implant Systems with the task to help the dentists and clinicians to stay up to date with the latest evidence and applying it effectively in clinical practice.

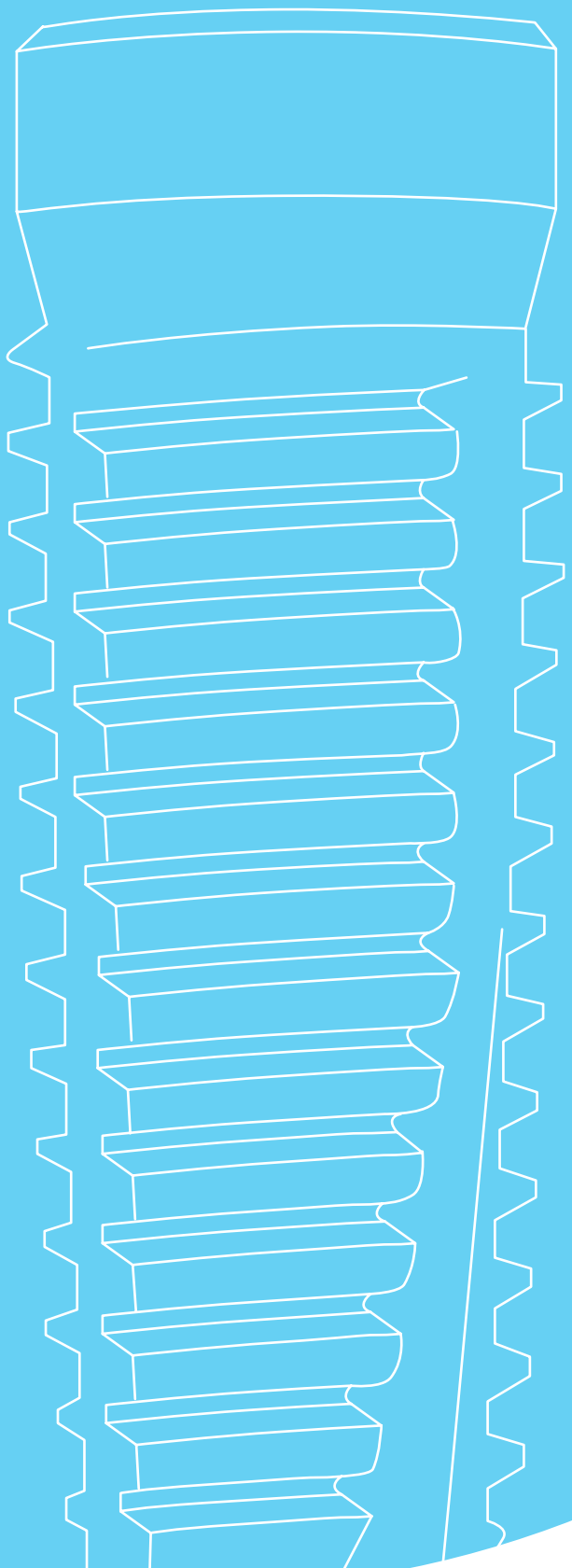
In addition to the publications cited in this brochure, a series of further important literature are named in the separately available 'Literature Overview' and of course Camlog as a company continues to invest in ongoing and future research.

2013
Full digital workflow (DEDICAM®)

2019
PROGRESSIVE-LINE design

2023
Clinical success – proven a million times

The Promote® implant surface



A state-of-the-art surface applied to titanium implants by sandblasting and acid etching leading to a positive clinical effect on bone growth and related osseointegration.

Use and development of titanium in implant dentistry

In the 1950s, Brånemark et al. discovered that titanium, experimentally implanted into rabbits, was treated as endogenous tissue by the surrounding bone. Further investigations confirmed this phenomenon which was a landmark in dental implantology. The inception of osseointegration as a concept was introduced (1).

Commercially pure titanium (or CPTi) with its high mechanical strength combined with excellent corrosion resistance is still the material of choice for endosseous dental implants today. It is recognized as an excellent implant material with high biocompatibility and has been the prime material for clinical use in implant dentistry for more than 40 years.

Since then, the morphology and topography of the implant surface has been continuously refined for optimal osseointegration. In the early 90s the first studies on sandblasted, acid etched titanium surfaces showed superior bone-to-implant contact compared to plasma-sprayed and machined titanium surfaces (2). In addition, micro-rough surfaces demonstrated accelerated osseointegrative properties. Sandblasting followed by acid etching may be regarded as the gold standard technique to create micro-rough surfaces (3).

The Promote® implant surface

The Promote® Surface, a sandblasted and acid etched surface, has been developed and applied to Camlog implants for more than 20 years (Fig. 2). It is based on current scientific knowledge and represents the state-of-the-art favoring rapid osseointegration. Results from cell cultures, osteohistology and in pull-out tests as well as clinical studies clearly illustrate this (Fig. 3) (4).

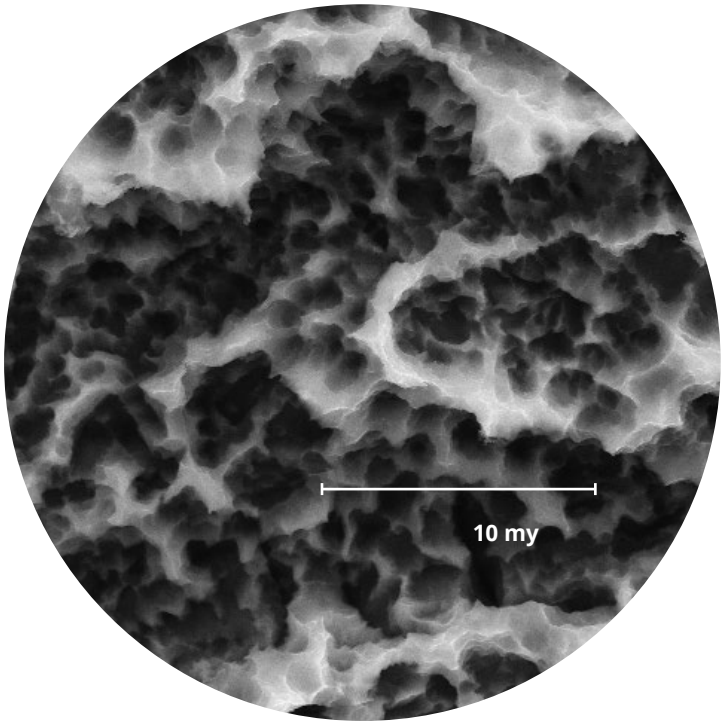


*Fig. 2*_Scanning electron microscope (SEM) image of the Promote® Surface

The Promote® Surface was initially only applied to the implant body of CAMLOG® implants while the implant neck remained untreated (1.4 mm machined surface). In 2006, as addition to the portfolio, the smooth-rough margin was set 0.4 mm from the implant shoulder allowing maximum flexibility of the vertical implant position. The 'Promote® plus surface' was introduced. With the market launch of the CONELOG® implants in 2011, the Promote® plus surface was applied all the way up to the implant shoulder (Fig. 4).

Characteristics:
The CAMLOG® SCREW-LINE implants are available with both the Promote® or Promote® plus surface. Difference is the length of machined neck section: 1.4 mm versus 0.4 mm. The CAMLOG® PROGRESSIVE-LINE implants are available with Promote® plus.

The CONELOG® implants Promote® plus, have a micro-rough surface up to the implant shoulder. The beveled implant shoulder (45°) on top of the CONELOG® implants is acid etched only (Fig. 4).

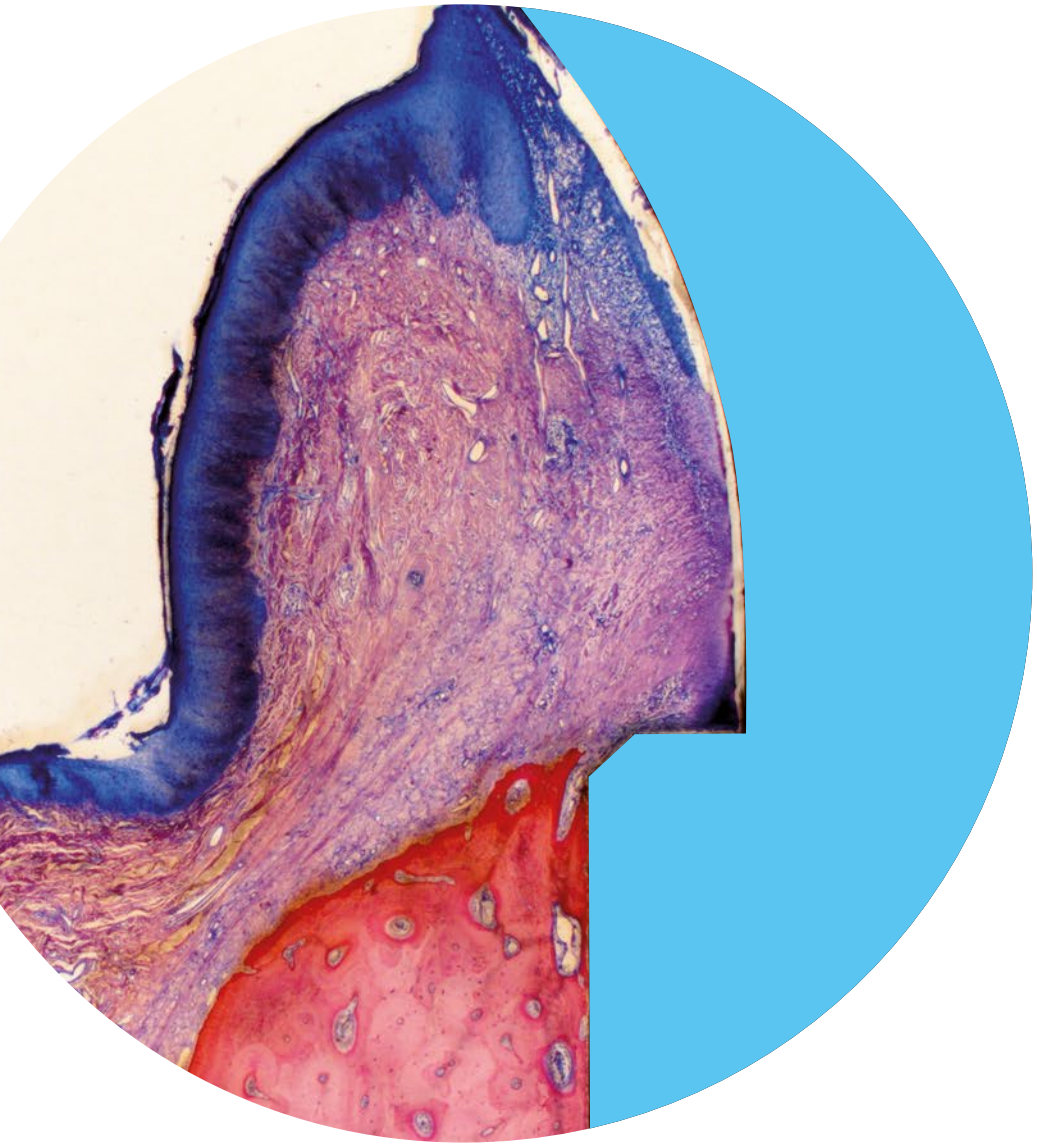


*Fig. 3*_Histological view of buccal crestal bone level preservation and soft tissue attachment at the implant abutment interface of CONELOG® SCREW-LINE implants Promote® plus at 12 weeks in dogs. Courtesy of Prof. Dr. F. Schwarz

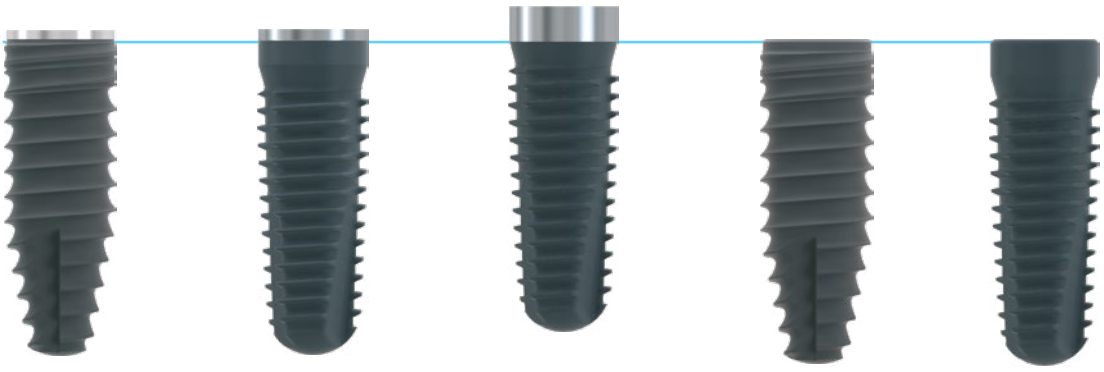
Osseointegration with Promote® vs Promote® plus design

In general, design changes and developments to improve the formation and maintenance of the soft and hard-tissue structures have systematically been tested in animal studies to prove their state-of-the-art technology. In 2006, the machined surface segment of the CAMLOG® implant neck was significantly reduced from 1.4 mm to 0.4 mm since studies have shown better bone-to-implant contact with rough surfaces.

Schwarz et al. (2008) investigated the effect of this design change on crestal bone resorption in a dog study (5). Both implant types were inserted into the mandibles of dogs following the standard protocol for CAMLOG® implants (0.4 mm above the bone crest). Histological evaluation took place after 2 and 12 weeks. Bone changes were found in both implant types after 12 weeks. However, the coarse neck area in the CAMLOG® Promote® implants appeared to have a positive effect on bone formation (bone to implant contact) and crestal bone level change. Data demonstrated that the new surface design efficiently reduced the initial crestal bone changes (6).

Vertical positioning of implants: effect of rough-machined border on bone resorption

The above results were strengthened by a systematic review of Messias et al.: Provided that the implant neck (machined or micro-rough) is placed endosseous, machined collar implants had higher risk of early failure than micro-rough collar implants and 0.4 mm higher bone resorption (7). Another review by Schwarz et al. evaluated the impact of positioning of the machined collar (8). Derived from their conclusions a clinical expert panel recommended in the Camlog Foundation Consensus Report that the smooth-rough border of the implants should at best coincide with the adjacent alveolar bone and determine the insertion depth to limit the peri-implant bone remodeling (9).



CAMLOG® PROGRESSIVE-LINE Promote® plus

CAMLOG® SCREW-LINE Promote® plus

CAMLOG® SCREW-LINE Promote®

CONELOG® PROGRESSIVE-LINE Promote® plus

CONELOG® SCREW-LINE Promote® plus

*Fig. 4*_Available implant variations from left to right, CAMLOG® PROGRESSIVE-LINE Promote® plus, CAMLOG® SCREW-LINE Promote® plus, CAMLOG® SCREW-LINE Promote®, CONELOG® PROGRESSIVE-LINE Promote® plus, CONELOG® SCREW-LINE Promote® plus

KEY TAKE OUTS:
PROMOTE® IMPLANT SURFACE

The application of the sandblasted and acid etched Promote® Surface on CAMLOG® and CONELOG® dental implants, with a history of more than 20 years, was steadily adapted according to the state-of-the-art. The micro-rough surface increased the bone-to-implant contact and stabilized the marginal bone level compared to machined surfaces. The success of the Promote® Surface was proven in multiple clinical studies (4).

References

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2. **Smeets R, Stadlinger B, Schwarz F, Beck-Broichsitter B, Jung O, Precht C,** et al. Impact of Dental Implant Surface Modifications on Osseointegration. BioMed research international. 2016; 2016: 6285620.
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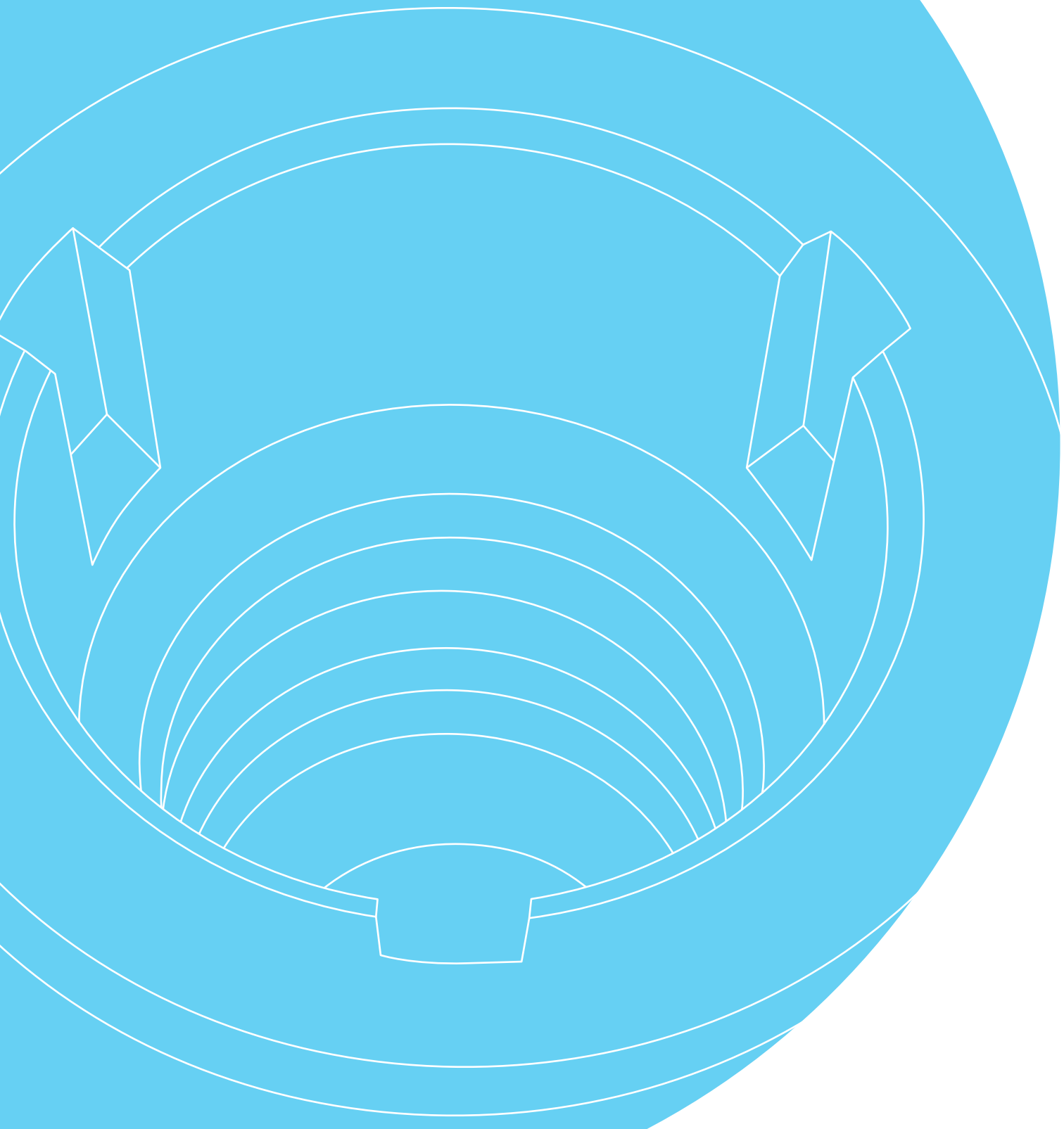
Science behind the implant-abutment connections



The Tube-in-Tube® butt-joint and the CONELOG® conical connections are well-established on the dental implant market and are proven to be clinically successful.

Since the introduction of two-piece dental implants, a lot of different types of implant-abutment connections (IAC) have been put on the market. Nowadays, internal connections are state-of-the-art with few maintenance requirements over time (e.g., retightening of screws). Technically, these are classified as either butt-joint or conical connections. Both types of connection are well-established on the dental implant market and are proven to be clinically successful. A significant impact of one of these connection types on crestal bone level changes lacks documentation (1). Important is a high precision of the connective part of the implant and abutment leading to a stable connection. In addition, the design of the connection must transmit and distribute the masticatory load and provide sealing capacity or at least minimal micromovement.

The Tube-in-Tube® connection – CAMLOG® Implant System

The well-known Tube-in-Tube® connection characterizing the CAMLOG® Implant System is a butt-joint connection with three symmetrically arranged interlocking grooves on the implant side and corresponding cams on the abutment as positional index design (Fig. 6). The tubular design allows an easy and safe insertion of the abutment into the implant and optimal positioning by the index design. Its special geometric design and precision of manufacturing ensures virtually perfect force and torque distribution as evidenced by some of the following publications.

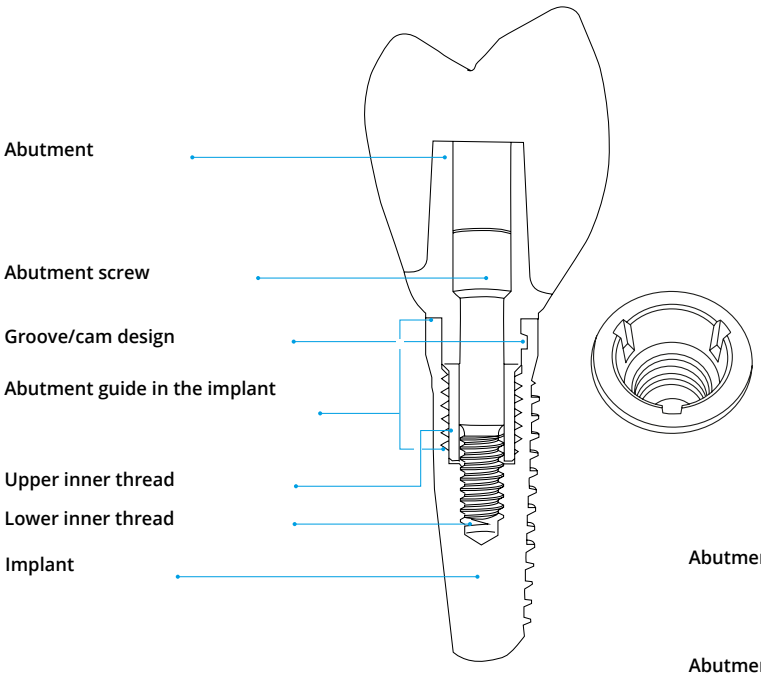


*Fig. 6*_Tube-in-Tube®, the CAMLOG® implant-abutment connection with the typical grooves and cams

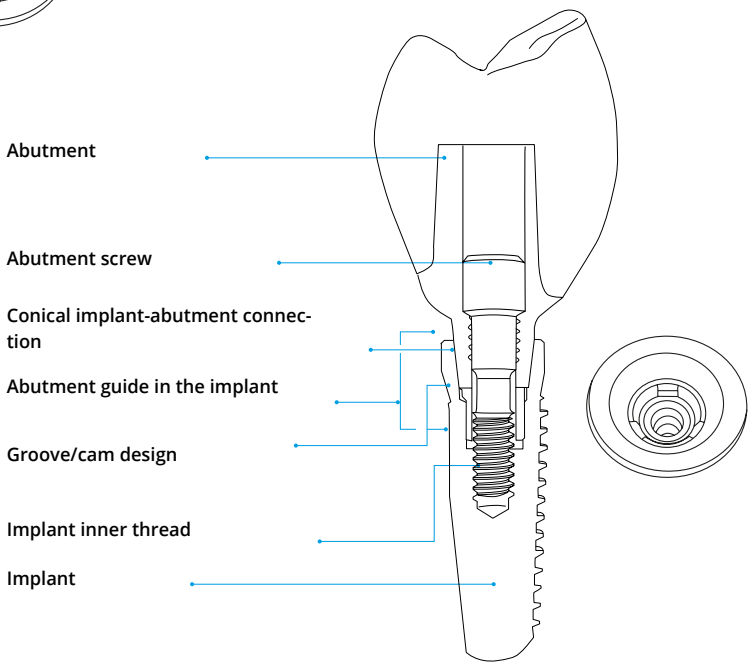


*Fig. 7*_CONELOG® implant-abutment connection with the index design at the bottom of the taper

The conical connection – CONELOG® Implant System

The patented CONELOG® implant-abutment connection features on the implant side a high-precision, deep, conical connection geometry with a coronal self-locking 7.5° internal taper followed by a short cylindrical segment with three symmetrically arranged grooves (Fig. 7). Upon insertion, the abutment is rotated until tactile engagement of the cams in the grooves of the implant (positional index design).

The Platform-Switching concept

Platform-Switching is one contributing method to preserve the peri-implant hard and soft tissue by increasing the distance between the implant-abutment connection interface and the alveolar crest. The concept is achieved by placing abutments of narrower diameter on implants of wider diameter (Fig. 8). The positive effect on marginal bone levels of this shift was first described by Lazzara and Porter 2006 (2). It is believed that the Platform-Switching concept decreases the effect of inflammatory cell infiltrates on bone resorption.

With CAMLOG® implants both the Platform-Switching as well as the platform matching option can be chosen with the respective selection of abutments. With CONELOG® implants the Platform-Switching concept is part of the implant-abutment connection design (integrated Platform-Switching).

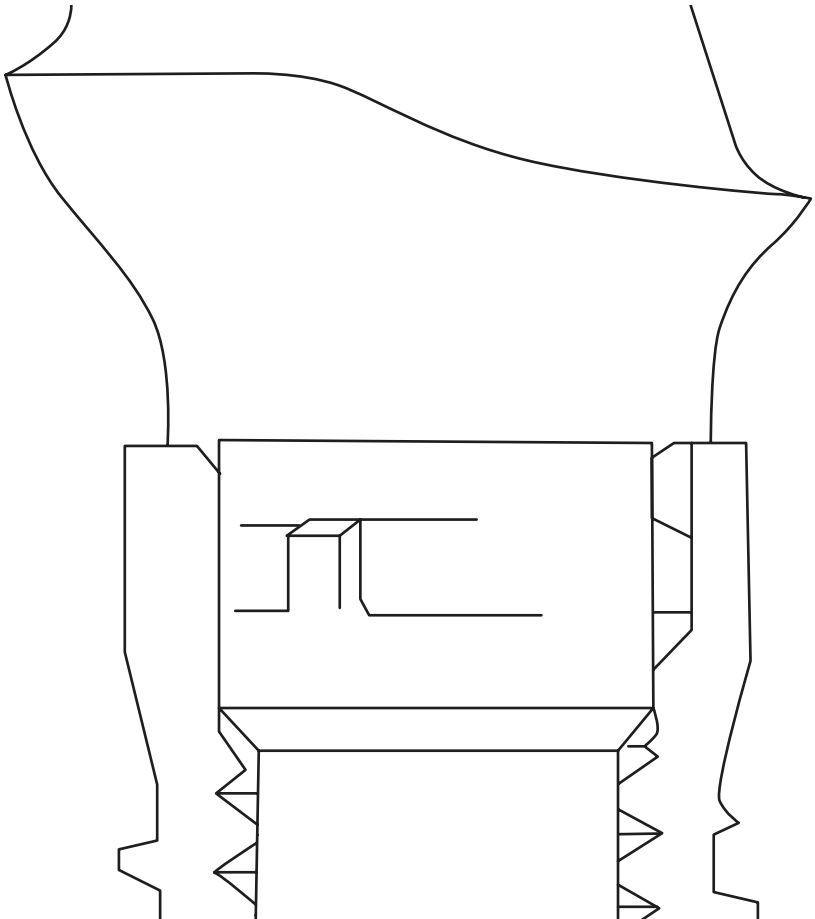


*Fig. 8_* **Platform-Switching concept: abutment with narrower diameter than implant platform**

Positional stability of the implant-abutment connection

Stability of the implant-abutment connection influences the manufacturing of the superstructure as well as the long-term success of implant-based prosthetic reconstructions. To ensure a precise fit of an implant-supported restoration, the reproduction of the exact abutment position in the patient's mouth and the laboratory is of fundamental importance. During superstructure fabrication, multiple repositioning of the implant and laboratory components is required. An imprecise connection may impair screw joint stability and result in unfavorable load transmission to the components of the reconstruction. Connection stability depends on the precision of fit, which is influenced by the design of the connection as well as by manufacturing tolerances. Numerous studies have been performed to analyze the connection stability of the CAMLOG® and CONELOG® Implant Systems and to compare both to other implant systems.

Rotational fit of the cam-groove index design: mathematical considerations

CAMLOG®

Positional stability of the abutment connected to the implant is ensured by the positional index that functions as an anti-rotation mechanism. Different geometric designs of positional indices are used in various implant systems. One main factor influencing the horizontal stability of the implant-abutment connection is the rotational freedom. A rotational displacement of the abutment may impair the fit of the prosthetic superstructure.

A research group at the Charité hospital in Berlin, Germany, evaluated the influence of the geometric design of positional indices on the horizontal position stability of the abutment (Semper et al., 2009) (13). The group performed mathematical analyses for three common geometric designs: regular polygon interface of different vertices (Steri Oss, Astra Tech, Straumann); rounded polygonal patterns (Replace Select implant system), and the cam-groove connection which is used in Camlog's implant systems. The calculations clearly showed that the geometric design as well as the size of the positional index influence the rotational freedom and thereby the horizontal stability of the abutment. The clearance between the implant wall and the abutment has a major influence on the positional stability emphasizing the importance of the manufacturing tolerances.

Based on above findings, Semper et al. (2009) used mathematical analyses and 3D-simulations to directly compare the rotational freedom of the three common positional index designs described above, i.e., regular polygon, rounded polygon as well as the cam-groove pattern (14). They hypothesized that the manufacturing tolerances, geometric pattern and dimensions of the index do not influence the positional stability. The study demonstrated that with an assumed clearance of 20 µm between implant and abutment the bidirectional rotation observed varied depending on the positional index design of the implant system. The largest positional freedom, i.e. worst rotational fit, was calculated for the regular polygonal positional index (varying from 3.0° to 3.7°). A better positional stability was determined with the rounded polygonal pattern (1.9°) (Fig. 9). However, the highest positional accuracy was calculated for the cam-groove design of the CAMLOG® Implant System (1.4°).

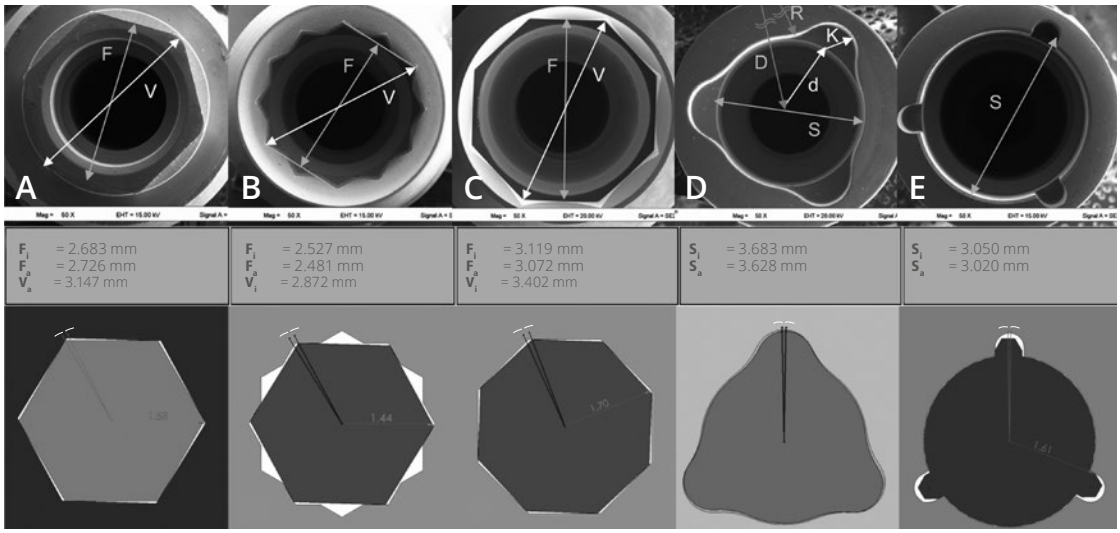


*Fig. 9*_Rotational freedom of regular polygonal patterns, polygon profiles, and other patterns. Measuring points and measuring results of (A) the hexagonal positional index (Steri-Oss), (B) of the dodecagrammal positional index (Astra Tech), (C) of the octagonal positional index (Straumann), (D) of the polygonal profile positional index (Replace Select), (E) of the cam-groove connection (Camlog). 3D simulation: rotational freedom (F) of the Steri-Oss system (hexagon), (G) of the Astra Tech system (dodecagram), (H) of the Straumann system (octagon), (I) of the Replace Select system, (J) of the CAMLOG® system.

Abbreviations: V = width across corners, F = width across flats demonstrated at the implant positional index, K = radius of the bulge, R = radius of the outer arc at the notch of the implant, D = distance from the center of the outer arc of the implant to the rotational axis, d = distance from the center of the inner arc to the rotational axis, S = diameter demonstrated at the implant positional index. (Semper et al. 2009, reproduced with kind permission of Thomson Reuters Corp., USA)

Simulation of rotational freedom of angulated abutments on CAMLOG® Implants

With the help of a three-dimensional computer simulation, the same group evaluated clinical relevance of the rotational freedom of angulated abutments on the marginal fit of the prosthetic superstructures (Semper et al., 2010) (15). The horizontal displacement of virtually constructed idealized abutments with different angulations (range from 0 to 20°) was simulated with various degrees of rotational freedom (range from 0.7 to 1.85°) as previously described (14). After quantification of the resulting displacement, a subsequent simulation was performed where the superstructure with different defined internal gaps (5 µm, 60 µm and 100 µm) was positioned pressureless on the displaced abutments. Finally, the resulting marginal gap between the abutment and the superstructure was measured with the software (Tab. 1). This gap depended on the degree of abutment angulation and the rotational freedom. Based on this investigation the authors concluded that the rotation of the abutment is of clinical relevance because of its impact on the marginal fit of the prosthetic superstructure.

Again, the precisely manufactured cam-groove index design of the implant-abutment connection seem to support precision-fit prosthetic restorations with little to no post-processing during placement.

Marginal fit of the superstructure at different assumed internal precisions simulated with different degrees of rotational freedom and abutment angulations

Internal gap / abutment angulation	Rotational freedom (α/2)				
	0.7 deg	0.95 deg	1.5 deg	1.65 deg	1.85 deg
5 µm assumed internal precision					
0 deg	17 µm	40 µm	183 µm	203 µm	266 µm
5 deg	187 µm	316 µm	578 µm	633 µm	782 µm
10 deg	401 µm	597 µm	1.03 mm	1.17 mm	1.31 mm
15 deg	597 µm	868 µm	1.47 mm	1.66 mm	1.87 mm
20 deg	796 µm	1.11 mm	1.82 mm	2.05 mm	2.33 mm
60 µm assumed internal precision					
0 deg	18 µm	23 µm	33 µm	43 µm	45 µm
5 deg	18 µm	23 µm	33 µm	43 µm	45 µm
10 deg	18 µm	23 µm	33 µm	43 µm	45 µm
15 deg	18 µm	23 µm	33 µm	89 µm	316 µm
20 deg	18 µm	23 µm	33 µm	576 µm	802 µm
100 µm assumed internal precision					
0 deg	19 µm	25 µm	37 µm	44 µm	50 µm
5 deg	19 µm	25 µm	37 µm	44 µm	50 µm
10 deg	19 µm	25 µm	37 µm	44 µm	50 µm
15 deg	19 µm	25 µm	37 µm	44 µm	50 µm
20 deg	19 µm	25 µm	37 µm	44 µm	162 µm

*Tab. 1*_The size of the marginal fit gap of the superstructures depends on the degree of abutment angulation and rotational freedom ranging from 17 µm to 2.33 mm maximum when the internal precision of the superstructure was 5 µm. A range from 18 µm to 802 µm was observed with an internal precision of 60 µm, and from 19 µm to 162 µm with 100 µm. Based on this investigation the authors concluded that the rotation of the abutment is of clinical relevance because of its impact on the marginal fit of the prosthetic superstructure. (Adapted from Semper et al. 2010)

Effect of the connection design on the accuracy of repositioning

CAMLOG®

The theoretical calculations described above (13–15) were also tested in an experimental study. Positional stability of five different implant systems (ITI, Steri-Oss, CAMLOG®, Astra Tech, and Replace Select: Fig. 10) was compared after multiple manual disassembly and reassembly (Semper et al., 2010) (16). Five implants were arranged with varying angles in a stainless-steel model to simulate a typical clinical situation. Abutments were assembled and reassembled manually by three test people for each implant system 20 times by using system-specific screwdrivers. Any rotational, vertical, and canting deviation from the initially determined position was monitored using a coordinate reading machine. Rotational freedom ranged from 0.92 to 4.92 degrees. CAMLOG® connections showed significantly smaller rotational discrepancy than the other systems tested (Fig. 11A). The systems with a horizontal butt-joint displayed significantly lower vertical alterations in position than beveled implant-abutment connections (Fig. 11B). Regarding canting discrepancies, the implant systems did not differ significantly (Fig. 11C). The authors concluded that reposition of rotation-safe abutments on the implants leads to a three-dimensional deviation compared to the initial position and that the accuracy of repositioning is influenced by the geometric design of the implant-abutment interface.

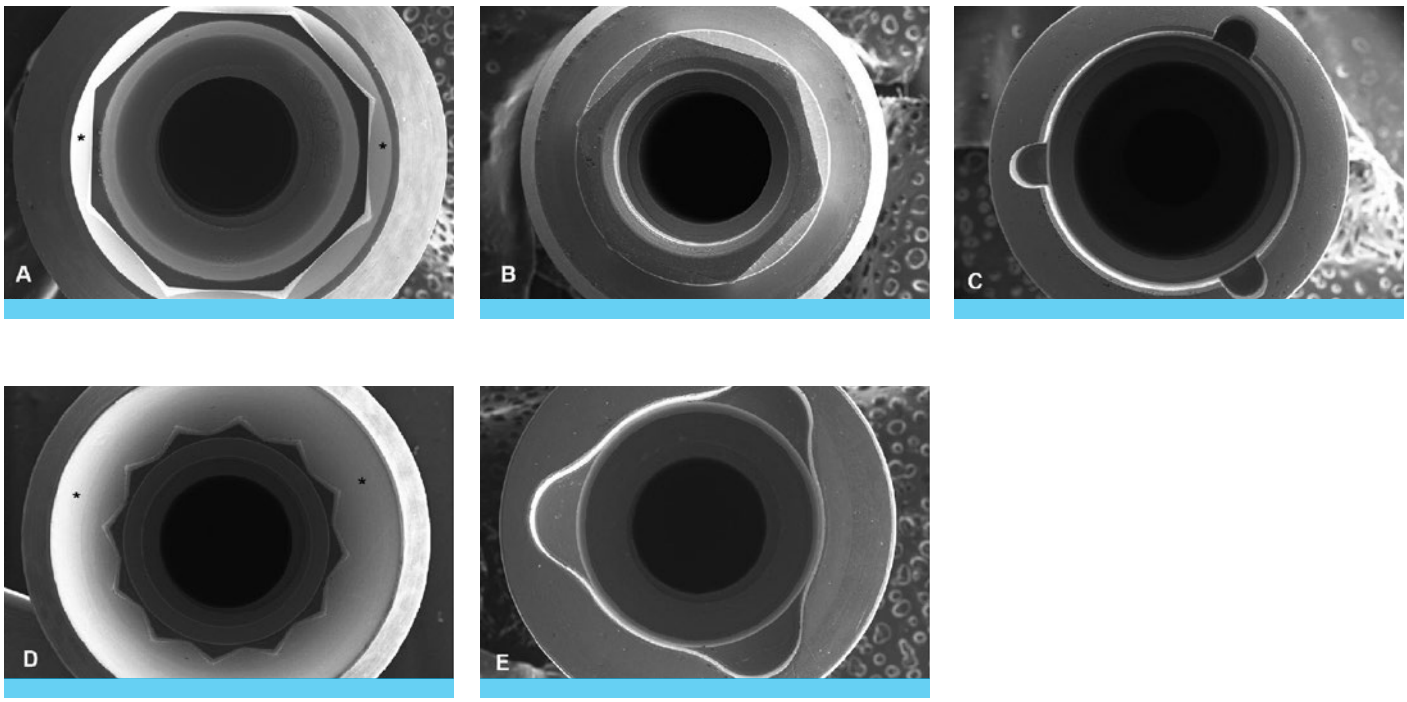


*Fig. 10*_Occlusal view of the five tested implant connections with their characteristic position indices: (A) ITI implant with conical-joint and octagonal positional index, (B) Steri-Oss implant with standard butt-joint and hexagonal positional index, (C) CAMLOG® implant with butt-joint and cam positional index, (D) Astra Tech implant with conical-joint and dodecagram positional index, and (E) Replace Select implant with butt-joint and polygonal positional index. (Semper et al. 2010, reproduced with kind permission of Quintessence Publishing co, Inc, USA)

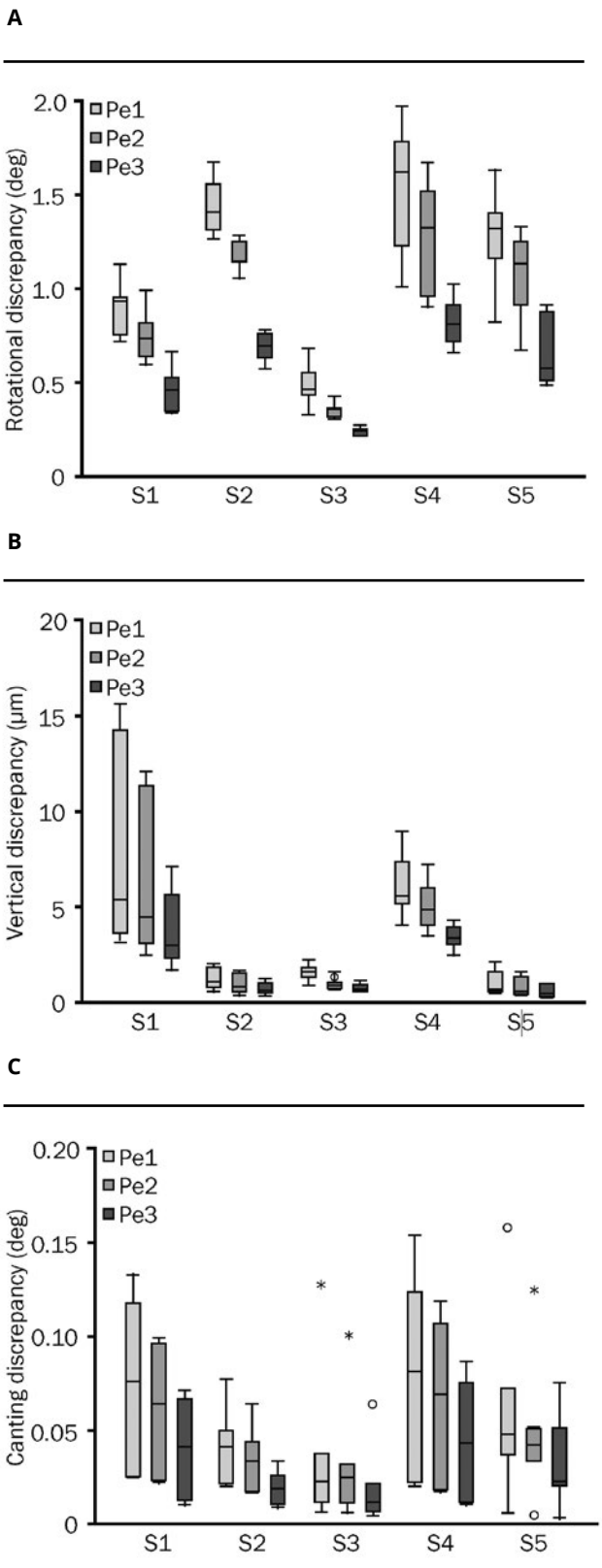


Fig. 11 A–C (A) Rotational deviations, (B) vertical deviations, and (C) canting discrepancies after repeated detachment and re-attachment procedures. Median values. Pe1, Pe2, Pe3 test persons performing the test procedures. S1 Straumann Tissue Level, S2 Steri-Oss, S3 CAMLOG®, S4 Astra Tech, S5 Replace Select. (Semper et al. 2010, reproduced with kind permission of Quintessence Publishing co, Inc, USA)

Superior positional stability of the CONELOG® conical connection

CONELOG®

The mathematical considerations of Semper et al. 2009 described above can be directly transferred to the rotational fit of the CONELOG® connection as the positional index is ensured with the same concept of a cam-groove design. Low manufacturing tolerances combined with the geometric design lead to a high positional stability. Both, the theoretical considerations and the established experimental set-up developed by Semper et al. were used to investigate the positional stability of different implant systems with hand-tightened conical implant-abutment connections, i.e., NobelActive, Bone Level, Ankylos C/X, and CONELOG® (Semper-Hogg et al., 2013) (17). Although malposition of the abutment was found to be possible in all tested implant systems, the values for rotational displacement of the CONELOG® Implant System were significantly lower than the ones of the other three implant systems. The median rotation was 0.25°, and the maximum range was 2.14° in the CONELOG® implants. Since the analytical and experimental results for CONELOG® were in very good agreement, the authors concluded high-precision manufacturing for this implant system.

The same experimental setup was used for a subsequent study investigating the influence of torque tightening on the positional stability of different conical implant-abutment connections (Semper et al. 2015) (18). The authors aimed to reveal if tightening of the abutment with a predefined torque during all laboratory and clinical procedures leads to more accurate positioning. The hypothesis had to be refuted since torque tightening caused similar displacements than with hand-tightening. In detail the range of the vertical displacement was higher compared to the hand-tightened implant-abutment complexes evaluated by Semper et al. 2013 (17) and was increased for implant systems with a cone angle >10°. The CONELOG® connection with its cam-groove indexing once more confirmed the lowest rotational freedom supporting the accuracy of fit of the prosthetic restoration (Fig. 12).

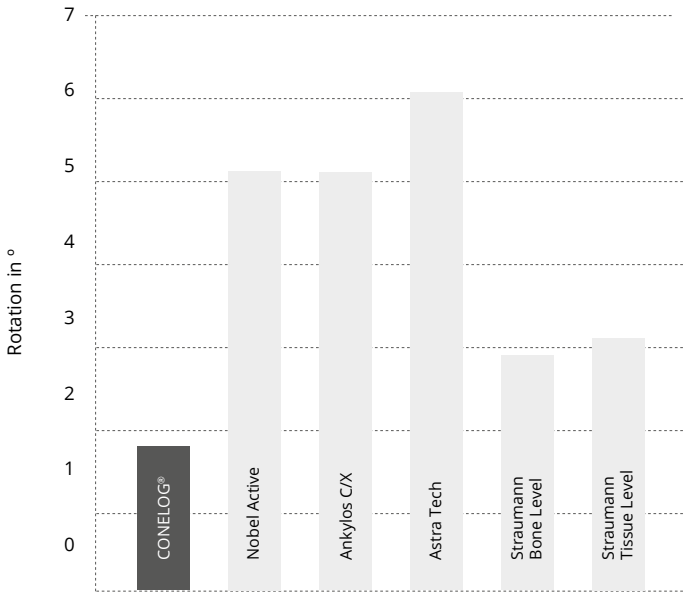


*Fig. 12*_Rotational displacement of six implant systems showing the lowest rotational freedom with the CONELOG® connection (adapted from Semper Hogg et al. 2015)

KEY TAKE OUTS:
STABILITY OF IMPLANT-ABUTMENT CONNECTIONS

Stability of the implant-abutment connection is strongly influenced by the precision of fit, the connection design and manufacturing precision. Several research groups analyzed and compared the stability of different implant-abutment connections. The CAMLOG® Tube-in-Tube® connection with its cam-groove index design showed favorable results in these analyses with regard to precision in reproducing the abutment position and rotational fit.

Although conical connections may have design-related disadvantages regarding precision of fit (vertical displacement), the CONELOG® implant-abutment connection demonstrated evidence of high-precision manufacturing and superior positional stability when compared to other conical connections. Additionally, the "vertical fit feature" of the system definitely ease the clinical handling of the connection: the impression post is not in contact with the cone during impression taking. The vertical discrepancies – inherent to all conical connections – are reduced by this concept (Fig. 13).

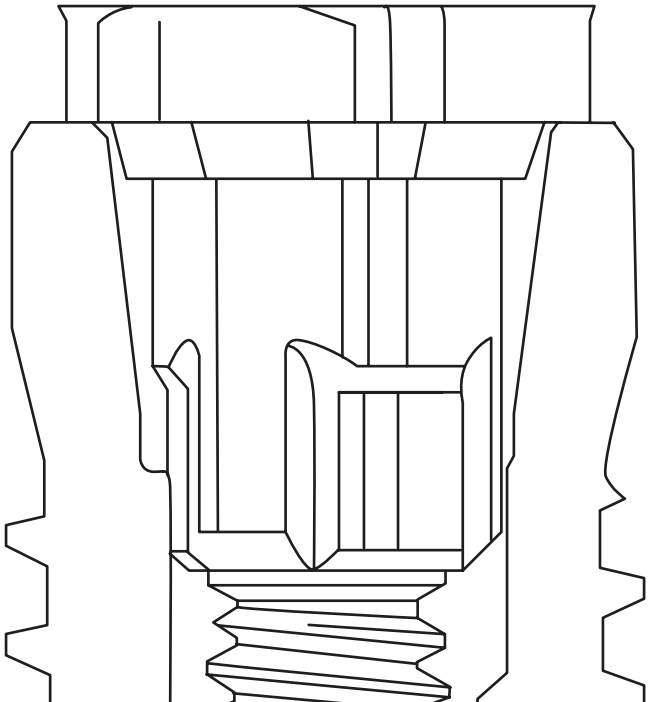


*Fig. 13*_«Vertical fit feature»: no contact of impression post and the cone during impression taking

Seal of the implant-abutment connections

Existence of microgaps with every implant-abutment connection

Microgaps between the implant and abutment favor microbial colonization of the implant-abutment interface. As a result, endotoxins may penetrate the surrounding tissue and may induce inflammatory processes leading to bone resorption and implant loss. Contrary to earlier publications with limited test possibilities several studies by e.g., Zipprich, Zabler and Rack (3–6) showed microgap formation evident in all implant-abutment connections regardless of their design. Visualizing and proving of the existence of microgaps in the internal conical implant-abutment connections for the first time was achieved by Rack et al. (2010) using synchrotron-based radiography (5). High resolution radiographic images were taken under varying static mechanical loads of up to 100 N on the systems Friadent Ankylos C/X, Ankylos Plus, and Straumann Bone Level. The images showed that the microgap size varied between 1 and 22 µm depending on the applied mechanical load. A subsequent study investigating the microgaps after fatigue loading revealed extended gaps with the possibility of micromovement of the implant-abutment complex (Rack et al., 2013) (6).

Seal of the CAMLOG® implant-abutment connection

CAMLOG®

The seal of CAMLOG® implants mounted with abutments was first measured by Steinebrunner et al. (2005) using dynamic loading in a chewing simulation test set-up including alternating load with 2 mm lateral movement on a 30° cusp slope with a force of 120N (7). Within five different implant-abutment connections, the Brånemark, FRIALIT-2, the Replace Select, CAMLOG® and the Screw-Vent, they checked migration of test microbes from the internal area of the connection in a sterile external culture medium during cyclic loading. The CAMLOG® Implant System reached a significantly higher number of chewing cycles than the FRIALIT-2 and Screw-Vent implant systems before microbial leakage was noticed (Fig. 14).

A follow-up study by Zipprich et al. (2016) examined the bacterial microleakage from outside into the implant interior during dynamic loading (3). The study team developed a new experimental design to eliminate some limitations of the Steinebrunner test set-up and to better simulate the clinical situation. Fourteen different implant systems, one half with conical the other with butt-joint connections, were loaded in a chewing simulator with gradually increased load (0 to 200N with steps of 25N). With the help of a channel drilled into the implant wall the lumen below the implant-abutment connection could be rinsed and analyzed for bacterial contamination after each loading step. The team concluded that in general conical implant-abutment connections showed better seal properties than butt-joint implant-abutment connections. However, the CAMLOG® SCREW-LINE implants tested (one group with Platform-Switching abutments, one group with platform matching abutments) did not show any microleakage in this study setup.

Seal of the CONELOG® implant-abutment connection

CONELOG®

Harder et al. (2012) investigated in-vitro, the leakage of bacterial endotoxins from conical implant-abutment connections in two implant systems (Straumann Bone Level, CONELOG®) (8). The test specimens were inoculated with endotoxin and submerged in human whole blood. Endotoxin leakage was assessed in terms of changes in gene and protein expression involved in inflammatory processes in the blood cells. With both implant systems, leakage could be demonstrated even under unloaded conditions. The authors concluded that based on the study results, the prevailing opinion of a good sealing capacity with conical implant-abutment connections should be reconsidered.

Further research with synchrotron radiography by Wiest et al. (2018) with the aim to validate a finite-element simulation revealed microgap formation with CONELOG® implants under loading (9). In all load applications with a force from the side it could be shown that the abutment is canted within the connection leading to gap formation. This study will be used as basis for investigating the impact of specific parameters such as screw pre-load on the micromovements since first modelling showed that the preload or screw mounting force has limited influence on microgap formation.

KEY TAKE OUTS:
SEALING PROPERTIES OF IMPLANT-ABUTMENT CONNECTIONS

In general, butt-joint and conical connections all showed microgaps and micromovements allowing the penetration of bacteria irrespective of the connection design. The CONELOG® and the CAMLOG® implant-abutment connection, however, showed good sealing properties in studies. Therefore, both connections seem to be resistant to bacteria penetration which could also be shown in limited bone resorption over time in various clinical studies (refer to chapter: Clinical evidence for CAMLOG® and CONELOG® implants).

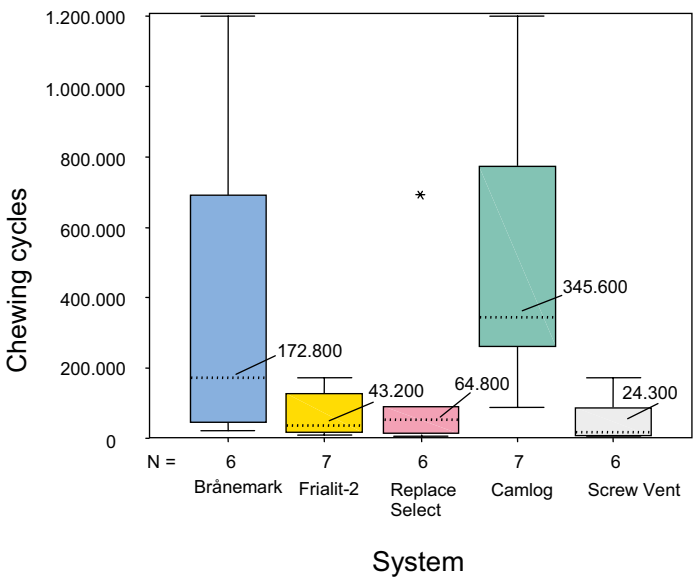


*Fig. 14_* **Box plot diagram showing the chewing cycles reached before microbial leakage occurred in the individual systems. ... median value. * extreme value. The CAMLOG® Implant System clearly reached the highest mean number of cycles among the tested systems (adapted from Steinebrunner et al. 2005)**

Load bearing capacity of implant-abutment connections

The design of the implant-abutment connection is of high relevance for the loading capacity as well as for the long-term stability of the peri-implant hard and soft tissues. The following studies give deeper insight into loading capacity of the implant systems.

Static resistance of Tube-in-Tube® connection

CAMLOG®

A research group from Hannover, Germany (Dittmer et al., 2011), compared different implant systems in an experimental study (10). On implants, centrally embedded in plastic material, corresponding abutments were placed and tightened with screws according to the manufacturers' recommendations. A universal testing machine was used to apply a 30° off-axis load linearly increasing until failure. Although all tested implants displayed load-bearing capacities that were considerably higher than average chewing forces, the authors could clearly demonstrate that the connection design had a significant influence on the load-bearing capacity as well as on the failure mode due to static overload. The CAMLOG® SCREW-LINE implants with Universal abutments demonstrated favorable results regarding their load-bearing capacity (Fig. 15).

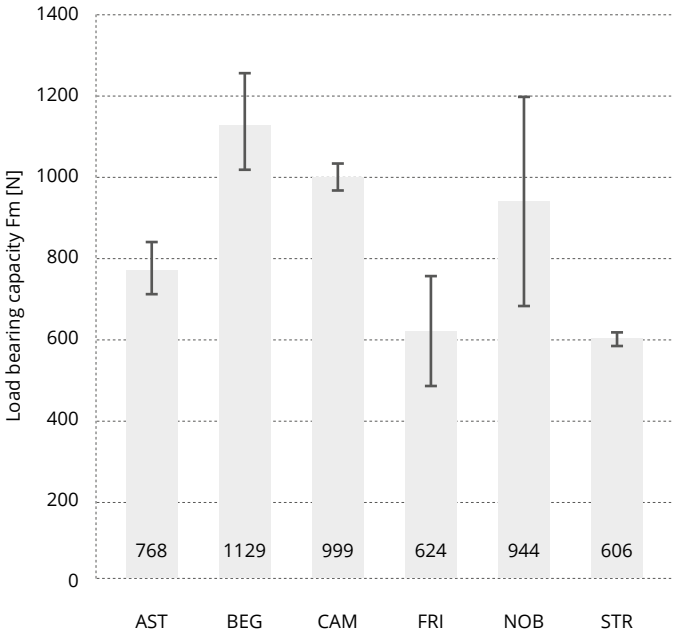


*Fig. 15*_Load-bearing capacity (Fm) versus implant-abutment connection type. Means and standard deviations are given. AST – Astra Tech, BEG – Bego, CAM – CAMLOG®, FRI – Friadent, NOB – Nobel, STR – Straumann (adapted from Dittmer et al. 2011)

Dynamic resistance (fatigue resistance) of Tube-in-Tube® connection

Steinebrunner et al. (2008) tested the influence of long-term dynamic loading on the fracture strengths of five different implant systems, one with external connection (Brånemark) and four with internal connections (FRIALIT-2, Replace Select, CAMLOG® and Screw-Vent) (11). The test specimens (molar) were subjected to dynamic alternating loading for a maximum of 1.2 million cycles in a dual axis chewing simulator before maximum loading was applied for fracture strength determination. The results demonstrated that the CAMLOG® and the Replace Select implant systems with deep internal tube-in-tube connections with cam-slot fixations had the highest fracture strength score (Tab. 2 and Fig. 16).

survival rates	loading cycles	failure [n]
Replace Select	1.200.000 ± 0	0
Camlog®	1.200.000 ± 0	0
Branemark	954.300 ± 121.014	3
Compress	922.800 ± 102.242	3
Screw-Vent	913.200 ± 102.242	6
Frialit-2	627.300 ± 164.097	6

*Tab. 2*_Survival rates of eight implants from each group in the dynamic, alternating loading test. The test was ended after 1 200 000 cycles (adapted from Steinebrunner et al. 2008)

Torsional resistance of Tube-in-Tube® connection

During chewing, grinding and/or clenching not only axial forces occur on the crowns but also rotational torque which can lead to fractures. Using a torsion testing device Watanabe et al. (2015) investigated the torsional strength of CAMLOG® implant-abutment connections (12). Six specimens of each diameter (3.3, 3.8, 4.3, 5.0, 6.0) were tested with a rotational speed of 3.6°/min until deformation or fracture occurred. The device registered the maximal torque and the torsional yield strength, and each specimen was examined by scanning electron microscope after being tested.

The implant diameters 3.3, 3.8, and 4.3 had comparable mean fracture torques. However, these were statistically lower than the ones of the diameters 5.0 and 6.0. The implant diameter and thickness of the implant wall seem to have a direct influence. The microscopic evaluations additionally revealed that the implants including indexing grooves remained intact while the notches of all the abutments were destroyed meaning that in the event of excessive torque the implant remained intact and most probably would not need to be explanted.

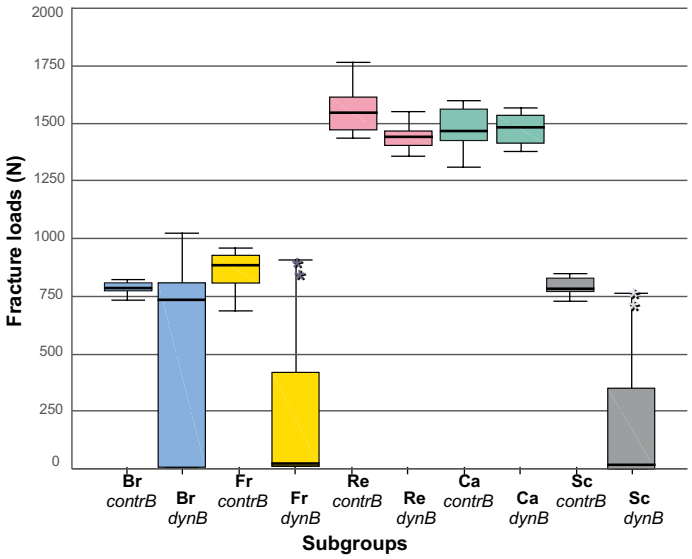


*Fig. 16*_Box plot diagram of the quasistatic fracture strengths of the five tested implant systems: Br – Brånemark, Fr – Frialit-2, Re – Replace Select, Ca – CAMLOG®, Sc – Screw-Vent. dyn = after chewing simulation using dynamic loading; contr = without dynamic loading (adapted from Steinebrunner et al. 2008)

KEY TAKE OUTS:
LOAD BEARING CAPACITY

The CAMLOG® Tube-in-Tube® connection demonstrated a very favorable load capacity under static as well as dynamic test simulations. The connection has proven to transfer and distribute more than the average chewing forces and to protect the implant from possible failure.

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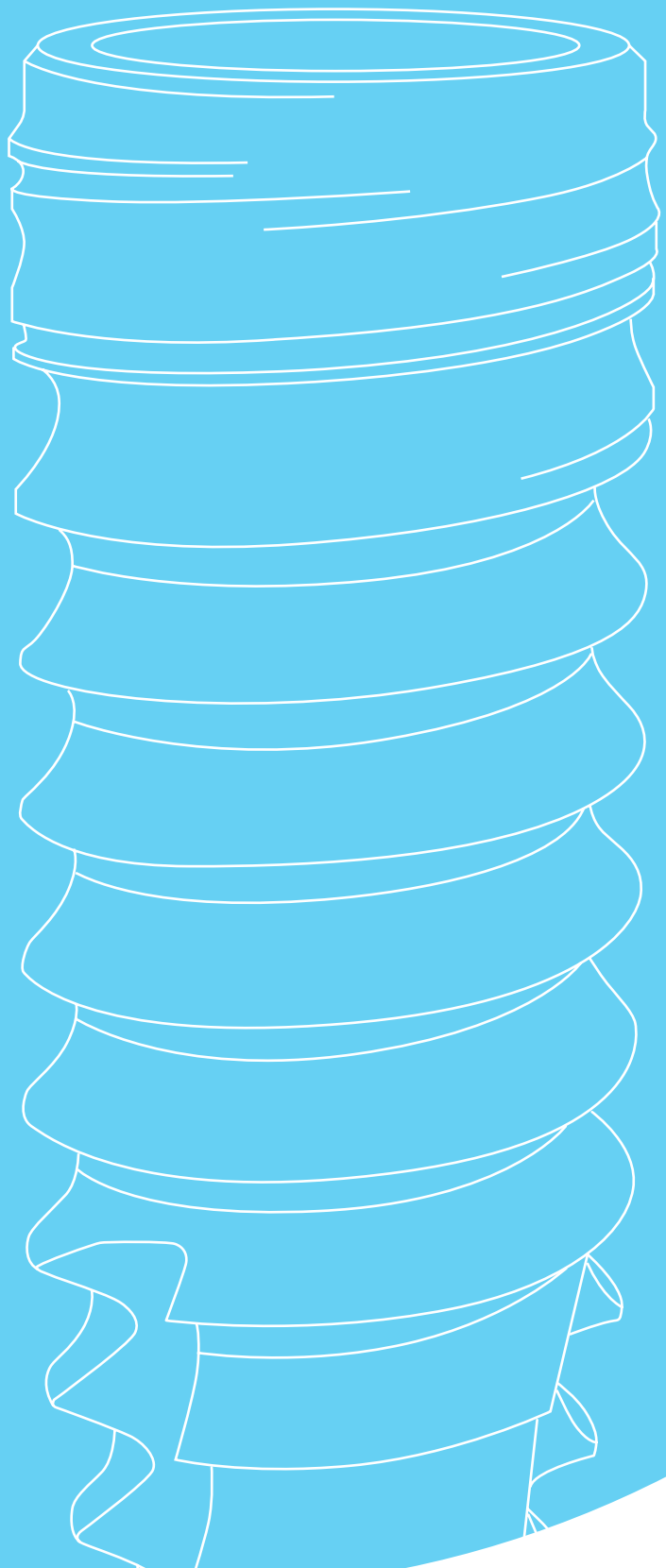
Clinical evidence for the Camlog Implant Systems



Long-term clinical data confirm the safety, performance, and effectiveness of CAMLOG® and CONELOG® implants.

Importance of well-documented implant systems

Generally, clinical data showing the performance and safety of the medical devices are a regulatory prerequisite for device approval. In implant dentistry the most important and at the same time the most investigated parameters are the survival and the success rates of implant restorations. Implant related factors such as peri-implant bone remodeling and bone loss, periimplantitis, mobility/stability, and adverse events like pain, infection etc. are taken to evaluate the implant success (Buser et al 2002 (1), Albrektsson et al. 1986 (2)). Long-term clinical data represents a reference in terms of safety and confidence not only for the user but also for the patient. A large number of clinical studies have been performed documenting Camlog's implant systems with its Promote® Surface in several indications and treatment options. They have confirmed excellent peri-implant clinical outcomes related to soft and hard tissues. Both, the CAMLOG® and CONELOG® Implant Systems are considered well-documented implant systems within the scientific community.

Authors	Year	Follow-up time (year)	Total Implants	CAMLOG® Implants	Survival in %	Comments
Retrospective studies						
Knöfler et al.	2017	20	10165 [1,4]	6063 SL	3.15 loss rate*	
Knöfler et al.	2019	20	10165 [1,4]	6063 SL	1.56 loss rate*	Camlog® over 10 years period (2001–2011)
Lee et al.	2019	12	19006 [1,3,4]	1317 SL	99.2 at 5-year 97.7 at 10-year	Survival related to implant fracture
Seemann et al.	2017	7	69377 [1]	69377: 11220 RL, 58157 SL	2.78 return rate	Return rate of total sold implants (complaint statistics)
Semper et al.	2008	6	464 [1]	464: 411 RL, 53 SL	99.6	
Nelson et al.	2008	5	532 [1,2]	463: 410 RL, 53 SL	99.4	
Semper et al.	2007	5	448 [1,2]	403: 363 RL, 40 SL	99.8	
Prospective clinical studies (cohort studies)						
Vanlioglu et al.	2014	10	253 [1]	253 SL	100	
Strietzel et al.	2007	5	333 [1]	333 SL	98.5	
Beschnidt et al.	2018	5	271 [1]	271 SL	98.6	
Krennmair S et al.	2018	5	284 [1]	284 SL and RL	99.3	
Krennmair S et al.	2019	5	295 [1]	295 SL	99.3	
De Lange et al.	2010	5	774 [1]	774 SL	96.7	
Randomized clinical trials						
Waller et al. (5)	2020	7.5	28 [1]	28 SL	100	
Messias et al.	2019	5	146 [1]	146 SL	96.6	

RL = Root-Line; SL = Screw-Line *Total implants observed vs lost implants [(1)] CAMLOG®, [(2)] Straumann, [(3)] Biohorizons, [(4)] Others

Tab. 3 Publications reporting mid-term and long-term survival rates of the CAMLOG® Implant System.

Long-term success

Excellent long-term success and survival with CAMLOG® implants

CAMLOG®

Meta-analyses of studies evaluating the survival of dental implants in general reported survival rates of 97.2 % after 5-year follow-up and 95.2 % (Jung et al. 2012 (3)) or 96.4 % (Howe et al. 2019 (4)) after 10-year follow-up. The performance of CAMLOG® implants in the mid- and long-term are absolutely in line with or even exceeding these survival rates. Table 3 summarizes retrospective, cohort, and randomized clinical studies evaluating CAMLOG® implants with a follow-up time of more or equal to 5 years (Tab. 3).

Performance in daily dental practice: observational studies

In observational studies the use and the performance of dental implants can be examined in daily dental practice and over the entire range of indications. This real-life data is of great importance for the assessment of dental implants by dental professionals. The following three studies include survival and success data from CAMLOG® implants used in broad indications and in both the maxillary and the mandible.

In an evaluation of patient/implant data from three dental practices Knöfler et al. reported clinical data of more than 10 000 implants from different manufacturers (mainly Camlog, Friadent, Astra-Tech) and over a period of 20 years (1991 to 2011) (6–8). The study team published three articles focusing on different influencing factors on the implant survival. Camlog implants were only introduced and used starting from 1999/2000. However, 6 063 implants evaluated were CAMLOG® and CONELOG® SCREW-LINE implants (60 % of all implants analyzed). Demography, implant dimensions and type, indication, type of restoration, treatment plan, and complications were collected. Cumulative survival rates of all involved implants were 96 %, 93 %, and 86 % after 5-, 10-, and 20-years, respectively, and the overall loss rate 4.54 %. Camlog implants, however, had a far lower loss rate of 1.56 %. General finding was that newly introduced implant systems required the practitioners to undergo a learning curve with the new system and that half of the lost implants were early failures, and the second half was usually lost due to periimplantitis (Knöfler et al. 2019 (7)). The Camlog implants did not show significant differences in survival rates regarding diameters and lengths. Additionally, Camlog implants with its Promote® Surface showed the highest probability of survival compared to other implant systems (Knöfler et al. 2017 (6)). In the third article the investigators looked at the influence of the type of restorations on implant survival: cemented vs. screw-retained; fixed versus removable prosthesis; single crowns, fixed partial dentures, full arch dentures. Single crowns had the lowest loss rate but the paper summarized all possible restorations performed well with low complication rates. (Knöfler et al. 2018 (8)).

In a multicenter observational clinical study with a follow-up of 5-years post-loading the survival and success rates of CAMLOG® SCREW-LINE implants, either restored with Platform-Switching abutments or platform matching abutments were observed (Beschnidt et al. 2018 (9)). The implant treatment had to follow the intended use but was open regarding type of surgery and restoration workflow. Patients were recruited in 17 private practices distributed over five European countries. 185 patients with 271 implants could be enrolled whereof 137 patients with 200 implants attended the final 5-year follow-up visit. Three implants were lost post-loading leading to a survival rate of 98.6 %. One more persisting complication (periimplantitis) is reflected in the success rate of 98 % (criteria by Buser et al. 2002 (1)). The authors attributed excellent clinical outcomes to the implants comparable with those achieved in controlled clinical trials.

Vanlioglu et al. (2014) (10) summarized on a congress poster presentation 10-year post-loading follow-up data of 67 patients with 253 implants placed in the posterior maxilla and mandible. Restorations included single crowns and fixed partial dentures. The cumulative survival was 100 %. Only a few technical complications within the fixed partial dentures occurred (success rate 96.9 %). Mean marginal bone level change was reported with 0.35 ± 0.11mm at 10-year post-loading.

Treatment success with reduced healing time: 6 weeks in mandible, 12 weeks in maxilla

Healing time depends – among other factors – on the surgical interventions performed during implant placement, on bone quality as well as the implant surface. In a retrospective study, Nelson and co-workers investigated the long-term efficacy of two different sand-blasted and acid-etched implant systems (CAMLOG® and Straumann implants) loaded with the same reduced healing time. The results were published in three articles (Nelson et al. 2008 (11) and Semper et al. 2007 (12) and 2008 (13)). Nelson reported the results of the entire study cohort including 532 implants placed in the maxilla (448) and in the mandible (84) following the standardized healing time of the department, i.e. six weeks post implant placement for mandible and 12 weeks for maxilla. The evaluation of the implant success was based on criteria defined by Buser et al. (2002) (1): absence of mobility, no apical translucency, no pain or other signs of persistent or irreversibly symptoms, no periimplant inflammation. Overall success was 99.4 % at five years and did not show any statistical difference between the two implant systems. Semper using the same approach, reported the results of the implants inserted in the maxilla. No statistical difference between the two systems was noticed, either. This 'time saving' offers psychological, functional, and aesthetic benefits for the patients without compromise.

Success based on time of implant placement and time of loading

De Lange et al. (2010) (14) studied the treatment success of 774 implants in fresh or healed extraction sites in anterior positions, with immediate or delayed loading. A mean cumulative survival rate of 96.7% resulted over 5-years with no differences regarding time of implant placement and time of loading. The authors concluded that individual risk factors such as smoking, inflammation or endodontic treatments were much more critical to success than the time points of implant placement and loading.

Success of implants combined with augmentations and sinus lifts

In the posterior maxilla, placement of implants has often been combined with sinus floor augmentations. Five-year clinical outcomes were gathered by Krennmair et al. (2018) (15) for 81 patients with 119 staged sinus floor elevations and 284 dental implants. Three patient groups with sinus grafts with three different ratios of bovine bone mineral and autogenous bone mixture were evaluated. With only two implant losses over 5-year (survival 99.3%, success 96.7%) the implants provided predictable clinical outcome irrespective of the mixture of bovine sinus grafts with autogenous bone used.

In another clinical study with CAMLOG® implants placed in staged maxillary sinus augmentations the survival and success rates were similarly high (99.3 %, 96.5 % respectively) and confirmed the safe use of these implants within this indication (Krennmair et al. 2019) (16).

Success depending on implant diameter and length

Strietzel & Reichart (2007) (17) compared the treatment success of short (9, 11mm) and long (13, 16mm) CAMLOG® implants. The authors did not observe any significant differences between lengths. The average survival rate of all 325 implants was 98.5 % over an observation period of up to four and a half years.

In Austria a big data analysis (retrospective study) was performed with 70 000 sold implants over seven years (Seemann et al. 2017 (18)). With the support of the implant company the return rate of lost CAMLOG® implants as part of an osseointegration guarantee program was analyzed by implant diameter, length, and type. The overall return rate due to implant loss was 2.78 %. Compared to the smaller diameters the implant diameter 6.0mm showed significantly higher return rates. Same was observed with short implants (9 mm) compared to implant length 13mm. Most of the implant losses were early failures occurring within 157 days after implant placement (80 %). The authors highlighted the importance of selecting the implant dimensions according to the specific indications.

Implant fracture analysis over 10 years

In a dental hospital in Korea all implants placed over a period of 10 years and additionally followed-up over a further three years were retrospectively investigated for implant fractures. Over 19 000 internal connection implants of 14 different implant manufacturers (Astra-Tech, Bego, Biohorizons, Dentis, Osstem, Zimmer and others) could be included and evaluated for potential risk indicators. In this study 1317 CAMLOG® implants were placed and revealed a fracture incidence of 0.73 % which was below the overall incidence rate of 0.92 %. For the actual K-Line series (CAMLOG® implants, marketed since 2008) no fractures were reported (Lee et al. 2019 (19)).

KEY TAKE OUTS:
HIGH LONG-TERM SUCCESS WITH CAMLOG® IMPLANTS

Irrespective of the choice of the implant dimensions and the selected treatment plan e.g., immediate or delayed implant placement, CAMLOG® SCREW-LINE implants showed high survival and success rates comparable or even higher to the average of the implant systems on the market. Also, real-world data from studies in daily dental practices revealed predictable and satisfying outcomes for CAMLOG® implants. Even in more complex indications like the sinus floor elevation the implant system convinced with its survival and success rates comparable to those achieved in healed alveoli.

The implant fracture rate of the CAMLOG® implants identified in a retrospective study with an observation period of more than 10 years was considerably lower than that of other implant systems. With the given reliability of the CAMLOG® implants the users can apply it with a level of confidence.

High success rate of CONELOG® implants with the Promote® Surface

CONELOG®

With the market introduction of the CONELOG® implants in 2010 clinical studies were initiated to collect data on both safety and performance. The already established features of the system like the sand-blasted and acid-etched Promote® Surface, the Platform-Switching, and the outer geometry were evaluated in numerous mechanical, in-vitro, and clinical studies for the CAMLOG® Implant System and were understood to be the state-of-the-art.

In an observational multicenter clinical study performed in six centers in Germany, the use and performance of the CONELOG® implants for single tooth restorations and fixed partial dentures were prospectively documented in daily dental practice (Ackermann et al. 2020 (20), Cacaci et al. 2019 (21)). In yearly follow-ups the peri-implant status, any complications, and the patient satisfaction from 94 patients with 130 implants were collected with good results: The cumulative survival rate up to 7-year post-loading was 96.6 %. Few further complications like increased bone loss (> 2 mm) in three patients and crown loosening (n=2) and chipping of crown (n=1) on a prosthetic level were reported. At the last follow-up, all patients reported to be satisfied with their restoration. In summary, the results demonstrated successful functional and esthetic outcomes of restorations with CONELOG® implants from both the dentist as well as the patient side.

Survival rates > 95 % were also achieved in other clinical studies and retrospective analyses with CONELOG® implants (Tab. 4).

Success with short implants of 7 mm length

Short implants are a viable option to treat clinical situations with limited vertical bone height. Instead of performing a sinus augmentation and vertical augmentation in atrophic maxilla or mandible respectively which is associated with costs and comes with chance for possible complications short implants can be inserted. However, compared to longer implants, bone loss as well as typically greater crown-implant ratios are potentially more detrimental with short implants.

Survival rates > 95% were also achieved in other clinical studies and retrospective analyses with CONELOG® implants (Tab. 4).

CONELOG® implants with lengths of 7 mm were evaluated in two clinical studies:

In a retrospective study Lorenz et al. 2019 (23) analyzed 30 CONELOG® implants in the posterior maxilla. Short implants were applied to avoid sinus augmentation procedures. After a mean follow-up of 5 years, the implant survival and success rate were 100% and the mean marginal bone loss was minimal (0.5 mm). Also, the peri-implant soft tissue showed no signs of inflammation (probing pocket depth, bleeding on probing). Therefore, the above-mentioned disadvantages of short implants seem not to have a negative influence on the implant success in the posterior area.

A second study by Al-Sawaf et al. (2020) (24) focused on the crown-implant ratio topic and investigated the influence of splinted versus non-splinted fixed dental prostheses on short implants in the posterior mandible. The mean crown-implant ratio was 1.6 ± 0.3. At the 3 years follow-up examination no implants were lost and there was no loss of restoration of the 48 implants noted. The hard and soft tissue parameters in this randomized trial showed no significant differences between splinted and non-splinted superstructures. From loading to 3 years post-loading even a slight bone gain occurred in both groups (splinted: 0.1 ± 0.5 mm and non-splinted: 0.3 ± 0.8 mm). Both studies demonstrated stable peri-implant conditions around CONELOG® short implants in areas of limited vertical bone height and with increased crown-implant ratios and can be used as an alternative to augmentation measures in the posterior area.

KEY TAKE OUTS:
HIGH SUCCESS RATE OF THE CONELOG® IMPLANTS

CONELOG® implants showed high success and survival rates in clinical studies comparable to the ones of CAMLOG® implants. Sharing the same implant surface (Promote®) and outer geometry equal success rates could be expected and were confirmed. The short implants with a length of 7 mm revealed promising clinical results in areas of limited vertical bone height and are a true alternative to bone augmentation measures in the posterior area.

Authors	Year	Follow-up time (yrs)	CONELOG® Implants	Survival in %
Ackermann et al.	2020	7	130	96.6
Cacaci et al.	2019	3	130	98.4
Moergel et al.	2021	5	52	95.4
Lorenz et al.	2019	7	30	100
Al-Sawaf et al.	2020	3	48	100
Fierravanti et al. (22)	2018	3	60	98.3

Tab. 4 Publications reporting mid-term and long-term survival rates of the CONELOG® Implant System

Bone preservation

Factors with an impact on bone remodeling and bone resorption

The peri-implant marginal bone level is an important factor for maintaining the soft tissue around the implant and securing the implant health in general. Contrary to an earlier acceptance criteria of 0.2 mm bone loss per year after the first year, modern implants and treatment plans aim to preserve the bone in the long-term after an initial bone loss which is considered as a biologic response to the implant placement (bone remodeling) (Strietzel et al. 2015 (25)). Based on systematic reviews and meta-analyses, a working group Schwarz et al. (2014) (26) pointed out important facts to consider at implant placement to preserve the marginal bone level: 1) positioning of the machined collar (smooth-rough border) has a direct influence on the initial bone response; 2) subcrestal positioning of the microgap may be associated with higher bone loss; 3) the Platform-Switching concept seemed to prevent or minimize bone loss. The controversial discussed topic related to the impact of Platform-Switching was presented within two meta-analyses (Strietzel et al. 2015 (25), Mishra et al. 2019 (27)). Both publications showed a significant effect of platform-switched implants in reducing peri-implant marginal bone level compared to platform matched implants. In the maxilla the effect was even more pronounced (Mishra et al. 2019 (27)).

Effect of Platform-Switching versus platform matching

The positive effect of Platform-Switching was addressed with multiple studies using both CAMLOG® and CONELOG® implants.

Pre-clinical background information:
The principle of Platform-Switching in the CAMLOG® Implant System was evaluated in a dog study over six months (Becker et al. 2009 (28)). SCREW-LINE Promote® plus implants (diameter 3.8 mm) were inserted according to the standard surgical protocol. Wide-body matching healing abutments and non-matching abutments were connected in a randomized split-mouth design and served either as control or test implants with a circumferential horizontal platform of 0.3 mm, respectively. The histological evaluation after four weeks demonstrated formation of mature woven bone in the gap between the alveolar bone and the implant surface in both groups. A first tendency for crestal bone changes was noticed in both groups. At 12 weeks, mainly mature lamellar bone was found. Bone loss tended to be slightly increased for the control implants compared to the platform-switched implants. The difference between control and test implants regarding the distance between implant shoulder and bone crest was 0.5 mm at the buccal aspect and 0.4 mm at the lingual aspect ($p<0.05$), respectively. A similar result could be observed at six months when remodeling at the alveolar crestal bone seemed to decline. The difference of implant shoulder and bone crest between both groups was approximately 0.3 mm.

The study demonstrated that the CAMLOG® implant design both in its standard and in its Platform-Switching configuration successfully integrated into hard and soft tissue. Bone remodeling as well as soft-tissue adaption appeared to be minimal at the implant-abutment interface during the first eight weeks of osseointegration and was considerably less pronounced after six months resulting in a stable crestal bone level. The platform-switched implants tended to yield better results regarding maintenance of the bone level.

In another dog study, Becker et al. (2007) (29) evaluated the influence of Platform-Switching on crestal bone changes by comparing CONELOG® implants (internal Platform-Switching, referred to as experimental implants) and CAMLOG® implants with matching healing abutments. Bone healing and formation of a junctional epithelium was evaluated histologically up to 28 days. In the implants with standard healing abutments, a significantly increased epithelial downgrowth was noted lingually (1.1 ± 0.6 mm) and buccally (0.9 ± 0.4 mm), which was associated with significant buccal bone loss. In contrast, the Platform-Switching design of the CONELOG® implants prevented apical epithelial downgrowth significantly and reduced bone loss. However, the difference in bone loss between both groups did not reach statistical significance.

Platform-Switching and CAMLOG® implants

CAMLOG®

A research group from Kiel, Mainz (Germany) and Coimbra (Portugal) started in 2010 a randomized controlled multicenter clinical study. Using one implant geometry (CAMLOG® SCREW-LINE, same connection, same outer geometry) and being able to restore the implants with Platform-Switching and platform matching abutments respectively, the team hypothesized that the clinical and radiographic performance of platform switched restorations is not equivalent to platform matched restorations. The Platform-Switching or matching concept was applied from the beginning. Right after implant placement healing abutments with the relevant platforms were placed. With baseline loading standardized intraorally digital radiographs were taken at yearly follow-ups until 5 years post-loading from which the bone level changes were measured and calculated (primary outcome). Secondary outcome measures were implant survival and success, plaque index, sulcus bleeding index, and probing pocket depth measurements. From 68 patients treated with 146 implants 121 could be radiologically evaluated at the end of the study. Within the group with Platform-Switching a bone gain of 0.19 ± 0.53 mm was observed while the group with platform matching had a bone loss of -0.04 ± 0.58 mm, corresponding to a significant mean difference of 0.23 mm ($p<0.025$). Considering the bone level change over time, with Platform-Switching the bone recuperated after the remodeling phase while a stabilization was seen with platform matching. Together with the good results for survival, success, and the soft tissue parameters, the group concluded that patients may benefit from the use of Platform-Switching components in terms of bone maintenance if good hygiene and follow-ups are established (Fig 17). (Messias et al. 2019 (30), Guerra et al. 2014 (31), Rocha et al. 2016 (32))

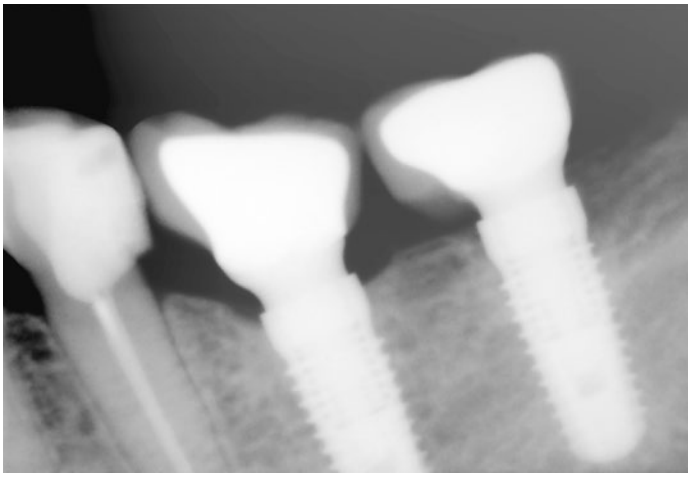


***Fig. 17*_Radiograph of CAMLOG® implants with Platform-Switching, situation 5-year post-loading. Courtesy of Prof. F. Guerra**

Platform-Switching and CONELOG® implants

CONELOG®

With the introduction of the CONELOG® implant system with the integrated Platform-Switching concept, Moergel et al. (2016 and 2021) (33, 34) conducted an observational study based on the study design of Messias et al. (2019) (30) described above. The implants were inserted in the same indication (single crown, posterior mandible) and according to the same treatment protocol. Again, the marginal bone level changes were evaluated using standardized intraoral radiographs up to 5 years post-loading. The results with CONELOG® implants resembled strongly to the ones achieved with the CAMLOG® implants with Platform-Switching (Messias et al. 2019 (30)). After an initial bone remodeling (-0.50 ± 0.40 mm) the marginal bone level recuperated until 5 years post-loading (bone gain of 0.27 ± 0.47 mm) to the level of the implant shoulder, independent of the initial crestal positioning (sub-, epi-, supracrestal).

The biological process with initial bone remodeling after implant placement and subsequent stabilization of the marginal bone level post-loading was also seen in the observational study published by Ackermann et al. 2020 (20). From surgery to loading 0.52 ± 0.55 mm bone was lost. Up to 5 years post-loading the crestal bone remained clinically stable. The mean loss was -0.09 ± 0.43 mm and only 23% of the implants had a noticeable bone loss of more than 0.25 mm.

KEY TAKE OUTS:
PROVEN BONE MAINTENANCE

After a noncritical initial bone remodeling phase, CAMLOG® and CONELOG® implants demonstrated excellent preservation of the crestal bone in the midterm. Post-loading, the marginal bone level around the implants even stabilized better with restorations applying the Platform-Switching concept.

PROGRESSIVE-LINE – First clinical evidence

The PROGRESSIVE-LINE implants were launched to meet the modern treatment concept «immediacy». They were developed based on many years of experience with SCREW-LINE implants. The proven surface and connections were transferred to this implant line. The outer geometry was consistently designed for situations requiring high primary stability, for example for immediate implantation in extraction sockets, as well as for implantation in very soft bone. The thread design – a saw tooth thread with extended flank height – led to an optimized distribution of axial forces and showed reliable bone integration in a histologic and histomorphometric analysis after 4 months of healing (Iezzi et al. 2006 (35)). The outer geometry of the PROGRESSIVE-LINE implants is conically designed in the apical area knowing the influence of tapered implants on the primary stability (36). The insertion torque can still be influenced with the appropriate drilling protocol. In the coronal area, a crestal anchoring thread gives support for optimal hold with limited bone height, e.g. in sinus lift procedures (Fig. 18).

Clinical appliance with sinus lift augmentation

The suitability of the PROGRESSIVE-LINE implants for shortened treatment protocols i.e. immediate loading and in combination with simultaneous sinus floor augmentation procedures was evaluated by Ruppin in a retrospective case series after one year in use (Ruppin 2020 (37)). All 166 implants achieved primary stability and the mean insertion torque was 31.6 ±

5.4 Ncm. The torque was controlled using the appropriate drilling protocol with dense bone drill or tap in situations with exceeding torques. Sinus augmentation procedures with direct implant placement were performed successfully in 149 cases. Even with residual bone height of 2.4 mm in combination with external sinus lift the implant showed primary stability. More importantly, no complications and no implant losses were noted during the observation period. The author concluded that with the possibility to control the insertion torque with the flexible drilling protocol the implant system can be used in every indication and bone quality.

Immediate implant placement in extraction sockets

The use in extraction sockets (immediate implant placement) and immediate loading was analyzed in a small case series with 11 CONELOG® PROGRESSIVE-LINE implants by Conserva (2019) (38). Insertion torques in a range from 36 to 55 Ncm were noted and high ISQ values between 74 and 87 were measured. Accordingly, the primary stability was high enough to restore the implants immediately.

Use in soft bone

In very soft bone the drill protocol for PROGRESSIVE-LINE implants demands an under dimensioned preparation of the implant bed to achieve adequate primary stability. The primary stability of two different tapered implant systems (CONELOG® PROGRESSIVE-LINE and ICX Active Master, Medentis) in soft bone was assessed by RFA (ISQ) and Periotest in an experimental study using bovine ribs (Krischik et al. 2021 (39)). Comparing the results of the CONELOG® implants when inserted according to the standard drilling protocol better primary stability could be achieved with the under preparation drilling protocol allowing the implants to be immediately loaded.

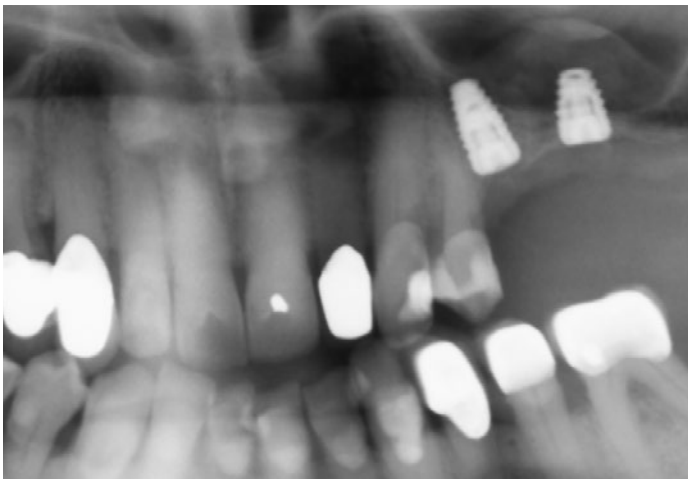


Fig. 18 **PROGRESSIVE-LINE implant placed in posterior maxilla with simultaneous sinus lift. Courtesy of Dr. R. Polsbroek**

KEY TAKE OUTS: PROGRESSIVE-LINE

The PROGRESSIVE-LINE implants are consistently designed to develop high initial stability. First clinical cases confirmed an excellent primary stability of the PROGRESSIVE-LINE implants based on insertion torque, ISQ measurements, and Periotest in the intended indications soft bone, extraction sockets, and with sinus lift procedures (Hermann (40), Conserva (38), Ruppin (37), Krischik et al. (39)). The crestal anchorage thread seem to make it possible to place the implant with primary stability in patients with low residual bone height of less than 3 mm (37).

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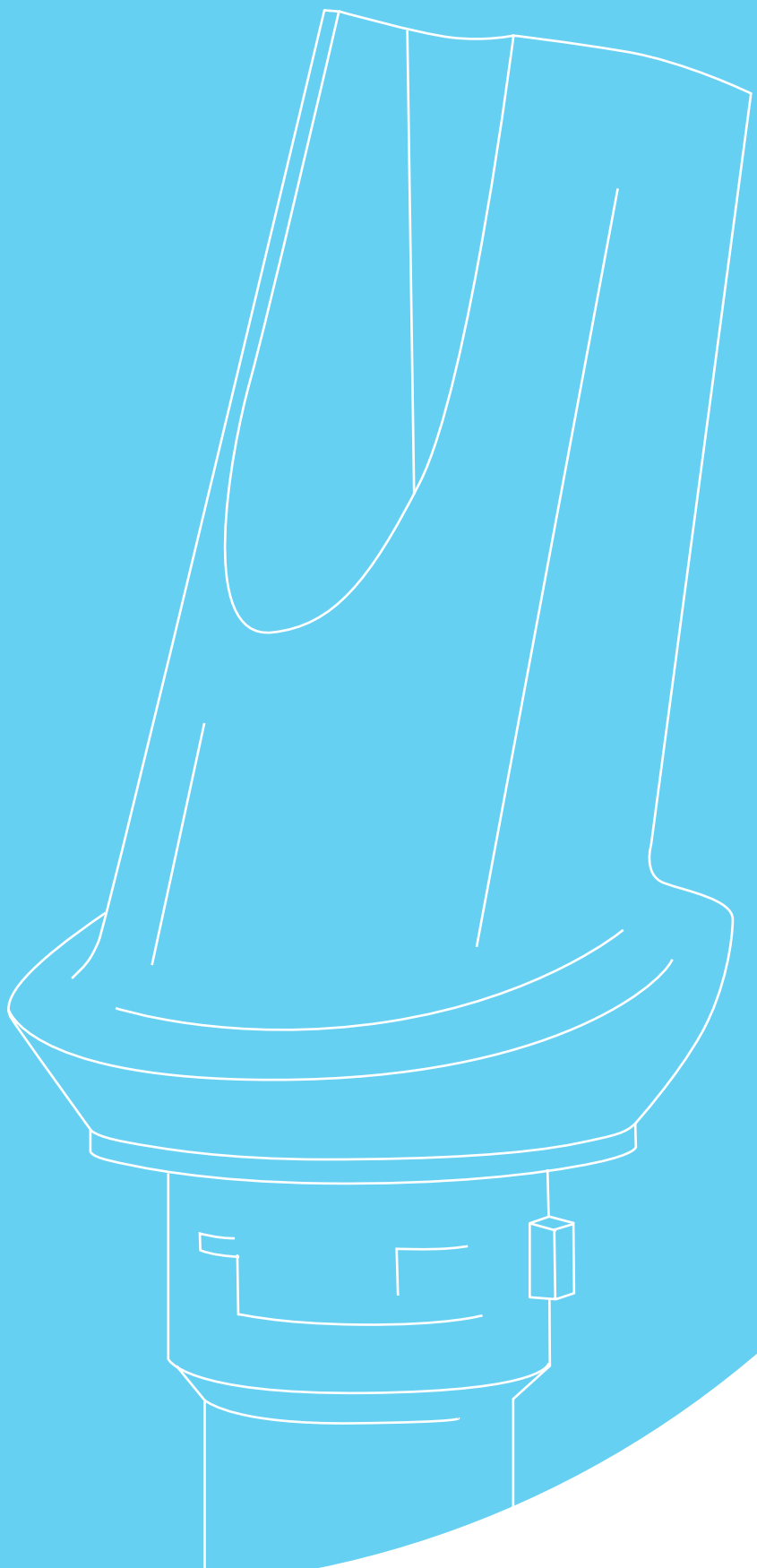
Prosthetic restorations: scientifically based treatment options



Modern treatment protocols like immediate and early loading allow functional and aesthetic outcomes with high clinical success in multiple indications.

Dental implant restorations can be differentiated in three main categories: crowns, bridges, and dentures. They can replace any number of missing teeth fixed to dental implants. To restore a dental implant multiple prosthetic treatment solutions and abutments can be selected by the dentist/prosthodontist. Modern treatment protocols focus on immediate restorations. With improved implant geometries and surface technologies better implant stability and faster osseointegration could be attained. Thanks to these further developments the possibility to shorten the healing time and immediately restore the implants was created. This allows to treat the patients with fewer visits and to satisfy their need to have immediate functional and aesthetic restorative solutions. A consensus report by Schwarz et al. (2016) documented in general high survival rates for immediate and conventional loaded implants (1).

For edentulous patients, implant-supported overdentures with four implants in the mandible and six implants in the maxilla are recommended as the standard treatment. Removable overdentures with retention methods like ball abutments, Locator abutments, or bars supported by implants with Promote® Surface were scientifically evaluated in various publications in the past. A tendency to fixed prostheses may be explained by the fact that the better stability and retention as well as the comfort led to more satisfied patients.

The following publications impressively document the clinical success of immediate and early loading protocols as well as fixed complete prostheses on CAMLOG® and CONELOG® implants. Additionally, interesting facts regarding fabrication of the prostheses are given.

Loading protocols

Clinical success with the immediate loading concept

CAMLOG®

De Lange et al. presented at the EAO Congress 2010 their data of four treatment protocols (2): CAMLOG® implants in group 1 and 2 were placed in fresh extraction sockets followed by either immediate or delayed loading; in group 3 and 4 the implants were inserted in normal healed bone with immediate or delayed loading, respectively. They examined the risk ratio of failure for several parameters and concluded after five years of follow-up that individual risk factors such as smoking, inflammation from cement excess, or endodontic treatments were much more critical to success than the time points of implant placement and loading.

Ricken et al. retrospectively collected clinical data from immediately loaded CAMLOG® implants in edentulous patients with a follow-up of up to five years (3). At least four abutments were always splinted together with a provisional on PEEK abutments. After final loading no implants were lost giving a survival rate of 99.2%. Commonly with de Lange et al., the authors concluded that with adequate bone quality and quantity at the implant site and good primary stability high success rates can be achieved with immediately loaded implants in edentulous patients.

CONELOG®

In a randomized split-mouth design in 16 patients immediately loaded CONELOG® implants were directly compared to delayed loaded implants with a healing time of eight weeks (Erhan Cömlekoglu et al. 2018) (4). In the test group of the immediately loaded implants the definitive abutment was placed from the beginning and was digitally restored while in the control group repeated disconnections and reconnections had to be done. At the 12 months control the test group exhibited significantly reduced vertical bone loss. The soft tissue health and aesthetics as well as the complications rate was similar in both groups.

The one abutment-one time concept

The concept of placing the definitive abutment from the beginning without detaching it again, called «one abutment-one time protocol», as applied in the study described above, is believed to preserve the peri-implant soft and hard tissue in contrast to multiple disturbance of the peri-implant region by exchanging healing caps, impression posts, and abutments.

This was shown in a pre-clinical dog study using CONELOG® implants with two exchanges of abutments (Becker et al. 2012) (5). The abutments were disconnected and reconnected four and six weeks after implant insertion or left undisturbed. Histological evaluation at eight weeks demonstrated that abutment exchanges resulted in a disruption of the mucosal seal as well as in an increased apical extension of the junctional epithelium and bone resorption compared to undisturbed healing. The authors concluded that repeated abutment manipulation may increase soft and hard-tissue changes in implants with Platform-Switching design.

In the clinic, a review by Atieh et al. (2017) found significant differences for marginal bone level changes in favor of the «one abutment-one time protocol» but on the same time questioned the clinical significance (6). A deeper insight in the following clinical studies investigating the concept with Camlog products may give a clearer picture.

Similar to the study of Erhan Cömlekoglu et al. as described above a study team from the University of Complutense, Madrid, investigated in a randomized clinical study the effect of placing the definitive abutment right at the time of implant placement compared to a healing time of 6–12 weeks (Molina et al. 2017, Fierravanti et al. 2018) (7, 8). The outcome of the soft and hard tissues were assessed in detail by measuring the marginal changes of the gingiva, the papillae, and the bone level changes also in relationship to the adjacent teeth. The patients received CONELOG® implants with integrated Platform-Switching in the posterior maxilla or mandible. Molina et al. (2017) reported the one-year follow-up data while Fierravanti et al. (2018) presented the three years follow-up at a congress. The group with connection and disconnection of the healing abutment showed a statistically significant increased bone loss compared to the group with definitive abutments placed at surgery. The difference was established during the healing phase up to 6 months post-loading. Afterwards both concepts showed stable bone level changes and even a slight bone gain from the one year to three years follow-up. The soft tissue parameters, however, demonstrated no statistical significances between both groups.

From a clinical side, the one abutment-one time concept applied with CONELOG® implants seems to preserve the bone better during the initial remodeling phase.

CAMLOG®

Within a study performed by Edinger et al. (2021) the impression was taken at the time of implant placement and after a submerged healing of two to three months the definitive crown bonded to a titanium base was placed at the second stage surgery (9). Three different implant brands (CAMLOG® SCREW-LINE (61%), Straumann, Thommen) were included in this retrospective study. The outcome focused on the pink esthetic score including formation of papillae and the patient satisfaction with the treatment. The efficient procedure with only three treatment sessions to finally restore the gap and the good adaption of the mucosa to the final restoration led to a very high acceptance and satisfaction rate by the patients after three years of follow-up.

Early loading in aesthetic zone

In the anterior maxillary region, the patients have a need for early functional and aesthetical solutions. Kahramanoglu et al. (2019) provisionally restored CAMLOG® implants in the anterior region up to the first premolar after a healing time of three weeks. This was then exchanged to the final restoration after eight weeks (10). The clinical and radiological evaluation parameters were collected at yearly follow-ups until three years post implant placement. The early loading concept in the aesthetic zone with single tooth restorations showed promising results with only minor bone loss of 0.47 ± 0.75 mm and a survival rate of 100%. The early functional loading had also no negative effect on the soft tissue stability.

KEY TAKE OUTS:
LOADING PROTOCOLS

Following an appropriate treatment protocol with adequate implant stability immediate loading, early loading as well as conventional delayed loading led to success of the implant restorations from the point of view of hard and soft tissue integration. The possibility of immediacy has positive side-effects like shortened treatment duration, improved aesthetics, and high patient acceptance.

Edentulous situation

Fixed full-arch restorations on four implants in the mandible

CAMLOG®

Treatment of edentulism with dental implants increases the quality of life and functionality for patients affected. A working group at the Consensus Meeting of the Oral Reconstruction Foundation discussed and issued clinical recommendations for implant-supported full-arch rehabilitations in edentulous patients based on elaborated systematic reviews, e.g. about how to treat an edentulous mandible or maxilla and the influence of material selection and attachment type (Schwarz et al. 2021) (11).

Prof. Gerald Krennmair and Dr. Stefan Krennmair from Austria published various papers on the topic of four implants-supported fixed prosthesis in the mandible in edentulous patients which has become the predominant method for fixed rehabilitations. The fixed overdentures were in all cases screw-retained on CAMLOG® SCREW-LINE implants.

The common concept of placing four implants in the edentulous mandible is to place the anterior implants in an axial direction and the distal ones tilted. Krennmair et al. 2016 compared with two groups the clinical outcome of only axial implants versus two axial/two distal tilted implants (12). The follow-up of the restorations with cobalt-chromium framework covered three years. The evaluation showed no implant loss nor major prosthetic complications (fractures). The only significant difference found was for plaque index and calculus index when comparing the posterior implants of both groups. All other parameters like bone level change, pocket depth, bleeding index, and gingival index as well as from a complication's perspective showed no differences and a good clinical outcome for both concepts.

In a retrospective review including 38 patients 152 implants were analyzed (Krennmair et al. 2013) (13). After a healing time of 8 to 12 weeks splinted superstructures consisting of cobalt-chromium were fixed to the implants. The survival and success rates on the implant level after a follow-up time of five years were very high with 100 % and 98.6 %, respectively. The prostheses, however, required more maintenance like repairs, especially of resin teeth fractures and relining of the base. Also, they had to be removed twice during the follow-up time for professional cleaning activities.

Another investigation examined the outcome of immediately loaded distally cantilevered fixed mandibular prostheses on four implants (Krennmair et al. 2014) (14). The implants were placed either in fresh extraction sockets or healed sites and immediately restored with a fixed prosthesis. After three months the definitive resin veneered prosthesis with a metal framework was integrated. At two years follow-up no implants were lost. Again, complications were more often found on the prosthetic level. In total, five provisional dentures fractured. No fractures occurred with the definitive prostheses. Interestingly, the implants placed in fresh extraction sockets experienced less bone loss than the implants placed in healed sites.

In another prospective study with a follow-up time of five years but with the same design and study procedure, the implants showed still a survival of 100% (Krennmair et al. 2022) (15). The marginal bone level change with the implants placed in fresh extraction sockets, however, was different. The initial bone loss was more pronounced than with the implants placed in healed sites. After the one-year follow-up, the bone loss was again similar and not statistically significant different between the groups.

Lastly, the same study team evaluated patient specific risk factors affecting the peri-implant marginal bone loss in full-arch restorations supported by four implants in the mandible (16). They found a time-depending reduction of the bone and additionally, a significant correlation between smoking, underlying cardiovascular disease or rheumatic disorder, presence of plaque and alterations of peri-implant marginal bone. Other factors like age, gender, diabetes, position of implants, etc. showed no influence. The survival rate of implants and prostheses was 100 % after three years in situ.

KEY TAKE OUTS:
FIXED RESTORATIONS ON FOUR IMPLANTS

The restoration of the edentulous mandible with four implants supporting fixed distal cantilevered prostheses showed very high survival and success rates up to five years follow-up irrespective of the time of implant placement and the implant direction in the jaw (axial, tilted). With appropriate hygienic measures and regular follow-up visits these restorations may be successful also for the long-term.

COMFOUR® System: Occlusally screw-retained prosthetics

The COMFOUR® System is indicated for several treatment options as a multivaried concept with options for occlusal screw-retained bar, single tooth, and bridge restorations on straight and angled bar abutments. It offers the possibility for immediate and comfortable dentures. Beretta et al. (2021) and Schnutenhaus et al. (2018) described in their overview work including case reports the use of the system in combination with the digital workflow in complete edentulous situations (17, 18). Both authors planned the implant positions using CBCT scans and a software and printed surgical guides to place CONELOG® SCREW-LINE implants guided. Berretta et al. used a cast-free process with intraoral scanning to plan and produce the provisional restoration with CAD/CAM while Schnutenhaus chose to use casts for scanning the oral situation. After guided placement of four or six implants in both jaws the straight or angled bar abutments were immediately placed and provisionally restored only few hours later. After a standard healing period of three to six months the definitive restoration was placed. Both reports confirmed a successful immediate restoration of the patients with the COMFOUR® System which increases the patients' comfort and quality of life.

Ongoing clinical studies may further confirm the success with the COMFOUR® System.

KEY TAKE OUTS:
COMFOUR® System

The COMFOUR® System especially in combination with a digital workflow allowed a successful immediate restoration of the patients and increased the patients' quality of life in case reports.

Titanium bases

Pre-treatment of bonding surface, restorative possibilities as hybrid abutment or hybrid abutment-crown

Nowadays, the use of titanium bases in combination with CAD/CAM technologies is a common treatment option for single tooth restorations. The benefits of screw-retained restorations are less cement excess, possibility of individualized emergence profiles, and stable metallic implant-abutment connections. Additionally, the digital workflow allows for efficient treatment protocols with reduced visits and costs and an excellent aesthetic outcome.

In a pre-clinical test setup, a research group from the University of Geneva investigated the stability of restorations with CONELOG® titanium bases. The testing specimens were artificially aged by means of thermocycling and mechanical loading in a chewing simulator. Afterwards, the retention forces between the crowns and abutment were tested by using a pull-off test or the samples were loaded until fracture.

Pitta et al. (2021) evaluated the effect of different sand-blasting particle sizes while pretreating the bonding surface of the titanium bases before cementation with crowns made from lithium disilicate (19). Airborne particle abrasion demonstrably increased the retention forces and stability between titanium bases and crowns compared to untreated surfaces. The use of 50 µm Al2O3 showed the most stable connections and could be recommended by the team.

Two further studies by Pitta et al. (2019 and 2021) evaluated the stability of different crown materials and the use of meso-abutments bonded to titanium bases.

In the first study customized zirconia meso-abutments bonded to titanium bases were restored with different crown materials: lithium disilicate, zirconia, and polymer-infiltrated ceramic network (PICN) (20). The control group consisted of a customized titanium abutment with a lithium disilicate crown. After thermomechanical testing, no failures were observed in any group. The static failure test revealed a statistically significant higher bending moment in the zirconia group. But all tested combinations reached values that would withstand the oral loading during biting. The study team attested very good stability to all crown materials tested in combination with hybrid abutments.

The second study examined monolithic lithium disilicate abutment-crown, zirconia abutment-crown, or polymer-infiltrated ceramic network (PICN) abutment-crown directly bonded to titanium bases (21). Additionally, a group with lithium disilicate abutment-crown bonded to a customized titanium abutment was tested. After aging, the two groups with lithium disilicate abutment-crowns revealed no fractures and less complications (e.g., loosening) than the other group. The authors recommended to use monolithic lithium disilicate abutment-crowns due to their good mechanical and bonding outcomes in case of a hybrid abutment-crown complex.

KEY TAKE OUTS:
HANDLING OF TITANIUM BASES

In order to achieve good retention between the crown or a meso-abutment with the titanium base pre-treatment of the bonding surface with sandblasting (50 µm Al2O3) demonstrably increases the stability. Titanium bases can then be restored with lithium disilicate, zirconia, and PICN that withstand the oral loading during biting.

Fixation and patient-reported outcome of restorations

Stability of cemented vs screw-retained restorations

The prosthetic reconstructions can be either screw-retained on implants or on designated abutments or cemented on standardized or customized abutments. Both retention methods can be used with single crowns, fixed partial dentures, or with full-arch reconstructions, but each have their own benefits and drawbacks. According to a systematic review by Sailer et al. (2012), cemented reconstructions may be easier to manipulate in the mouth but, on the other hand, experience more biological complications due to the difficulty to remove excess cement which is deemed associated with inflammatory processes in the peri-implant tissues (22). With screw-retained reconstructions more technical problems, like loss of retention, loosening, and chipping associated with the open screw access hole, could be observed. However, they can easily be removed in case of problems and biological complications are unlikely. However, the review could not show significant differences related to the survival of both type of retention after five years in function.

Obermeier et al. (2017) performed a mechanical test using artificial aging with thermal cycling and dynamic loading (23). The aim was to compare different veneering concepts on zirconia molar crowns either cemented or screw-retained with titanium bases to CONELOG® implants. They concluded that the mode of retention had no influence on the fracture strength of the reconstruction. A fact which could clinically be shown by Cacaci et al. (2017) (24). They analyzed any influence of screw-retained reconstructions compared to cemented ones in a clinical study with 58 patients. A mixture of 114 CAMLOG® and CONELOG® SCREW-LINE implants in the molar or pre-molar region were randomly assigned to a specific retention group. After a healing period of four months, the crowns made from zirconia with sintered veneering caps were placed and followed-up for three years. The results revealed no significant differences between screw-retained and cemented reconstructions regarding soft tissue health and technical failures. During the observation time, no implant loss nor crown fracture could be observed and only in 1.8% of all cases veneering fractures occurred. The authors pointed out the importance of checking by radiographs for excess cement after placing the definitive reconstruction. Then, both retention methods will show high success rates.

KEY TAKE OUTS:
CEMENTED AND SCREW-RETAINED RESTORATIONS

Clinically, cemented and screw-retained restorations on CAMLOG® or CONELOG® implants revealed successful outcomes and no differences regarding survival, soft tissue health and technical failures. Both have their justification in clinical application.

Patient-reported outcome measures (PROMs) of CAMLOG® and CONELOG® implant-supported restorations

Patient satisfaction must be regarded as one of the most important factors for the success of the chosen treatment concept. A plenum of publications reported if the patient's expectations with the restorations were met regarding aesthetics and functionality. With a categorical scale the ability to chew, the ability to taste, the comfort, the appearance, and the general satisfaction was assessed by the patients at different time points after loading. Restorations with CAMLOG® SCREW-LINE in the observational study by Beschnidt et al. achieved in every category and at every timepoint up to five years follow-up more than 98% of excellent or good satisfaction (25). With CONELOG® SCREW-LINE implants equally high numbers of satisfaction were reached. Ackermann et al. reported 87.5% of the patients to be highly satisfied and 12.5% to be satisfied with their restorations after 5 years in situ (26). Also, none of the patients within the study of Moergel et al. reported to be dissatisfied after a wearing time of five years (Fig. 19) (27).

The gathering of patient-reported outcome measures is supplementing other clinical parameters and confirmed the treatment success with CAMLOG® and CONELOG® SCREW-LINE implants in the chapters before.

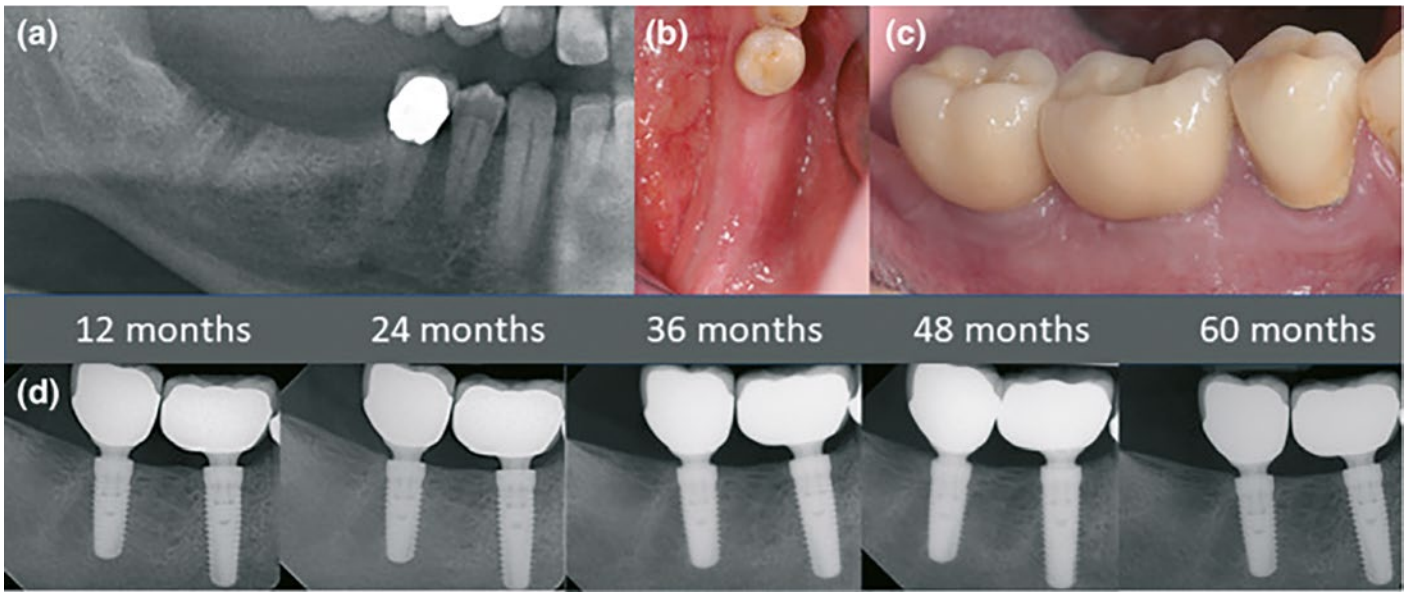


*Fig. 19*_Clinical example with the initial orthopantomography (a), the clinical view intraoperatively (b) and the prosthetic rehabilitation after 60 months (c). In (d) the bone levels as presented annually (Moergel et al. 2021, reproduced with kind permission of John Wiley & Sons, Inc, USA)

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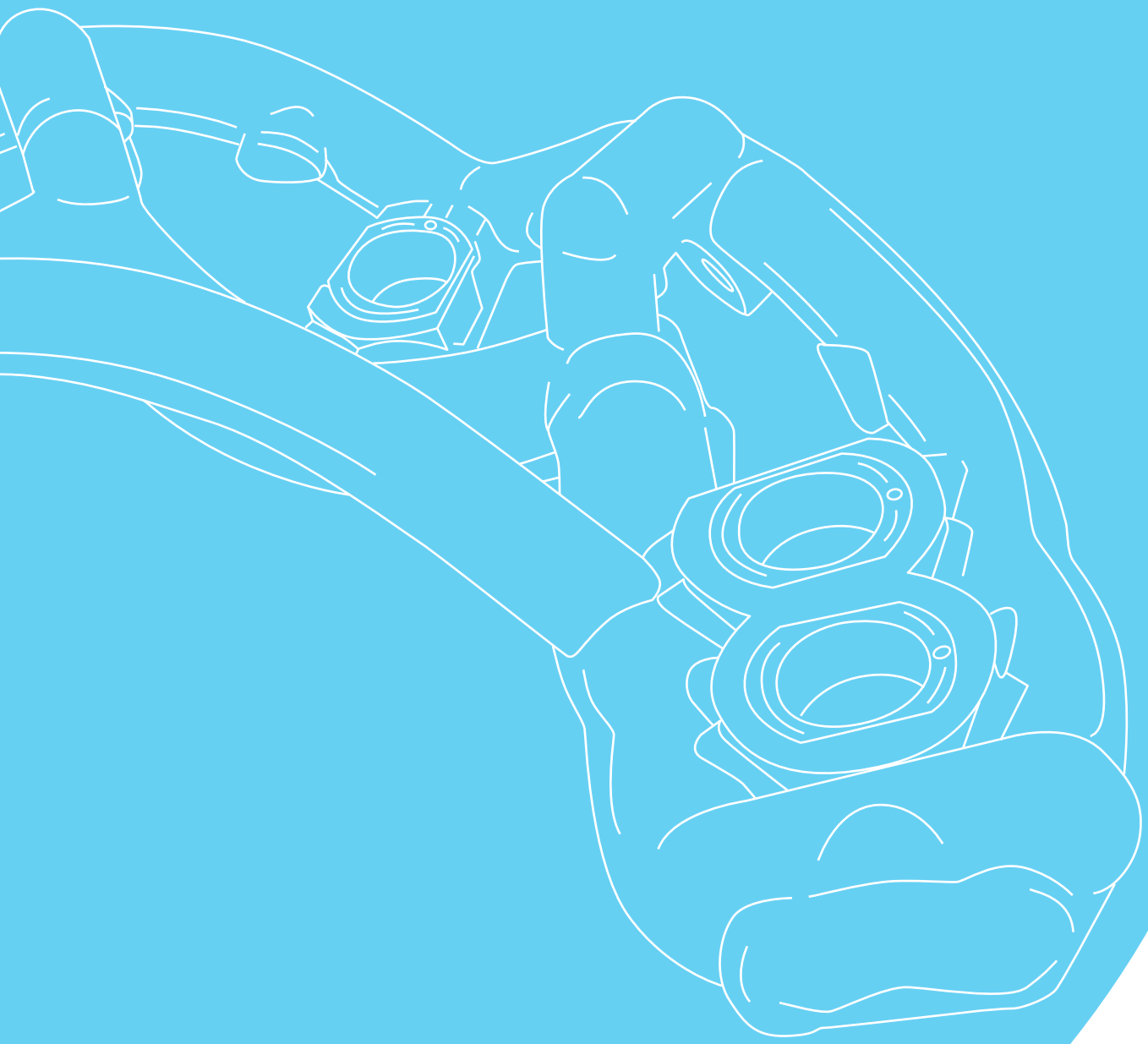
Digital workflow



Use of digital workflows in implant treatment with advantages in case planning and execution lead to more predictable implant and restoration outcomes.

Guided surgery and CAD/CAM workflow

The possibility of accurately digitizing the oral situation by cone beam computed tomography (CBCT) and intra-oral scanning allows the surgeon and prosthodontist to virtually plan the implant position as well as the prosthetic restoration. With this progression, the patients can be treated less invasively and often with less treatment visits. The 3D based diagnosis of the existing bone and the anatomical situation, e.g., the inferior alveolar nerve, helps for an optimal position planning of the dental implant and for a predictable prosthetic outcome.

For the Guided Surgery procedure with the support of a surgical drill template, guiding sleeves, guided drills, instruments, and implants are available in the portfolio of the CAMLOG® and CONELOG® SCREW-LINE as well as PROGRESSIVE-LINE Implant Systems. The most commonly used implant planning software include the dimensions of Camlog's guided implants. Secondly, for the preparation of individualized CAD/CAM abutments and restorations, system specific CAM blanks are available, in some countries even including CAD/CAM services (e.g., DEDICAM®).

Accuracy of the CAMLOG® and CONELOG® Guided Systems

During the multi-step process in the planning of an implant position from the CBCT, through the virtual planning in a software and the fabrication of a drill template inaccuracies during transfer may occur. A study group around Schnutenhaus et al. tested the accuracy of Camlog's guided implant system with a procedure of superimposing the data of the virtually planned versus the actual achieved implant position and published several papers. Measurements were done on the 3D deviations between the implant positions relating to the radial deviation (implant shoulder and apex), the axial deviation (angular) and the vertical height deviation (Fig. 20).

In a retrospective evaluation of 56 patients with 122 CAMLOG® SCREW-LINE implants, the aim was to assess the 3D deviations of the implant position as a function of type of edentulous space, residual dentition, and surgical protocol (gingiva punch versus full flap surgery) (1). A regression analysis revealed only one significant impact: i.e., the presence of adjacent natural tooth had an influence on the height and angle of the implant position. The overall results showed adequate accuracy of template-guided implant placement which were in the same range as seen in other studies. Due to the possible deviations, it was highlighted to keep appropriate safety distances from anatomical structures at risk while planning the implant positions. A conclusion which was also made by Beretta et al. 2014 who investigated the accuracy of CAMLOG® Guide in situations of treating edentulous jaws with drill templates fixed with surgical pins (2).

With CONELOG® SCREW-LINE implants further influencing factors like the region of implant placement, the dimensions of the implants, their primary stability, and the use of alveolar ridge preservation methods were examined (3). Before implant planning, sixty patients were randomized to either receive an alveolar ridge preservation after tooth extraction or the alveoli were left to heal spontaneously. Due to several dropouts, only the data of 48 patients could be superimposed and measured. The implant diameter, implant length, and the primary stability showed a significant effect, but only on one dimension of the implant position. Longer implants, implants with larger diameters, and high insertion torques seem to have an effect on the transfer accuracy. However, still a high degree of accuracy could be achieved with template-guided implant placement. The accuracy was considered superior to freehand implant placement and a clear benefit from a prosthetic point of view.

The aim of the third study was, to examine the accuracy depending on the macro design of the implants (4). The freshly marketed guided CONELOG® PROGRESSIVE-LINE implants were compared to CONELOG® SCREW-LINE implants. Again, a high level of accuracy was obtained. The only significant difference was seen in the height of the implants. However, the authors concluded that a learning curve of the user when preparing the implant beds will lead to an increased accuracy of the position.

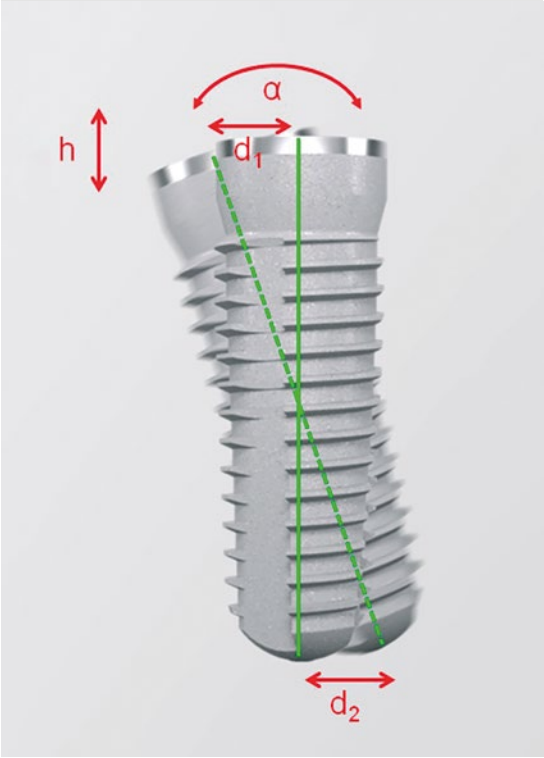


Figure 20 **_3D measurement methodology: Metric analysis of the implant position: three-dimensional deviations between the center axis of the planned and actual implant positions as measured at the implant shoulder (d1) and at the implant apex (d2), the vertical deviation measured at the implant shoulder (h) at the center of the coronal implant surface, and the deviation of the planned and actual implant axes (α) (adapted from Schnutenhaus et al. 2018)**

Chairside digital workflow

A chairside digital workflow saves time for the patient by providing the dental restoration within one visit. A randomized clinical trial performed by Zhang et al. (2019) evaluated quantitatively the benefits of the chairside digital workflow (5). The study compared the clinical adjustments and the time consumption on fabricating and placing a posterior single crown between chairside digital workflow and hybrid digital workflow. The chairside digital workflow included intraoral scanning, CAD/CAM fabrication of a lithium disilicate crown, and mounting the restoration within one visit. With the hybrid digital workflow, the position of the implants was transferred via impression taking to a stone model which was then scanned to design the crown. The zirconia crown was milled and sintered by outsourcing manufacturing and individually veneered and finalized in the lab. Afterwards the restorations bonded to titanium bases were placed on CAMLOG® SCREW-LINE implants in a second visit. After the clinical fitting and adjustments to obtain adequate interproximal and occlusal contacts the 3D deviations of the pre and post crown (superimposed data file) were measured. The outcome of 33 patients showed statistically significant differences. The chairside digital workflow resulted in fewer adjustments and especially precision of the occlusal surface. Additionally, the total time consumption was a fifth of the hybrid digital workflow (Tab. 5).

Although both workflows led to successful treatment results, increased digitized steps seem to be the future in implant dentistry and save treatment time for the patient.

	Test group Chairside digital workflow	Control group Hybrid digital workflow
Implant restorations	n = 17	n = 16
Median adjustment count*	2.00 ± 1.09	3.00 ± 1.05
Total active working time (min)	92.3	146.3
Total time for workflow (min)	113.7	684.5

Tab. 5_ **Overview of adjustments and time consumption for digital workflows (adapted from Zhang et al. 2019)**

*** p = 0.001**

KEY TAKE OUTS:
DIGITAL WORKFLOW

With the use of digitized processes and guided surgery the patients can be treated more gently and time and cost effectively. Template-guided implant placement was proven to be accurate for the CAMLOG® and CONELOG® Implant System and can be recommended to achieve predictable prosthetic restorations.

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