4. Scientific studies

The Tube-in-Tube™ connection is the centerpiece of the CAMLOG® Implant System. It ensures simple, secure chair-side and laboratory handling consistently over all four CAMLOG® implant lines. The Tube-in-Tube™ connection is an integrative factor for the team approach between oral surgeon, prosthetic dentist, and dental technician.

This section addresses the most important scientific publications on connection design between implant and abutment. Two observations emerge:

1. The patented Tube-in-Tube™ design is outstanding for its precision, positional stability, and transfer accuracy (Patent EP 851 744 and corresponding trademark rights).
2. A two-piece implant without micro-gap and without micro-movement has not yet been developed. Even conical implant/abutment connections are not bacteria-proof and can lead to microbial colonization of the periimplant hard and soft tissues.

Loading capacity and seal of modern implant/abutment connections

Steinebrunner et al. (2005a, 2005b) have published a newly developed testing approach for the pre-clinical testing of implant/abutment connections. The test design and results for fatigue resistance and maximum loading were published in the journal "Implantologie" (2005a). The results from seal measuring were published in the "International Journal of Oral and Maxillofacial Implants" (2005b). The Brånemark System®, FRIALIT®-2, Replace® Select, CAMLOG® and Screw-Vent® implant systems were included in the studies. The test design is shown in Figure 7.

The fatigue test and seal measuring were performed in a dual axis chewing simulator (Willytec, Munich). The effect of dynamic alternating loading on both the mechanical strength and the bacterial seal of the implant/abutment connections were studied through concurrent storage in an aqueous solution (Fig. 8). According to Richter (1995), the mean physiological force applied in the axial direction on a single crown in the posterior area is 120 N. The researchers therefore chose this value for their test set-up. An occlusion model with 30° cusp slope was simulated. In the Willytec dual axis chewing simulator, a 2-mm lateral movement was added on vertical loading, which is somewhat similar to what occurs in natural mandibular movement during chewing.

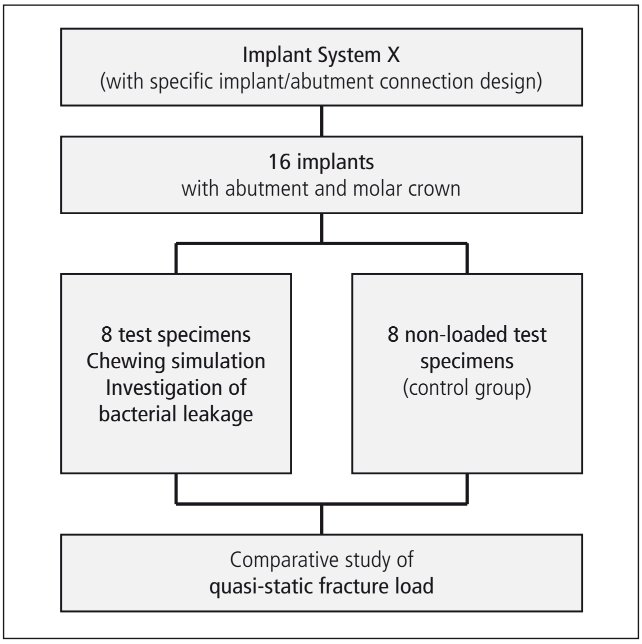

Fig. 7 Test design principle. For each implant system to be tested, 16 implant/abutment combinations were fitted with a crown and loaded until fracture point under quasi-static load in subgroups of 8 implants each. In one subgroup, the test specimens were exposed to dynamic alternating load in a chewing simulator prior to the quasi-static fracture load test. During this dynamic loading, any leakage between the implant and abutment was detected through evidence of bacterial penetration from the implants in a sterile external culture medium (source: Steinebrunner 2006)

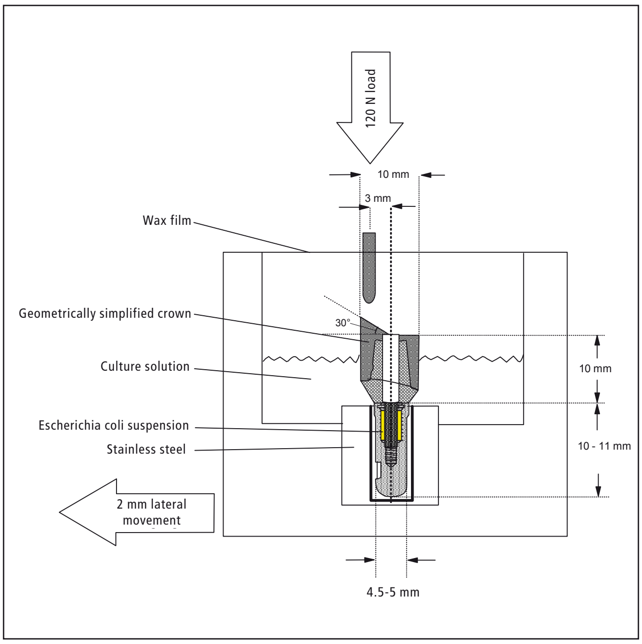

Fig. 8 Schematic presentation of the test set-up in the multifunction chewing simulator (Willytec, Munich). This takes into account a 30° cusp slope, a 2-mm lateral movement, and the physiological vertical chewing force reported by Richter (1995) (source: Steinebrunner 2006)

Special testing chambers were used to perform the bacterial study (seal measuring) concurrently with the chewing simulation, which enable not only rigid fixation of the test specimens in the chewing simulator but also their concomitant storage in aqueous solution. Injection of the implant inner surfaces with test microbes (Escherichia coli) enabled bacterial penetration from the implant/abutment connection to be measured.

Results of fatigue resistance test
(Steinebrunner et al. 2005a)

During the dynamic alternating load test (fatigue resistance) in the Willytec dual axis chewing simulator, the test specimens were subjected to a maximum of 1.2 million cycles at a rate of 1 Hz. No mechanical failure occurred during the chewing simulation in any restoration using the CAMLOG® or Replace® Select implant systems. The mean survival times were:

- in the FRIALIT®-2 group: 627,300 ± 164,097 cycles
- in the Screw-Vent® group: 913,200 ± 102,242 cycles
- in the Brånemark system® group: 954,300 ± 121,014 cycles
- in the Replace® Select group: 1,200,000 ± 0 cycles
- in the CAMLOG® group: 1,200,000 ± 0 cycles.

The test was ended after 1,200,000 cycles.

Results of seal measuring
(Steinebrunner et al. 2005b)

To measure the seal of the implant/abutment connections, the migration of microbes from the gap area between the implant and abutment was checked in increasing cycle intervals: after 5,400, 10,800, 21,600, 43,200, 86,400, 172,800, 345,600, 691,200 and 1,200,000 cycles. The CAMLOG® Implant System reached a significantly higher number of chewing cycles than the FRIALIT®-2 ($p^{1)}$ = 0.004) and Screw-Vent® (p = 0.005) implant systems. Before bacterial penetration occurred, the groups reached the following mean cycle values (Fig. 9):

- Screw-Vent® group: 24,300 cycles
- FRIALIT®-2 group: 43,200 cycles
- Replace® Select group: 64,800 cycles
- Brånemark System® group: 172,800 cycles
- CAMLOG® group: 345,600 cycles.

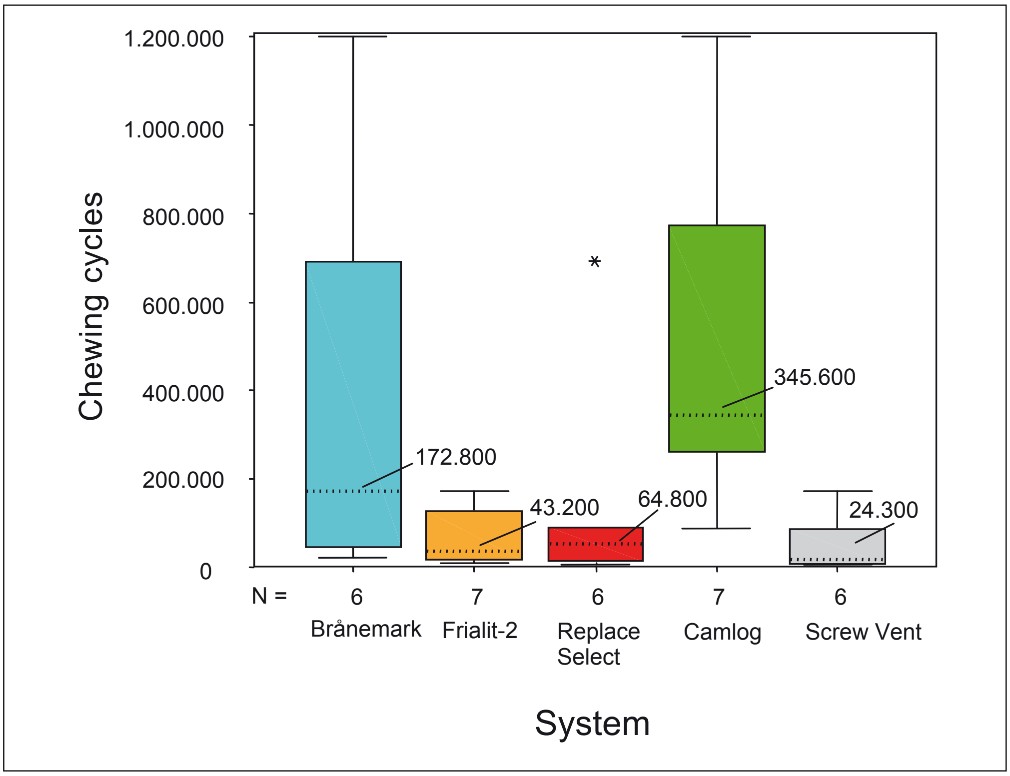

Fig. 9 Box plot graph. The boxes show the chewing cycles reached before microbial leakage occurred in the individual systems. Each box is divided by a broken line, the median value. The value indicated by a star represents an extreme value. The CAMLOG® Implant System clearly reached the highest mean number of cycles among the tested systems (source: Steinebrunner 2006)

1) The p value is the result of a statistical significance test; it is used to test a priori hypotheses.

Results of maximum load test
(Steinebrunner et al. 2005a)

To test the maximum load, the researchers utilized a deviant test set-up. Figure 10 shows a schematic representation of the test set-up in the Zwick Z010A TN 2A universal testing machine. Implant systems with a deep internal connection had the highest fracture strength score (Fig. 11).

The publications of Steinebrunner et al. in "Implantologie" and the "Journal of Oral and Maxillofacial Implants" support the superior fatigue strength, stability, and measured seal of the CAMLOG® Tube-in-Tube™ connection compared with the other implant systems tested.

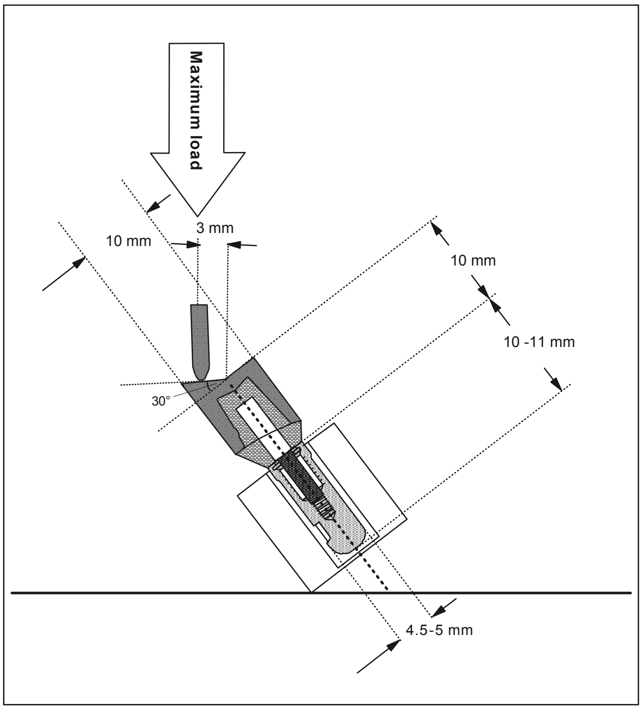

Fig. 10 Schematic representation of the test set-up in the Zwick Z010A TN 2A universal testing machine. The force input point was identical to chewing simulation at 3 mm eccentric from the crown midpoint on the central cusp, sloped at 30° to the occlusion plane and 11.5 mm distant from the implant shoulder (source: Steinebrunner 2006)

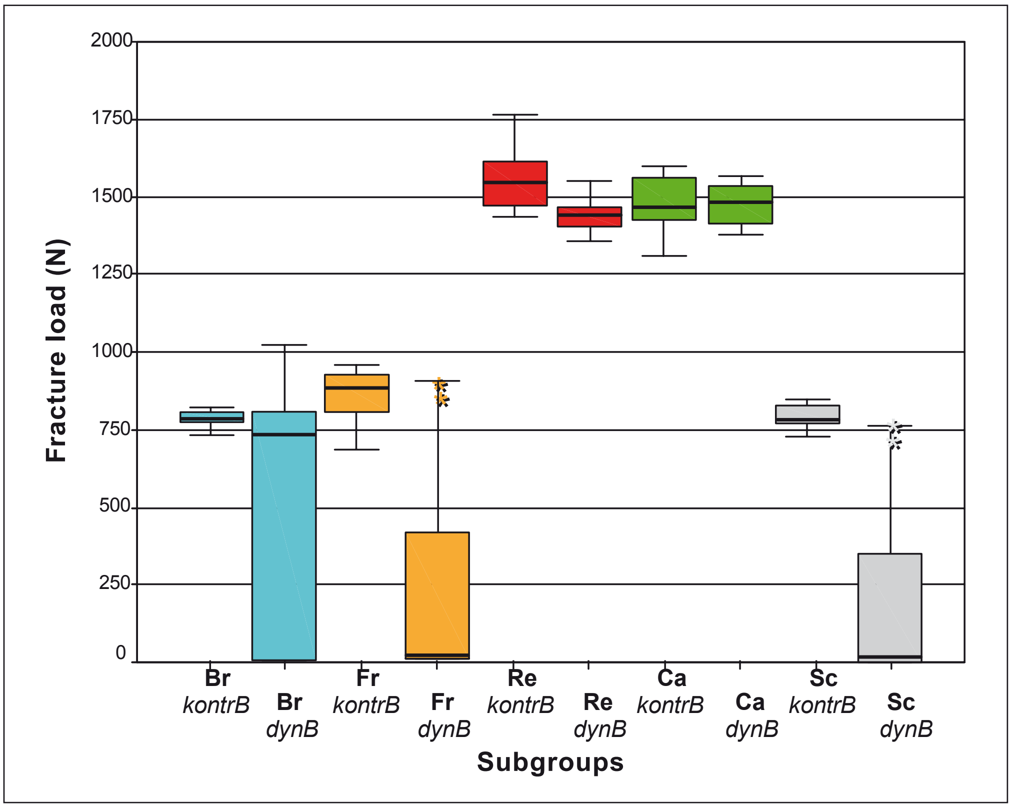

Fig. 11 Box plot diagram of the quasi-static fracture strength values of all test groups.
Br = Brånemark, Fr = FRIALIT®-2, Re = Replace® Select, Ca = CAMLOG, Sc = Screw-Vent®; kontrB = no-load control group, dynB = after chewing simulation (source: Steinebrunner 2006)