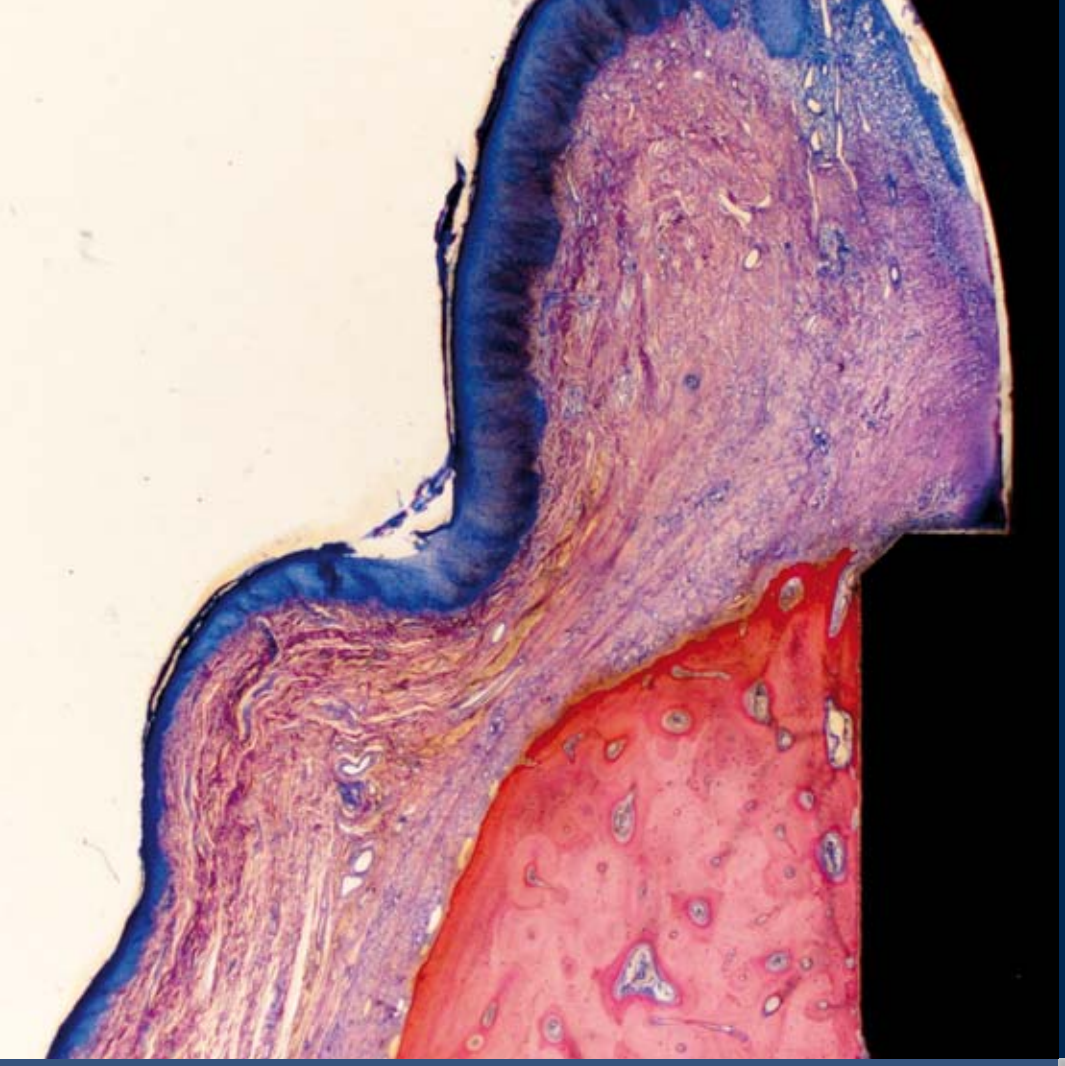
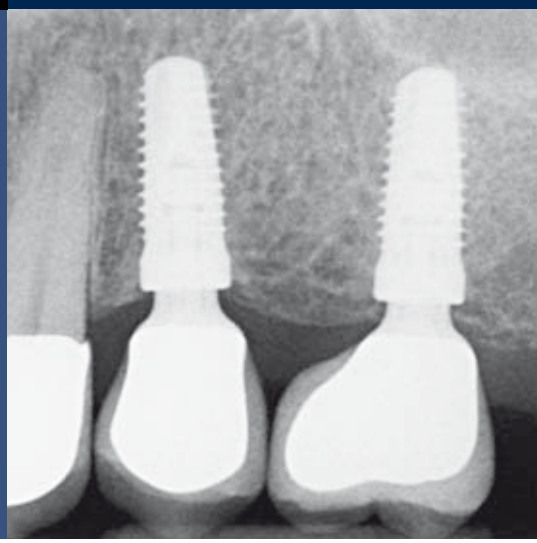


CAMLOG AND SCIENCE



a perfect fit™

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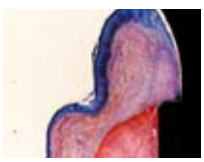
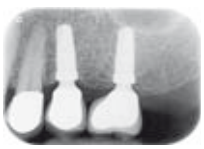
COVER PICTURES



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



CONELOG® SCREW-LINE Implants Promote® plus (Ø 4.3 mm, length 11 mm) located in the posterior maxilla one year post-loading.

Courtesy of Dr. M. Schlee

TABLE OF CONTENTS

THE CAMLOG® AND CONELOG® IMPLANT SYSTEMS

The CAMLOG® Implant System with its patented butt-joint Tube-in-Tube™ connection is one of the world's leading implant systems. Since its market introduction in 1999, more than two million implants have been inserted. To satisfy the customer demand, CAMLOG Biotechnologies AG developed and introduced in 2011 the CONELOG® Implant System, which features the same outer "SCREW-LINE" geometry as the CAMLOG® Implant System, but offers the tapered implant-abutment connection CONELOG® (patent pending; Fig. 1). One of the key benefits reflected in both implant systems is the simplicity of their prosthetic handling.

From the beginning on, CAMLOG Biotechnologies AG has set high standards in scientific documentation of all essential properties of their implant systems either independently by their Research and Development or as a sponsor. Furthermore, their effort in supporting research projects in basic as well as in applied science was further strengthened in 2006 by the CAMLOG Foundation (www.camlogfoundation.org). This permanent support has been well recognized by the yearly growing number of articles published in highly ranked international scientific journals (Fig. 2).

This brochure gives an overview on the numerous published scientific articles relating to the CAMLOG® and CONELOG® Implant Systems.

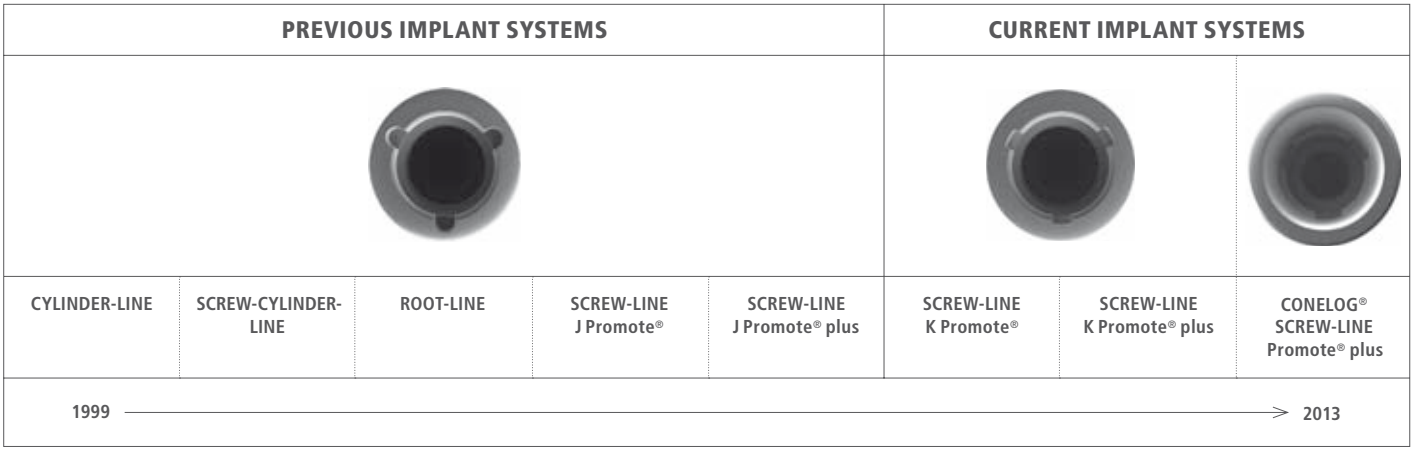


Fig. 1: CAMLOG® and CONELOG® history: Development of the implant-abutment connection

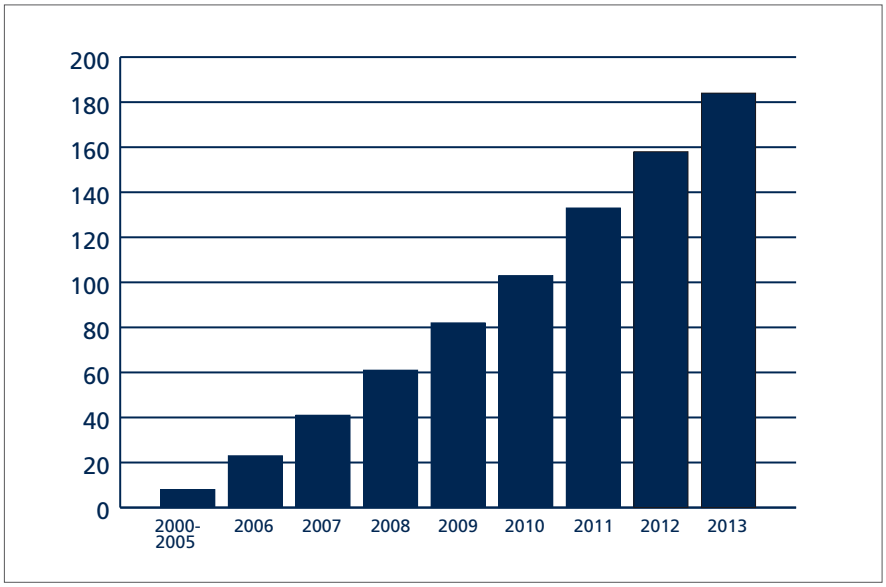
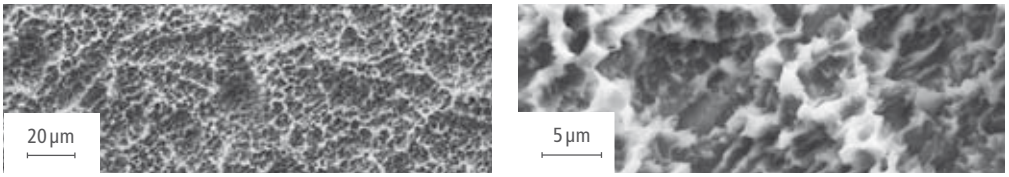


Fig. 2: Cumulated scientific publications 2000 – 2013

CAMLOG® SCREW-LINE AND CONELOG® SCREW-LINE IMPLANTS: SIMILARITIES AND DIFFERENCES

Implant system	CAMLOG® Implant System		CONELOG® Implant System
Implant	CAMLOG® SCREW-LINE Promote®	CAMLOG® SCREW-LINE Promote® plus	CONELOG® SCREW-LINE Promote® plus
			
Geometry	Conical, threaded screw with cylindrical neck		
Rough enossal surface	The state-of-the-art, sand-blasted, acid-etched Promote® surface favors rapid and stable osseointegration. Evidence for this derives from cell culture experiments, animal studies and clinical trials.  Different magnifications of scanning electron microscopy pictures of the Promote® surface		
Machined surface at implant neck	1.4 mm	0.4 mm	no
Surgical drill sequence	Due to the identical geometry of all three implant types, one surgical kit and an identical surgical drill sequence can be used.		
Platform switching	Platform-switched or non-platform-switched restoration possible		Only platform-switched restoration possible
Implant-abutment connection	 The Tube-in-Tube™ (patented) connection contains coronal a 1.9 mm long cylindrical tube with three symmetrically arranged grooves followed by a smaller cylindrical longer tube. When inserting the abutments, their tubular extension towards the apex affects the simple, easy and safe orientation in the longitudinal axis of the implant before the three cams lock into the grooves of the implant. By rotation, the correct abutment position is easy to find. The CAMLOG® Tube-in-Tube™ connection was subject of intensive research and comparative studies with other well-known implant systems demonstrating above average results for fitting accuracy and leakage prevention for the Tube-in-Tube™ connection.		 The CONELOG® (patent pending) connection consists of a coronal 1.5 to 1.9 mm long, self-locking 7.5° taper for reliable transfer of forces and torques followed by a short cylindrical segment with three symmetrically arranged grooves. The grooves of the implant fit perfectly in the corresponding cams of the abutment enabling precise abutment positioning.
Prosthetics	Small prosthetic units, CAD/CAM based restorations, intraoral bonding to obtain passive fit, passive fit bar technology, and high-precision adaptation of the secondary parts for electroplated telescopic crowns are all standard with the CAMLOG® and CONELOG® Implant Systems.		

Tab. 1: Similarities and differences of the CAMLOG® and CONELOG® Implant Systems

STABILITY OF IMPLANT-ABUTMENT CONNECTIONS

Stability of the implant-abutment connection is of high importance for the long-term success of implant-based prosthetic reconstructions. 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.

PRECISION IN REPRODUCING THE ABUTMENT POSITION

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 since during superstructure fabrication, multiple repositioning of the implant components is required.

Reinert and Geis-Gerstorfer (2007) studied the fit of the dental prosthetic components of the CAMLOG®, OSSEOTITE® Certain, BPI, FRIALIT® and Straumann synOcta® implant systems in vitro. In this study, the situation of an edentulous maxilla was simulated with the aid of titanium demonstration models. Four implants were distributed over the titanium models in the shape of a polygon (slope of implant axis: 15° or 20°) and bonded with a bonding adhesive. Impressions were taken from each titanium model under standardized conditions, and plaster casts were fabricated. The precision of the systems was investigated by measuring six distances between the four connected abutments of the demonstration models using a 3-D coordinate measuring machine (Fig. 3). These measured values vary depending on design and fabrication precision. The measuring variance is an indicator for the accuracy of fit of the entire system including implant, impression post, lab analogue and abutment.

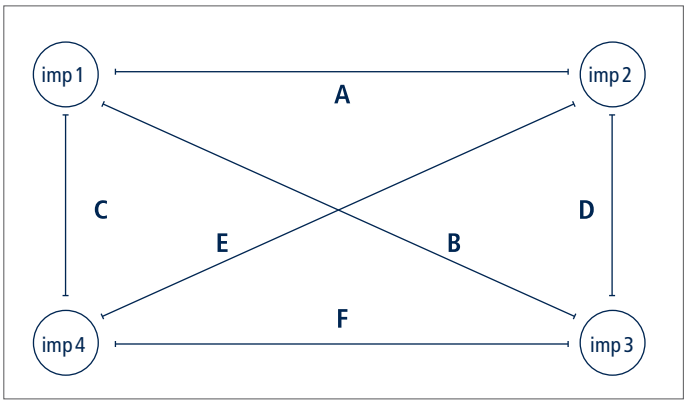


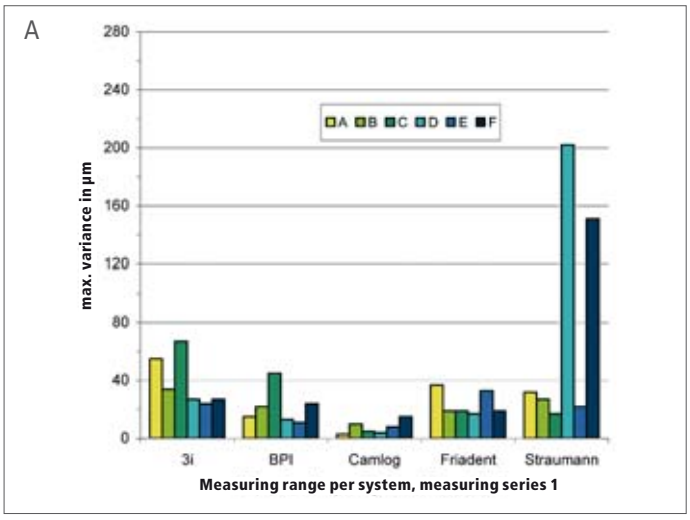
Fig. 3: Schematic representation of the implant arrangement in the demonstration model and the corresponding measuring distances. (Adapted from Reinert and Geis-Gerstorfer (2007)). Measuring distance A = imp1 – imp2, B = imp1 – imp3, C = imp1 – imp4, D = imp2 – imp3, E = imp2 – imp4, F = imp3 – imp4

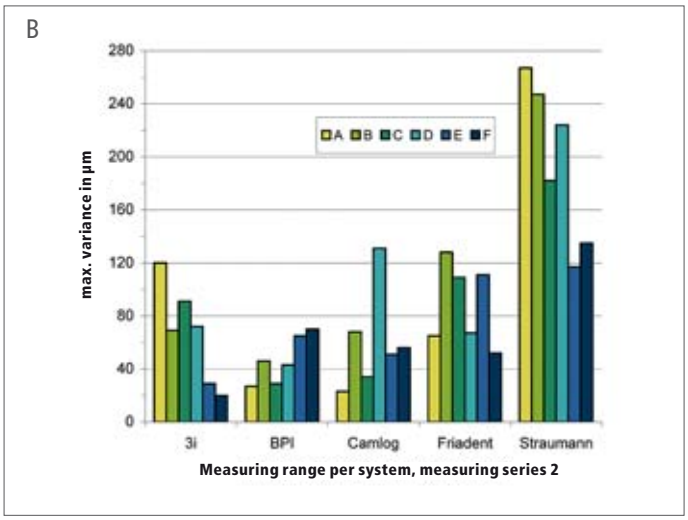
Three measuring series were performed, and the results are shown in Figures 4A–4C and Table 2. Each column stands for the measured values of a measured section. In measuring series 1, the CAMLOG® Implant System was conspicuous; its mean measuring variance lay within the measuring precision of the measuring device established in pretests. Measuring series 2 showed the greatest measuring variance since here the impression material and the plaster were added as sources of defects. The researchers believed that the impression post design is of decisive importance. Here, the BPI system appeared to offer benefits. In measuring series 3, the CAMLOG® Implant System again was superior and showed the least measuring variance.

The authors concluded that the precision of fit of a superstructure on an implant may not only be determined by the dental laboratory fabrication process, but also by the system itself through an inadequate fit of the abutment on the implant.

3i	BPI	CAMLOG	Friadent	Straumann
Re-attachment of abutments to titanium model				
39.0 µm	**21.7 µm**	**7.5 µm**	**24.0 µm**	**75.2 µm**
Precision of entire system				
66.8 µm	**46.7 µm**	**60.5 µm**	**88.7 µm**	**195.3 µm**
Re-attachment of the abutments to plaster cast				
28.3 µm	**24.0 µm**	**8.0 µm**	**23.8 µm**	**27.3 µm**

Tab. 2: Mean measured values of the measuring series. (Adapted from Reinert and Geis-Gerstorfer (2007)).





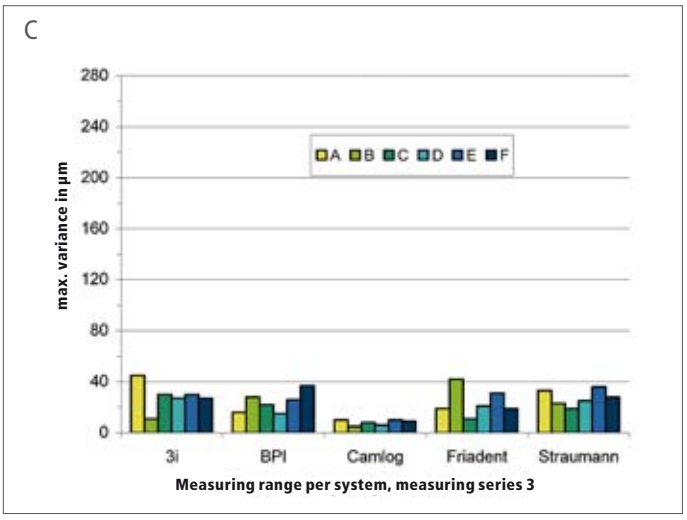


Fig. 4A: Abutments were removed from the titanium/patient model seven times and refastened with 10 Ncm, 20 Ncm and 30 Ncm torques to the same model in order to analyze system-inherent inexactness resulting from the abutment/implant fastening method. (Reinert and Geis-Gerstorfer 2007, reproduced with kind permission of Deutscher Ärzte-Verlag).

Fig. 4B: Defects resulting from the transfer method used with open impressions were evaluated by measuring six plaster casts obtained from the same titanium model. The effect of the impression material and plaster on precision is evident. (Reinert and Geis-Gerstorfer 2007, reproduced with kind permission of Deutscher Ärzte-Verlag).

Fig. 4C: Defects in precision and stability or resistance in the lab analogues during the fabrication process for superstructures in the laboratory were evaluated by removing all abutments from one of the six produced plaster casts seven times and by refastening them with torques of 10 Ncm, 20 Ncm and 30 Ncm to the same model. (Reinert and Geis-Gerstorfer 2007, reproduced with kind permission of Deutscher Ärzte-Verlag).

ROTATIONAL FIT: COMPARISON OF IMPLANT SYSTEMS

Edinger et al. (2007) performed an in vitro investigation of the rotational fit of the Astra Tech, CAMLOG®, OSSEOTITE® Certain, Brånemark and Replace™ Select implant systems. Depending on the fastening of the abutment on the implant (manually, 30 Ncm, left stop, right stop), a range of rotational play was measured from 0.46° to 3.50°. The CAMLOG® Implant System demonstrated a favorable range of rotational play with only 0.46° to 1.20° (Fig. 5).

In addition, Edinger et al. (2007) studied the rotational play between the abutment and the superstructure. It is less than the rotational play between the abutment and the implant or the model analogue (range: 0.6°). Therefore, the play between the abutment and the implant or the model analogue is clinically relevant.

The authors concluded that the rotational play of all investigated implant systems – independent of the connection type – is the source of defect. They deduced from the test set-up that the superstructure can compensate for malposition of the abutment on the implant at best to a certain degree. This means for the dental technician: The more precisely he works, the greater the probability that problems will occur at the try-in. In other words: The more precisely the dental technician works, the less the rotational play of the components must be.

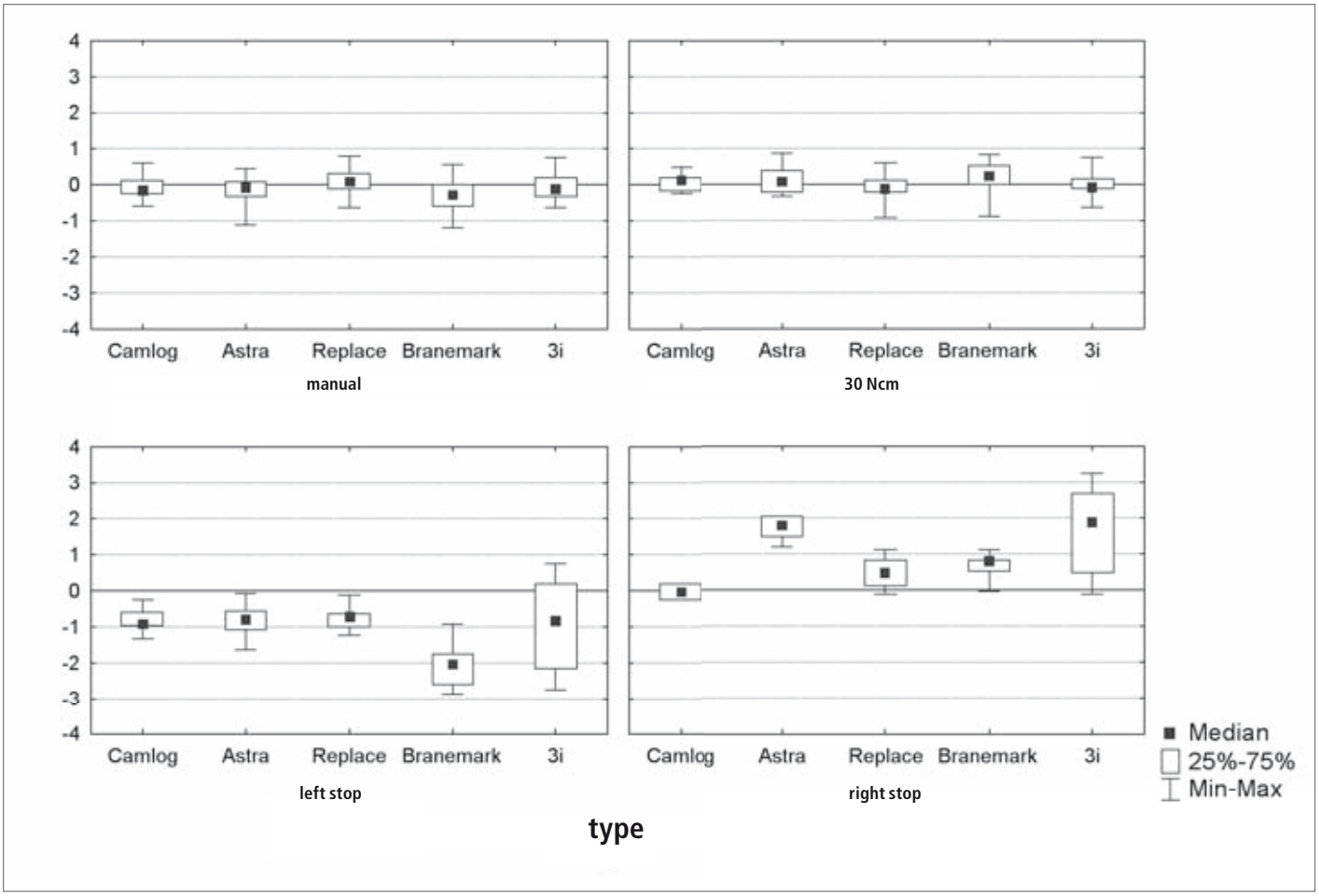


Fig. 5: Box plot of the rotation angle of the individual implant types for each of the four measuring methods: manual, 30 Ncm, left stop, right stop. (Edinger et al. (2007) reproduced with kind permission of BDIZ EDI).

IMPLANT POSITIONAL INDEX DESIGN INFLUENCES ROTATIONAL FIT

Stability of the implant-abutment connection 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. A 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., 2009a). The group performed mathematical analyses for three common geometric designs: regular polygon interface (Steri Oss and Astra Tech implant systems) of rounded polygonal patterns (Replace™ Select implant system), and the cam-groove connection which is used in the CAMLOG® Implant System. 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.

GOOD ROTATIONAL FIT FOR CAM-GROOVE DESIGN

In another evaluation, Semper et al. (2009b) 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. They hypothesized that the manufacturing tolerances, geometric pattern and dimensions of the index do not influence the position stability. The study demonstrated that with a specific 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. 6). However, the highest positional accuracy was calculated for the cam-groove design (1.4°).

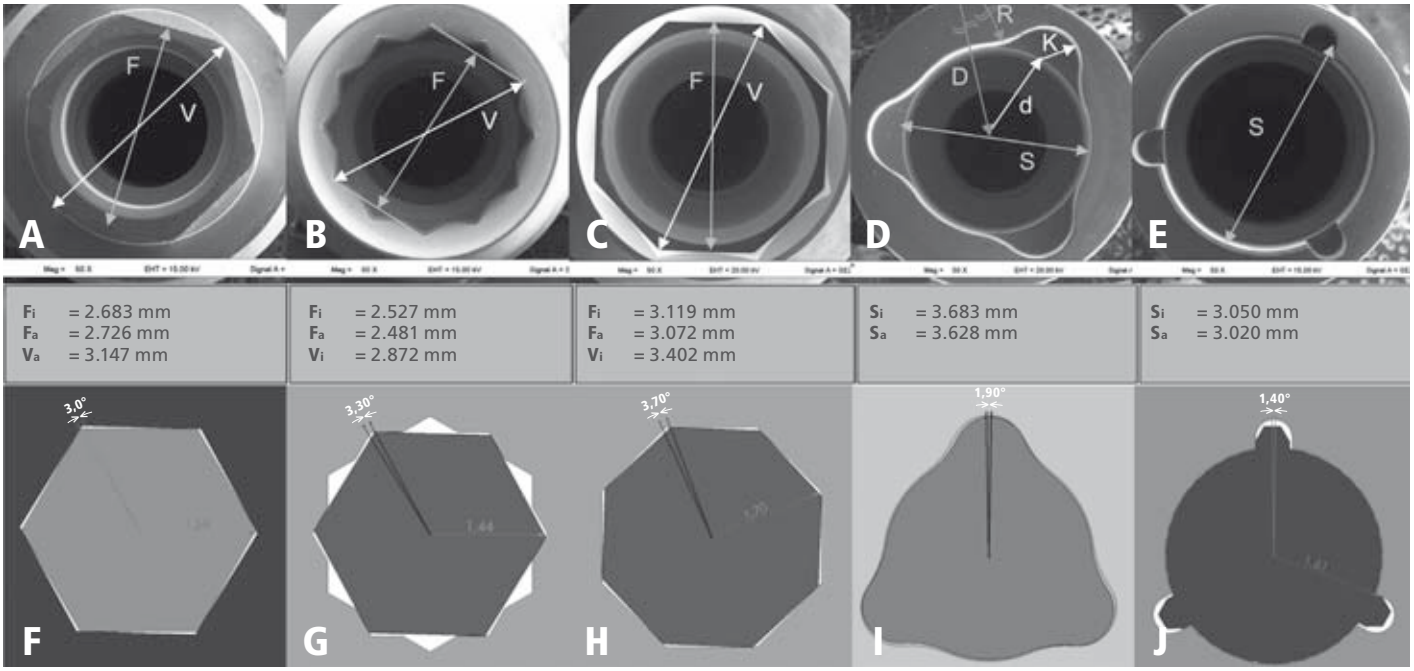


Fig. 6: Rotational freedom of regular polygonal patterns, polygon profiles, and other patterns. (A) Measuring points and measuring results of the hexagonal positional index (Steri Oss). (B) Measuring points and measuring results of the dodecagrammal positional index (Astra Tech). (C) Measuring points and measuring results of the octagonal positional index (Straumann). V = width across corners, F = width across flats demonstrated at the implant positional index. (D) Measuring points and measuring results of the polygonal profile positional index (Replace Select). 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. (E) Measuring points and measuring results of the cam-groove connection (CAMLOG). S = diameter, R = distance of the contact point to the rotational axis, δ = angle between R and the implant wall demonstrated at the implant positional index. (F) 3D simulation: rotational freedom of the Steri Oss system (hexagon). (G) 3D simulation: rotational freedom of the Astra Tech system (dodecagram). (H) 3D simulation: rotational freedom of the Straumann system (octagon). (I) 3D simulation: rotational freedom of the Replace Select system. (J) 3D simulation: rotational freedom of the CAMLOG system. (Semper et al. (2009b) reproduced with kind permission of Thomson Reuters Corp., USA).

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., 2010a). 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°) previously described (Semper et al., 2009b). 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 pressure-less on the displaced abutments. Finally, the resulting marginal gap between the abutment and the superstructure was measured with the software (Tab. 3).

MARGINAL FIT OF THE SUPERSTRUCTURE AT DIFFERENT ASSUMED INTERNAL PRECISIONS SIMULATED WITH DIFFERENT DEGREES OF ROTATIONAL FREEDOM AND ABUTMENT ANGULATIONS

Internal gap / abutment angulation 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. 3: 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. (2010a)).

EFFECT OF CONNECTION DESIGN ON THE ACCURACY OF REPOSITIONING

The theoretical calculations described above (Semper et al., 2009a; Semper et al., 2009b and Semper et al., 2010a) were also tested in an experimental in vitro study. Positional stability of five different implant systems (ITI, Steri-Oss, CAMLOG®, Astra Tech, and Replace™ Select) was compared after multiple manual disassembly and reassembly (Semper et al., 2010b).

Five implants were arranged with varying angles in a stainless steel model to simulate a typical clinical situation (Fig. 7). Abutments were assembled and reassembled manually by three test persons for each implant system for 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® showed significantly smaller rotational discrepancy than the other systems tested (Fig. 8A). The systems with a horizontal butt-joint displayed significantly lower vertical alterations in position than beveled implant-abutment connections (Fig. 8B). Regarding canting discrepancies, the implant systems did not differ significantly (Fig. 8C). 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.

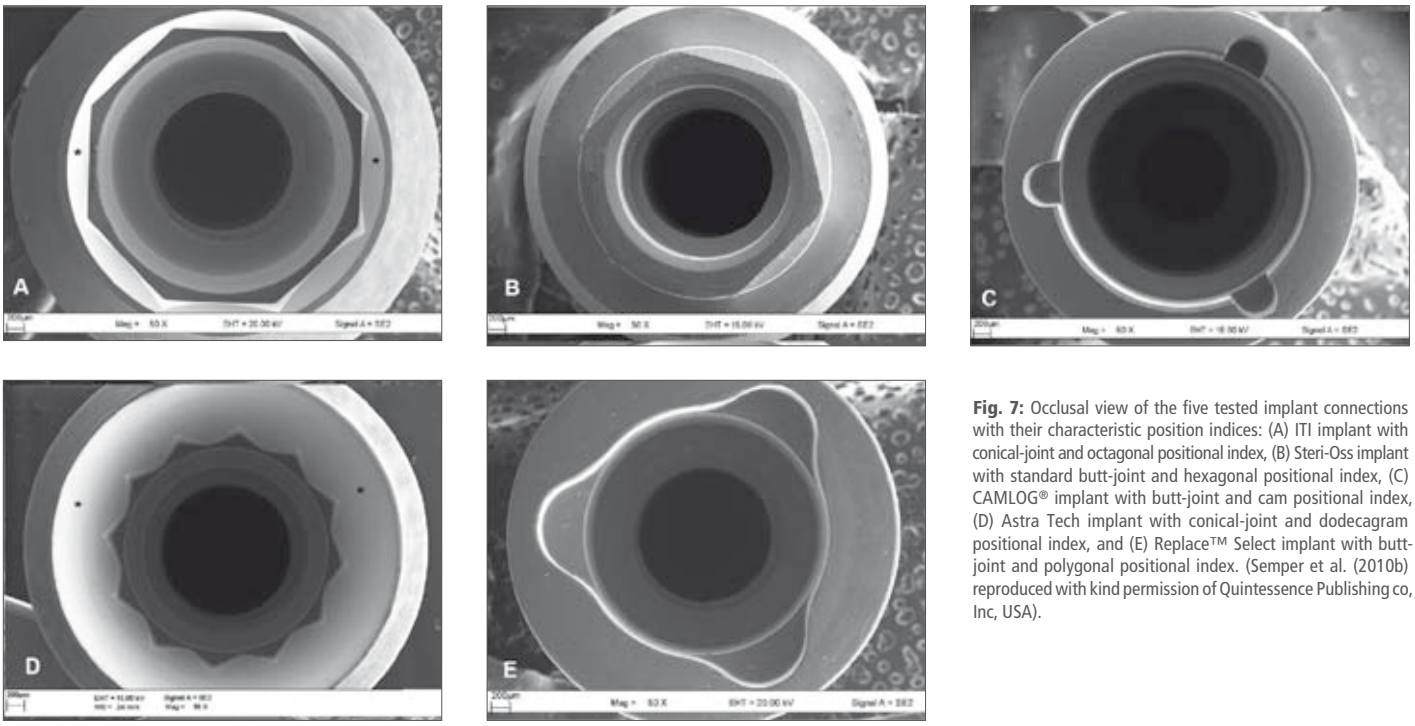
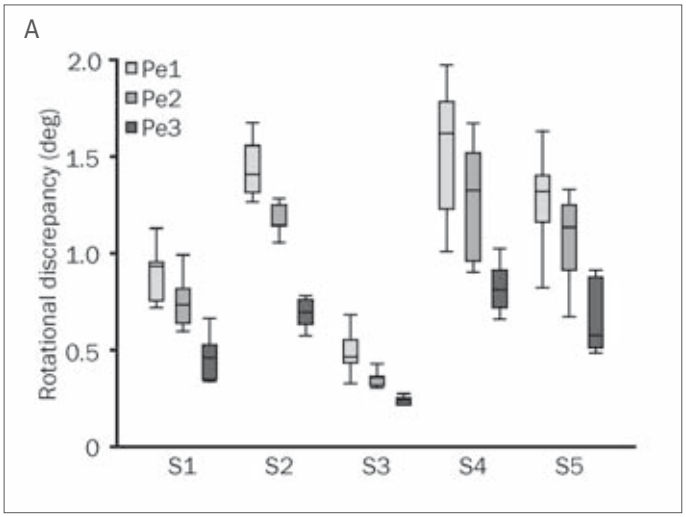
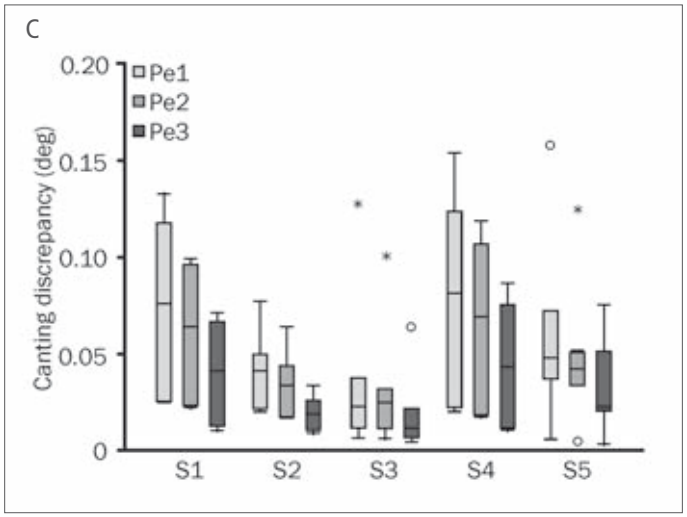


Fig. 7: Occlusal view of the five tested implant connections with their characteristic position indices: (A) ITI implant with conical-joint and octagonal positional index, (B) Steri-Oss implant with standard butt-joint and hexagonal positional index, (C) CAMLOG® implant with butt-joint and cam positional 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. (2010b) reproduced with kind permission of Quintessence Publishing co, Inc, USA).





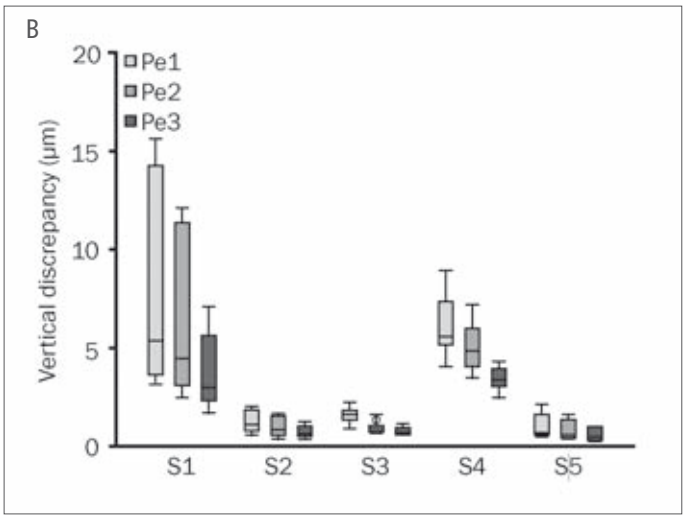


Fig. 8 A–C: Rotational deviations (A), vertical deviations (B) and canting discrepancies (C) after repeated detachment and re-attachment procedures. Median values. Pe1, Pe2, Pe3 test persons performing the test procedures. S1 Straumann® Tissue Level, S2 SteriOss, S3 CAMLOG®, S4 Astra Tech, S5 Replace™ Select. (Semper et al. (2010b) reproduced with kind permission of Quintessence Publishing co, Inc, USA).

CONICAL CONNECTION: POSITIONAL STABILITY

The theoretical considerations and the established experimental set-up developed by Semper et al. were recently used to investigate the position stability of different implant systems with a conical implant-abutment connections, i.e., NobelActive™, Bone Level, Ankylos C/X, and CONELOG® (Semper-Hogg et al., 2012). 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 supposed high-precision manufacturing for this implant system.

SUMMARY

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, rotational fit as well as load distribution and load-bearing capacity. Although conical connections may have design-related disadvantages regarding precision of fit and load distribution, the CONELOG® implant-abutment connection demonstrated in studies evidence of high-precision manufacturing and superior positional stability when compared to other conical connections.

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LOADING CAPACITY, SEAL AND FIT OF MODERN IMPLANT-ABUTMENT CONNECTIONS AND PROSTHETICS

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. Micro-gaps 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. While it is widely accepted that butt-joint connections present micro-gaps, the situation in conical connections has been under discussion for many years since many direct visualization tests have failed. Recent studies give deeper insight into loading capacity and gap formation of different implant systems.

Other important aspects affecting the long-term success of implant-based reconstructions are abutment material, prosthetic fit and the retrievability of crowns in case of biological or technical problems. Various studies on these topics have been performed using the CAMLOG® and CONELOG® Implant Systems.

CONNECTION DESIGN AND LOAD-BEARING CAPACITY

Does the design of the implant-abutment connection influence the load-bearing capacity? A research group from Hannover, Germany, compared different implant systems in an in vitro study (Dittmer et al., 2011). On implants, centrally embedded in plastic material, corresponding abutments were placed and tightened with screws according to the manufacturers' recommendations. An 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® implants demonstrated favorable results regarding their load-bearing capacity (Fig. 9).

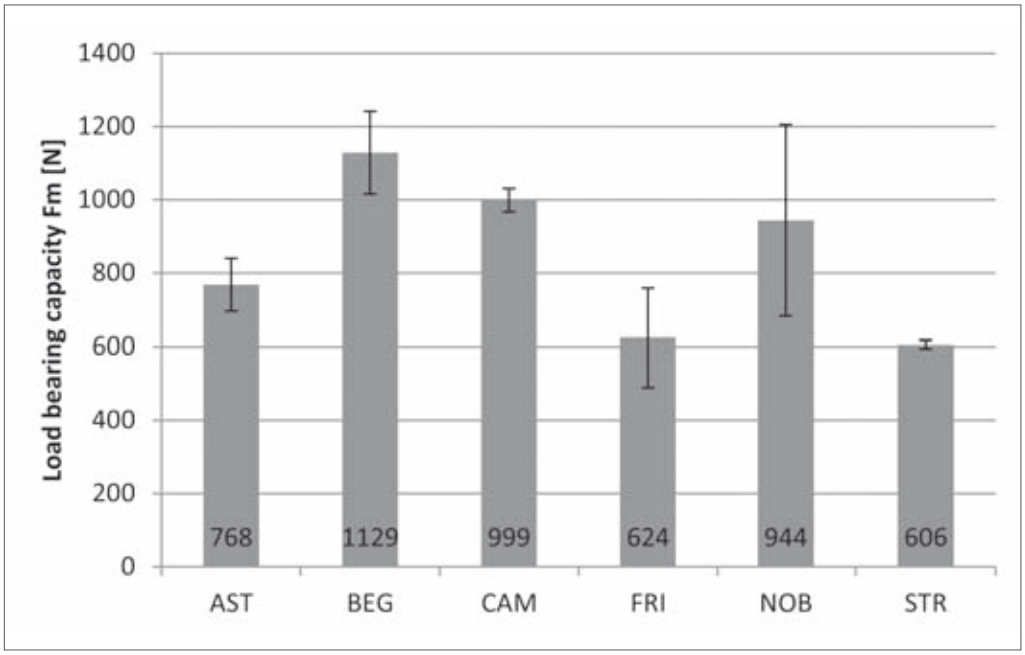
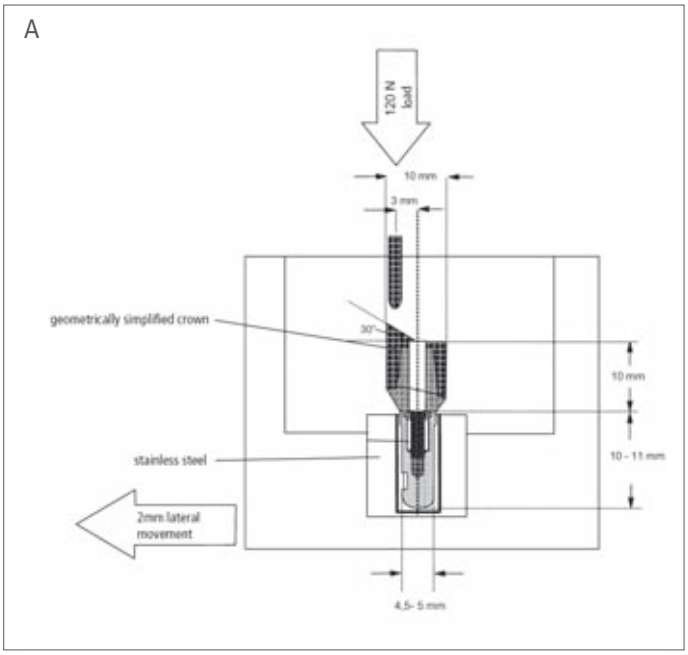


Fig. 9: Load-bearing capacity (Fm) versus implant-abutment connection type. Means and standard deviations are given. AST – Astra Tech, BEG – Bego, CAM – CAMLOG®, FRI – Friadent, NOB – Nobel, STR – Straumann. (Adapted from Dittmer et al. (2011)).

FATIGUE RESISTANCE AND SEAL: COMPARISON OF CAMLOG® AND OTHER IMPLANT SYSTEMS

Steinebrunner et al. (2005a, 2005b) 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®). The test specimens were subjected to dynamic alternating loading for a maximum of 1.2 million cycles at a rate of 1 Hz in a dual axis chewing simulator before maximum loading was applied for fracture strength determination (Fig. 10). 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. 4 and Fig. 11).



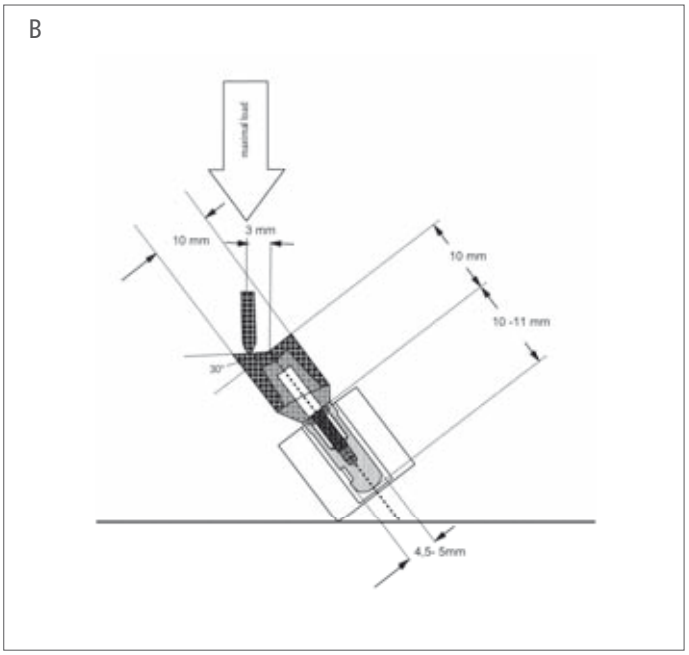


Fig. 10 A and B: Schematic representation of the test set-up for (A) dynamic, alternating and (B) maximum loading (adapted from Steinebrunner 2006). For each implant system to be tested, 16 implant-abutment combinations were fitted with a crown. A subgroup consisting of eight samples was exposed to dynamic alternating load in a chewing simulator that took into account a 30° cusp slope, a 2-mm lateral movement, and the physiological vertical chewing force of 120 N reported by Richter (1995). The surviving implants of this subgroup as well as eight control samples of the other subgroup were then subjected to the quasi-static fracture load test. Force input point was identical to chewing simulation at 3 mm eccentric from the crown midpoint on the central cusp, sloped at 30° to the occlusion plane and 11.5 mm distant from the implant shoulder (Figure 10A).

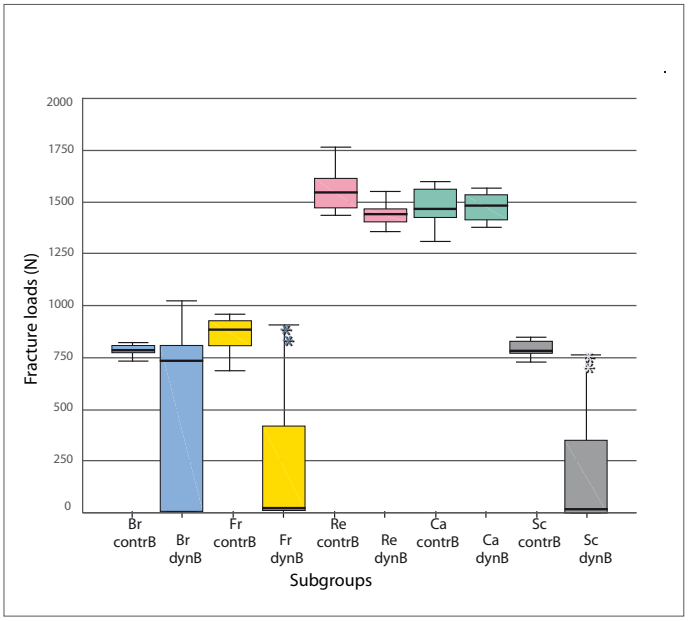


Fig. 11: Box plot diagram of the quasistatic fracture strengths of the five tested implant systems: Br = Brånemark, Fr = FRIALIT®-2, Re = Replace® Select, Ca = CAMLOG®, Sc = Screw-Vent®. dyn = after chewing simulation using dynamic loading; contr = without dynamic loading (adapted from Steinebrunner 2006).

Using the same chewing simulation test set-up as illustrated in Figure 10A, Steinebrunner et al. (2005a) also measured the seal of the implant-abutment connections of five different implant systems, the Brånemark, FRIALIT®-2, the Replace™ Select, CAMLOG® and the Screw-Vent®. They checked migration of test microbes from the internal area of the implant-abutment 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. 12).

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. 4: 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).

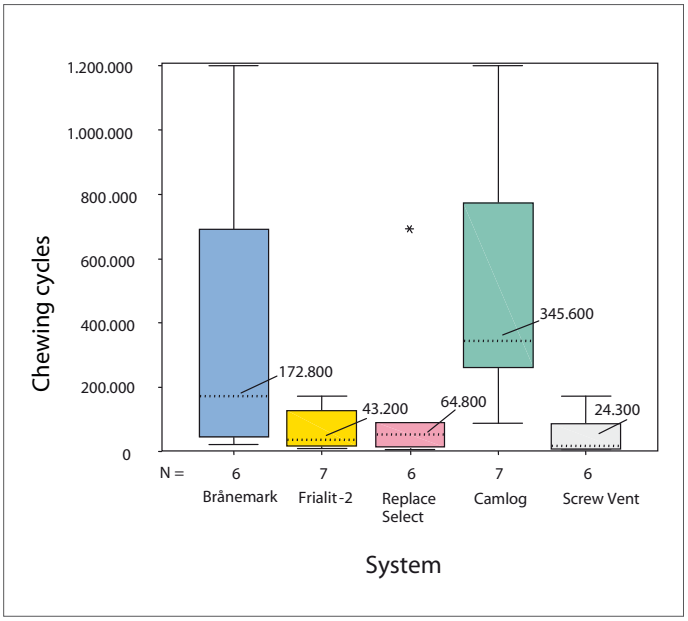


Fig. 12: Box plot diagram showing the chewing cycles reached before microbial leakage occurred in the individual systems. ... median value. * extreme value. The CAMLOG® Implant System clearly reached the highest mean number of cycles among the tested systems (adapted from Steinebrunner 2006).

SEAL AND MICROLEAKAGE

In the mid-90ies, several groups studied leakage at the implant-abutment interface. Jansen et al. (1995 and 1997) analyzed in vitro bacterial penetration from the bore of the implant-abutment connection to the external surrounding. Gross et al. (1999) used for a similar in vitro approach the dye gentian violet. Both research groups noticed that leakage was always a measurable phenomenon with differences in systems, samples and starting torques.

Rack et al. (2010) used synchrotron-based radiography to visualize for the first time microgaps in internal conical implant-abutment connections and thereby proof their existence in vitro. High resolution radiographic images were taken under varying static mechanical loads of up to 100 N. The images showed that the microgap size varied between 1 and 22 µm depending on the applied mechanical load. This finding indicates that also conical implant-abutment connections bear the risk of bacterial infiltrates, that may be responsible for inflammatory reactions at the implant-abutment interface as the measured microgap clearly exceeds the size of endotoxins and oral pathogens. The same research group (Rack et al., 2013) compared in a subsequent study the abutment stability during loading in three different new and fatigue-loaded conical implants (Dentsply Friadent Ankylos C and Ankylos Plus, Straumann® Bone Level). They again used synchrotron-based radiography in a test set-up very similar to the one described above. Before radiographic measurements were performed, fatigue-loaded implants had been generated by applying a force of up to 120 N for 5 million cycles. In all three tested conical implant-abutment systems, microgaps were detected regardless of the amount of static mechanical load applied. After fatigue loading, the gap had even been increased and facilitated micromovement of the implant-abutment complex. Finally, the cone angle of the connection seemed to have an effect on abutment stability, i.e., flatter cones were more stable.

Microgap enlargement due to fatigue loading was also demonstrated by Zabler et al. (in press). They tested four commercially available implant systems (Astra Tech, Straumann® Bone Level, Dentsply Friadent Ankylos and Ankylos c/x) using x-ray phase contrast microtomography before and after cyclic extra-axial load of 120 N. Before loading, all implants with the exception of Ankylos c/x showed high tightness of the implant-abutment connection with only small gaps ranging from 0.1 to 1.0 µm. However, loading resulted in an increase of the gap width. In addition, all systems showed plastic deformation at the implant-abutment connection, which was accompanied by the formation of broad and wide gaps around the pivotal point of the force vector.

Harder et al. (2012) investigated the leakage of bacterial endotoxins from conical implant-abutment connections in two implant systems (Straumann® Bone Level, CONELOG®) in vitro. 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 the good sealing capacity of conical implant-abutment connections should be reconsidered.

ZrO_2 ABUTMENTS – WEAR AND RECOMMENDATIONS FOR USE

Wear is an important aspect regarding the long-term success of implant-abutment connections. Stimmelmayr et al. (2012a) evaluated the wear of the interface between CAMLOG® titanium implants and one-piece zirconia abutments and compared it to titanium abutments in an in vitro study. Chewing simulation was performed with a similar test set-up as designed by Steinebrunner et al. (2005; Fig. 10A). After loading with 1.200.000 cycles at 100 N, neither implant or abutment fractures nor abutment screw loosening or screw fractures occurred. However, SEM micrographs revealed more wear and damage at the implants when they were connected to ZrO_2 abutments. The authors supposed that the reason for these differences was the stress distribution between components of different rigidity: When using ZrO_2 abutments on titanium implants, deformation energy is distributed to the material with the lower elastic properties, i.e., titanium, which results in increased wear and abrasion.

Use and processing of ZrO_2 abutments were also discussed at a consensus conference and the following recommendations were developed (Beuer et al., 2011):

- ZrO_2 qualities differ in their mechanical and optical properties. Only thoroughly tested, well known and scientifically documented ZrO_2 qualities should be used.
- One-piece monoblock ZrO_2 abutments with inner connections should not be used in the lateral tooth area. In the front area, one-piece abutments with outer connections and appropriate dimensions show fewer problems.
- Two-piece, bonded ZrO_2 abutments, do not show any limitations in use as long as they have appropriate dimensions.
- On standardized ready-for-use ZrO_2 abutments, crowns should be fixed in a conventional way since surplus fixation material is difficult to remove if the crown margin is placed subgingivally.
- When using individually CAD/CAM-prepared ZrO_2 abutments with which the margin can be placed to be well accessible, also adhesive / semi-adhesive systems may be used.
- In restorations which are fixed only by adhesion and without additional retentive preparations, classical adhesive multiple step systems should be used.
- It is strongly recommended not to fix ZrO_2 restorations provisionally.

PASSIVE FIT OF PROSTHETICS: IMPRESSION TECHNIQUES AND REPRODUCIBILITY OF SCANBODY FIT

Passive fit of prosthodontics is only achieved when the accuracy of the implant transfer between the original situation and the cast is optimal. Stimmelmayr et al. (2012b) digitally compared the accuracy of different impression techniques, i.e., transfer, pick-up and splinted pick-up. They inserted CAMLOG® SCREW-LINE implants into lower-arch models and took impressions. Scanbodies were mounted on the implants of the original models and on the lab analogues of stone casts and were digitized. Discrepancy between original and cast was 124 ± 34 µm for the transfer technique and 116 ± 46 µm for the pick-up technique. Least discrepancy was found for the splinted pick-up technique (80 ± 25 µm). The authors concluded that the splinted pick-up technique is recommendable for impressions when placing four implants evenly distributed in the edentulous jaw.

In their second study, the researchers evaluated the reproducibility of the scanbody fit (Stimmelmayr et al. 2012c). Scans were taken before and after repeatedly removing and re-attaching scanbodies to the same implant on the original model or to the lab analogue on stone casts. Comparison of these scans revealed a mean scanbody discrepancy of 39 ± 58 µm on original implants. Discrepancy of scanbodies on the lab analogues was significantly lower (mean 11 ± 17 µm) indicating a better reproducibility of the scanbody position (Fig. 13). The authors emphasized the importance of low manufacturing tolerances.

RETRIEVABILITY OF CEMENT-RETAINED IMPLANT CROWNS

Cement-retained restorations are regarded to have advantages when compared to screw-retained restorations since they allow improved esthetics and eliminate the risk of screw loosening. However, restorations may need to be retrieved in case of technical or biological complications. Mehl et al. (2012a and 2012b) compared in their in vitro studies different cement-retained materials regarding strength and crown retrievability. Crowns which were cement-retained to CAMLOG® titanium abutments using a glass-ionomer cement could significantly easier be removed than crowns cement-retained with a polycarboxylate or with resin cement. The authors concluded that glass-ionomer cement can serve as a semipermanent solution while polycarboxylate or composite resin cements should be used for permanent cementations.

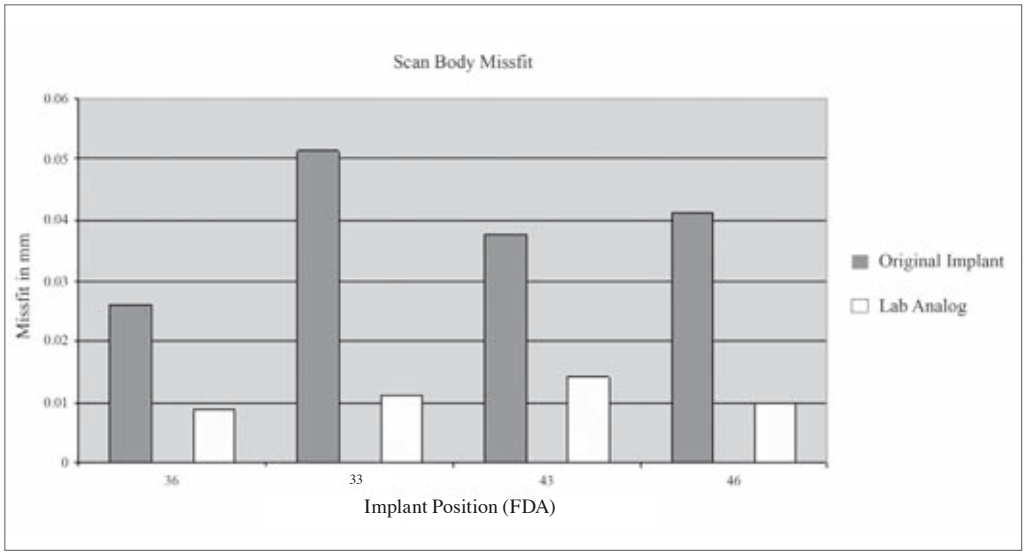


Fig. 13: The mean discrepancies of the scanbodies at the different implant sites (FDI 36, 33, 43, and 46) for the original implants and the lab analogues are shown (Stimmelmayr et al., 2012c reproduced with kind permission of Springer).

SUMMARY

There is general agreement that a two-piece implant without microgap and without micromovements still has to be developed. Even conical implant-abutment connections have microgaps, which increase under loading. For the CAMLOG® Implant System, a very favorable load capacity has been demonstrated. Numerous studies have been performed on prosthetic aspects of the CAMLOG® Implant System: Although the use of ZrO_2 abutments on titanium implants has various clinical advantages, increased wear and abrasion may be expected compared to titanium abutments, and recommendations for use and processing of ZrO_2 abutments should be followed. When using CAD/CAM technologies, a precise fit of scanbodies during implant transfer between the original and the cast is a prerequisite for achieving an optimal passive fit of the prosthetics. Glass-ionomer cements should be used for semipermanent cementations, polycarboxylate or composite resin cements are better suited for permanent cementations.

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PRE-CLINICAL STUDIES

Various pre-clinical studies have been performed to evaluate the biological behavior and reliability of the CAMLOG® and CONELOG® Implant Systems in vivo. 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.

IMPROVED OSSEOINTEGRATION WITH CAMLOG® PROMOTE® PLUS DESIGN

The machined surface segment of the CAMLOG® SCREW-LINE implant neck was significantly reduced from 2.0 mm (Promote®) to 0.4 mm (Promote® plus). Schwarz et al. (2008) investigated the effect of this design change on crestal bone resorption in a dog study. Both implant types were inserted in the mandibles of dogs following the standard protocol (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 SCREW-LINE Promote® plus implants appeared to have a positive effect on marginal bone growth. Data demonstrated that the new surface design efficiently reduced crestal bone changes. Another conclusion was that when a native thick gingiva was available, an approximately 1 mm higher bony integration level of the implant could be accomplished without the marginal epithelium reaching the microstructured surface (Becker et al., 2006).

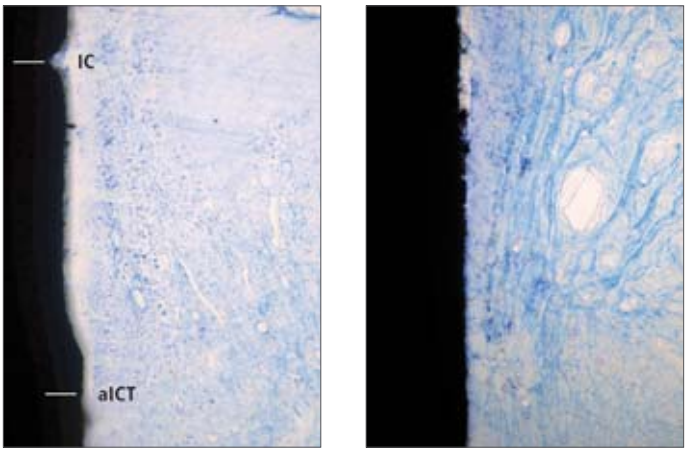

Fig. 14: Histological pictures after 12 weeks healing of (a) Promote® and (b) Promote® plus CAMLOG® SCREW-LINE implants (200x magnification, toluidine blue stain). The apical extension of the inflammatory cell infiltrate (aICT) and the level of the alveolar crest are clearly divided from each other by an intact connective tissue zone with parallel collagen fibers and a few formed blood vessels; IC = implant shoulder (reproduced from Schwarz et al. 2008; with kind permission of Quintessence Publishing Co, Inc, USA).

EFFECT OF MICROLEAKAGE ON CRESTAL BONE RESORPTION

Microgaps in the implant-abutment connection have been supposed to play a critical role in the crestal periimplant bone loss observed during the first year of loading. Steinebrunner et al. (2005a and b) hypothesized that the implant-abutment connection may be a reason for the different bacterial penetration profiles of various implant systems. Schwarz et al. (2008) detected only a mild inflammatory cell infiltrate at the implant-abutment interface of both implants, which was divided from the alveolar bone crest by an intact connective tissue zone (Fig. 14). The authors concluded that microleakage played no part in marginal bone resorption in the two groups.

CAMLOG K-SERIES: EFFECT OF PLATFORM SWITCHING DESIGN

Platform switching is intended to increase the distance between the implant-abutment interface and the alveolar crest and thereby decrease the effect of inflammatory cell infiltrates on bone resorption. The principle of platform switching in the CAMLOG® Implant System was evaluated in a dog study over six months (Becker et al., 2009). SCREW-LINE Promote® plus implants (K-series, ø 3.8 mm) were inserted according to the standard surgical protocol (Fig. 15A: Wide-body matching healing abutments ø 3.8 mm, H 4 mm, standard configuration) and non-matching abutments (Fig. 15B: ø 3.2 mm, H 4 mm, platform switching configuration) 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 (IS-BC) 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 remodelling at the alveolar crestal bone seemed to decline (Figs. 15C and 15D). The difference of IS-BC between both groups was settling down to approximately 0.3 mm.

The study demonstrated that the CAMLOG® implant design (K-Series) both in its standard and in its platform switching configuration successfully integrated into hard and soft tissue. Bone remodelling as well as soft-tissue adaption appeared to be minimal at the implant-abutment interface during the first eight weeks of osseointegration and 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.

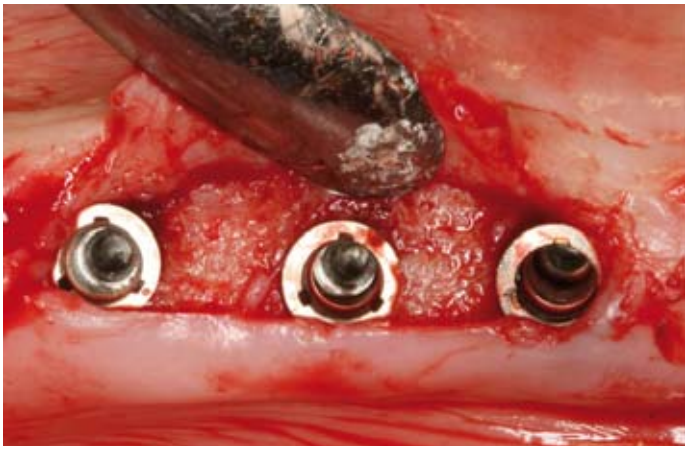

Fig. 15A: Implants (K-Series) inserted 0.4 mm supracrestal according to the standard surgical protocol.

Fig. 15B: Inserted implant covered with a non-matching healing abutment (plat- form switching).

Fig. 15C: Implant with standard healing abutment (control), histology after six months healing.

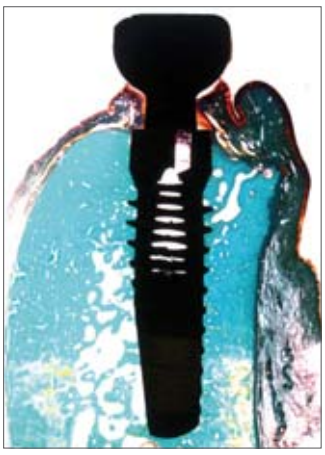

Fig. 15D: Implant with non-matching healing abutment (platform-switching), histology after six months healing. Bone loss is slightly reduced compared to the standard configuration.

Image source: F. Schwarz

CONELOG® IMPLANTS: EFFECTS OF PLATFORM SWITCHING ON BONE AND SOFT TISSUE

Becker et al. (2007) 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.

ABUTMENT EXCHANGES IN PLATFORM SWITCHING IMPLANTS AND DIFFERENT ABUTMENT MATERIALS

In order to condition the implant-supporting soft tissues, repeated abutment exchanges are often performed during the healing phase. In a dog study, the effect of two exchanges of titanium (Ti6Al4V) and zirkonum dioxide (ZrO_2) abutments was evaluated using CONELOG® implants (Becker et al. 2012). The abutments were dis- 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 formation of a junctional epithelium and bone resorption compared to undisturbed healing. There was no significant difference between both abutment materials although the undisturbed ZrO_2 abutments tended to show slightly better soft-tissue and bone values than Ti6Al4V abutments (Tab. 5). The authors concluded that repeated abutment manipulation may increase soft and hard-tissue changes in implants with platform-switching design regardless of the abutment material (Ti6Al4V or ZrO_2).

Group	Modification	PM-aJE	aJE-CBI	IS-aJE	IS-CBI
Vestibular aspects					
Test	Ti6Al4V	2.08 ± 0.67	2.19 ± 1.41	1.05 ± 0.61	1.14 ± 0.86
Test	ZrO_2	2.15 ± 0.21	0.21 ± 2.26	0.60 ± 0.84	1.50 ± 1.41
Control	Ti6Al4V	2.19 ± 019	1.24 ± 0.70	0.28 ± 0.33	0.95 ± 0.62
Control	ZrO_2	2.00 ± 0.14	0.95 ± 0.21	0.75 ± 0.07	0.20 ± 0.28
Oral aspects					
Test	Ti6Al4V	1.91 ± 0.25	1.30 ± 0.20	0.19 ± 0.24	1.11 ± 0.34
Test	ZrO_2	3.20 ± 1.55	3.80 ± 1.55	1.00 ± 1.41	2.80 ± 0.14
Control	Ti6Al4V	1.45 ± 0.59	0.92 ± 0.15	0.42 ± 0.29	0.50 ± 0.39
Control	ZrO_2	1.80 ± 0.42	0.65 ± 0.49	0.40 ± 0.56	0.25 ± 0.07
Vestibular and Oral aspects					
Test	Ti6Al4V	1.99 ± 0.40	1.74 ± 0.75	0.62 ± 0.18	1.12 ± 0.06
Test	ZrO_2	2.67 ± 0.67	2.95 ± 1.90	0.80 ± 1.13	2.15 ± 0.77
Control	Ti6Al4V	1.82 ± 0.37	1.08 ± 0.30	0.35 ± 0.29	0.72 ± 0.18
Control	ZrO_2	1.90 ± 0.28	0.80 ± 0.35	0.57 ± 0.24	0.22 ± 0.10

Tab. 5: Mean (± standard deviation in mm) of histomorphometrical measurements of periimplant tissues at eight weeks after implant placement in the jaw of three dogs and after repeated dis- and reconnection of the Ti6Al4V and ZrO_2 abutments (Test Group). PM = mucosal margin, IS = implant shoulder, aJE = the apical extension of the long junctional epithelium, CBI = the most coronal bone in contact with the implant. (Adapted from Becker et al. (2012)).

REMOVAL OF CEMENT-RETAINED IMPLANT RESTORATIONS

Periimplantitis therapy or technical complications such as screw loosening or ceramic fractures may result in the need of removing prosthetics. When removing cement-retained restorations, vertical mechanical loading is applied on the bone and on the implant-bone interface. Mehl et al. (2013) evaluated the impact of such loads in a study in minipigs with CAMLOG® implants. They imitated crown removal with 20 or 100 dynamic impulses of 18 Ns. After 13 to 18 weeks, they histologically did not find any differences regarding bone-implant contact area between loaded and non-loaded implants. The authors concluded that the removal of cement-retained restorations did not impair the mechanical implant stability, but increased bone remodeling activity. However, care should be taken when limited osseointegration due to peri-implantitis is evident since then vertical loading may result in implant loss.

SUMMARY

Design changes of the CAMLOG® and CONELOG® Implant Systems have systematically been tested pre-clinically. The enlargement of the coarse neck area of SCREW-LINE implants (Promote® plus design) has been shown to improve the osseointegration. Bacterial microleakage does not seem to play a role in marginal bone resorption around CAMLOG® implants. Studies on the concept of platform switching have demonstrated successful osseointegration of both standard and platform-switched implants. Repeated abutment dis- and reconnection during the healing phase may impair the stability of the hard and soft tissue both with titanium and ZrO_2 abutments. Vertical loading due to removal of cement-retained restorations does not impair implant stability when the implants are well osseointegrated.

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CLINICAL STUDIES

A WELL DOCUMENTED IMPLANT SYSTEM

There is general agreement between clinicians that the scientific documentation of an implant system reflects the engagement of a company in research and science. When selecting the most appropriate treatment, long-term clinical data represent a reference in terms of confidence not only for the user but also for the patient. A large number of clinical studies have been performed documenting the CAMLOG® Implant System with its Promote® surface in several indications and loading modalities. Results have been published in peer-reviewed journals or presented at congresses. Long-term results with follow-up controls between four and a half years and seven years have been documented in studies with more than 11,000 implants (Tab. 6). They have confirmed excellent implant survival and success rates between 97.8 to 99.8%.

Authors	Country	FU (up to years)	Total Impl.	CAMLOG Impl.	Survival or **Success** in %
Krennmair et al., 2008a	AUT	7	183 [1,4]	174	97.80
Semper et al., 2008	GER	6	464 [1]	464	99.60
Franchini et al., 2011	IT	6	201 [1]	201	99.50
Krennmair et al., 2010	AUT	5	541 [1]	541	97.30
Zafiropoulos et al., 2010	GER	5	252 [1,2]	118	95.20
Nelson et al., 2008	GER	5	232 [1,2]	463	99.40
Semper et al., 2007	GER	5	448 [1,2]	403	99.80
Wolf 2007	GER	5	245 [1,3]	151	98.40
Özkan et al., 2011	TR	5	244 [1,2,4]	90	99.59
Xiang et al. 2010, 2011	GER	5	353 [1]	234 119	Max. 98.72 Mand. 99.15
Referent presentation*					
Ackermann / Kirsch	AUT	7	3.588 [1]	3.588	98.60
Babbush	USA	7	273 [1]	273	98.90
Singer	GER	5	364 [1]	364	99.26
Watanabe	JP	5	552 [1]	552	98.60
Lin	PRCH	4.5	3.374 [1]	3.374	99.30
TOTAL CAMLOG IMPLANTS				**11.109**	

*Presentation at First International Camlog Congress in Montreux 2006

(1) CAMLOG, (2) Straumann, (3) Nobel, (4) Friadent, (5) Steri-Oss, (6) Brånemark, (7) others

Studies with observation periods from five years up to seven years with reported implant survival or success rate. Data published in peer-reviewed journals or presented at congresses.

Tab. 6:
Selected publicated and presented clinical studies

EXCELLENT SUCCESS RATES WITH THE SAND-BLASTED AND ACID-ETCHED PROMOTE® SURFACE

Healing time depends – among other factors – on the surgical interventions performed during implantation, bone quality as well as on 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 and Semper et al. 2007 and 2008). 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 implantation for mandible and 12 weeks for maxilla. The evaluation of the implant success was based on criteria defined by Buser et al. (2002): absence of mobility, no apical translucency, no pain or other signs of persistent or irreversible symptoms, no periimplant inflammation. Success (99.4% at five years) 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.

Özkan et al. (2007 and 2011) examined the treatment outcome of several implant brands after three and five years, respectively. The three-year evaluation encompassed CAMLOG® (53), ITI (105), and Frialit (45) implants. Recalls were performed at six, 12, 24 and 36 months and included clinical parameters as well as radiographs. The authors concluded that the three implant systems presented similar positive outcomes at three-year follow-up. Comparable results were described in the publication of the five-year follow-up including CAMLOG® (90), Straumann (86), Swiss Plus (35), and Frialit (33) implants in several indications. The authors observed no significant differences between the implant systems and concluded that the used systems led to positive treatment success at three and five years.

High success rates in everyday practice were also confirmed by Franchini et al. (2011). The authors reported the results of a retrospective study with an observational period varying from one year after loading up to six and a half years. In total, data from 96 patients with 201 CAMLOG® implants in different indications were analyzed: 158 implants were placed in partially edentulous patients, 49 in single tooth gaps. The success rate was 99.5%. Treatment success was independent of the times of implantation or loading, as well as of implant lengths.

TREATMENT SUCCESS BASED ON IMPLANT DIAMETER AND LENGTH

Krennmair et al. (2010) compared the treatment success of 541 CAMLOG® implants with different implant diameters. The implants were placed immediately (n=6), six to eight weeks (n=116) or more than eight weeks after tooth extraction (n=409). The authors reported cumulative success rates after five years of 96.2% for 3.8 mm implants, 98.6% for 4.3 mm implants and 99.0% for 5.0 and 6.0 mm implants. Prosthetic follow-ups were required in just a few cases. The average degree of patient satisfaction with the treatments reached 4.8 on a scale from one to five (five being the highest degree of satisfaction). Similar results were observed by Strietzel & Reichart (2007), who compared the treatment successes of short and long 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.

TREATMENT SUCCESS BASED ON TIME OF IMPLANTATION AND HEALING PERIOD

Various studies reported the implant survival rate depending on the time of implantation after tooth extraction. In a retrospective study over five years with 241 implants (118 CAMLOG® implants), Zafiropoulos et al. (2010) observed no differences in the implant survival rate depending on the time of implantation, implant type or time to loading (Table 7). These results were confirmed by De Lange et al. (2010), who studied the treatment success of 774 implants in fresh or healed extraction sites, with immediate or delayed 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 implantation and loading. Siebers et al. (2011) also studied the effect of implantation and healing time in 76 patients with a total of 222 implants over a period of up to seven years. They achieved a treatment success of 100% for implants placed in healed extraction sites. Treatment success was 91.3% for implants placed and loaded immediately and 98.5% for immediately placed implants with delayed loading.

IMPLANTS IN EDENTULOUS PATIENTS

Implant-supported overdentures with four interforaminal implants are recommended as the standard treatment of the edentulous mandible. In the edentulous maxilla, usually additional implants are often placed in the lateral area to improve stability. When using fixed restorations, a higher number of implants is used, i.e., six in the mandible, seven in the maxilla. Numerous independent studies have been performed to evaluate different retention methods and implant numbers in edentulous patients using implants with a Promote® surface. (Tab. 7).

Authors	Maxilla / Mandible	Duration / Follow-up	Retention	Treatment on N Implants	(in %) Implant survival rate	Prospective Retrospective
Krennmair et al. 2011	Mandible	5 years	Ball abutment, telescopic crown	2	100	prospective
Krennmair et al. 2012a	Mandible	3 years	Milled bar, telescopic crown	4	100	prospective
Krennmair et al. 2012b	Mandible	1 years	Ball abutment, locator abutment	2	100	prospective crossover
Xiang et al. 2011, 2010	Maxilla / Mandible	5 years	Horizontal / screw-retained fixation	6 – 9 5 – 8	99	retrospective
Weinländer et al. 2010*	Mandible	5 years	Milled bar / round bar	4 / 2 or 4	100	prospective
Krennmair* et al. 2008 a, b	Mandible	5 years	Milled bar (anterior vs lateral region)	6 – 8	98	retrospective
Krennmair* et al. 2008 c	Mandible	5 years	Milled bar round bar	4	100	prospective
Karabuda et al. 2008*	Maxilla / Mandible	23 months	Ball abutment, round bar	2 – 4	99	n.a.
Krennmair et al. 2007*	Mandible	59 months	Milled bar	4	99	retrospective
Nelson et al. 2006	Maxilla / Mandible	35 months	Galvano bar	5 – 6 4	99	retrospective
Krennmair et al. 2006 a, b	Mandible	3 years	Ball abutment, telescopic crown	2	100	prospective

*the publication included also other implant systems

Tab. 7: Clinical prospective and retrospective studies on treatment forms on CAMLOG®
Implants: retention technique, number of implants, study duration

DIFFERENT ANCHORAGE OPTIONS FOR REMOVABLE OVERDENTURES ON TWO OR FOUR IMPLANTS

In a study in 76 patients with edentulous mandibles, Weinländer et al. (2010) examined the mode of anchorage of overdentures on either two or four implants. With two implants, a prefabricated round bar was used for retention, with four implants, either several prefabricated bars were used or one milled bar. The authors concluded that the anchorage methods had no impact on treatment success and stability of the periimplant tissue, however, prosthetic complications were less frequent for the milled bars on four implants ($p<0.01$). This finding is supported by Krennmair et al. (2008c), who demonstrated that a milled bar on four interforaminal implants led to fewer technical complications than the use of several round bars.

While comparing the treatment success of mandibular overdentures on four implants retained with milled bars or telescopic crowns in 51 edentulous patients, Krennmair et al. (2012a) reported that the periimplant conditions and prosthetic follow-ups were stable for both techniques. Although more plaque and tartar was observed with the bar constructions, the prosthetic treatment showed slight benefits with this technique. The authors concluded that both retention methods were successful and that the clinician should choose the technique he/she is most familiar with.

In the maxilla, Krennmair et al. (2008a and 2008b) compared retrospectively overdentures retained either by four implants in the anterior region or by six implants inserted in the posterior regions after augmentation. After an average period of three and a half years, 34 patients with 179 implants were examined. The cumulative implant survival rate was 98%. There was no difference between the two treatment groups. The authors concluded that with good planning, both concepts allow high implant survival rates and excellent periimplant conditions. (Tabs. 6 and 7).

	MANDIBLE	MAXILLA
Milled Bar	✓	✓
Round bar	✓	✓
Ball abutment	✓	✓
Telescopic crown	✓	
Locator abutment	✓	
Horizontally screw-retained fixation	✓	✓

Tab. 8: Overview of the documentation on treatment forms on CAMLOG® Implants in the maxilla and mandible of edentulous patients with different retention techniques

EXCELLENT RESULTS INDEPENDENT OF THE RETENTION MODE USED FOR AN OVERDENTURE

Several publications reported prospectively or retrospectively the influence of the different mode of prosthetic retention in edentulous maxilla and / or mandible (tables 7 and 8). Krennmair et al. (2012b) performed a cross-over prospective study including 20 subjects and reported the patient satisfaction and preferences for implant-supported mandibular overdentures as well as the prosthetic maintenances of the two retention modes. Each patient received two mandibular implants. After healing (three months and two-stage surgery), patients received a new maxillary denture and an implant-retained mandible overdenture using either ball or locator attachments in alternating frequencies of three months each. Thereafter, a longitudinal follow-up of one year was performed. The study showed a statistically significantly improved satisfaction for all item scores between baselines (old dentures without implants) and after the three months of function of the implant-retained overdentures ($p<0.05$). No statistically significant difference was noticed between the two retention modes. However, in terms of prosthetic maintenance, more aftercare interventions due to more matrix activation were necessary for the locator abutment in comparison to the ball attachment.

Another prospective study (Krennmair et al. 2006a and 2006b) including 25 patients compared the overdentures retained with ball or telescopic crown attachments on two interforaminal implants after three years. It was demonstrated that technical complications with the ball abutments (61% of cases) occurred much more frequently than with the telescopic crowns (38%, $p<0.01$). The five-year follow-up (Krennmair et al. 2011) confirmed the three-years results in terms of maintenance, however during year four and five no difference was observed concerning prosthetic complication. Despite this, implant treatment success in both groups was 100% during five years. The conditions of the periimplant tissue and treatment satisfaction did not differ significantly. Similar results and success rates were found by Karabuda et al. (2008) comparing overdentures with bar and ball abutments on two to four implants using different implant systems.

CONDITIONALLY REMOVABLE BRIDGES

Implant-supported bridges with galvano elements are clinically successful and can be reliably removed at the scheduled times, as a retrospective analysis in 45 patients over five years demonstrated (Xiang et al. 2010, 2011). Fifty-five bridges were placed on 353 implants. On average, seven implants were placed in the maxilla, six in the mandible. After a mean observation period of slightly more than four years, the cumulative implant survival rate was 99%. According to the authors, galvano elements combine the benefits of screw-retained fixation and cementation, in addition, the use of an electroformed substructure allows long-term retention, while the suprastructure can be removed again at any time. The research group also evaluated patient satisfaction and treatment successes of 118 implant-supported galvano bar prostheses placed on five to six implants in the maxilla and four in the mandible after an average period of three years (Nelson et al. 2006). Only seven of 568 implants were lost, i.e., the success rate was 99%.

The prosthetic seats were stable in 93%, only 7% showed slight movements during unilateral loads. 85% experienced no mechanical complications. Patient satisfaction was very high (97%).

PATIENT PREFERENCE AND SATISFACTION

Patient satisfaction must be regarded as one of the most important factors for the success of the chosen treatment concept. A plenum of projects has evaluated the oral health-related quality of life including four or less implants in the edentulous maxilla or mandible. Comparing the patient preferences between implant-retained overdentures attached either with locator or with ball anchor in 20 edentulous patients, Krennmair et al. (2012b) noted that patient satisfaction was significantly improved between baseline and the new restoration ($p<0.05$), however, no significantly difference was observed between the prosthesis.

Wolfart et al. (2012) reported the effect of strategic implant placement under removable partial or full prosthesis in 23 patients. Patients who had either removable partial dental prostheses or a complete dental prostheses received additional implant-supported ball abutments. The existing prosthesis was adapted to the additional point of retention. The Oral Health Profile questionnaire (49 Questions) was completed by patients over time (up to 12 months). The authors concluded that increasing the number of abutments improved quality of life related to the oral health (OHRQoL).

SUMMARY

Clinical studies have reported high success rates with the sandblasted and acid-etched Promote® surface for single restorations, in partially edentulous patients, and in edentulous jaws. Implant type, diameter or length, time point of implantation or time of loading did not show significant influence on the implant survival rates.

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