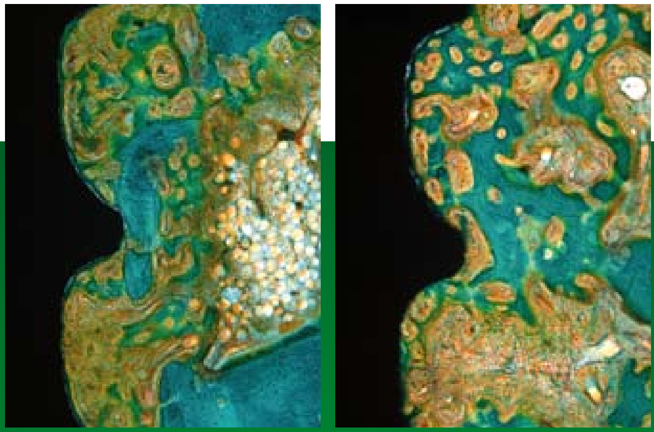
straumann®

# SCIENTIFIC RESEARCH SUMMARIES



Straumann® Dental Implant System

COMMITTED TO
**SIMPLY DOING MORE**
FOR DENTAL PROFESSIONALS

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[1]Shown in animal studies

# Introduction

The Straumann® Dental Implant System has over 20 years of proven clinical research behind it, with a constant flow of independent scientific publications, making it one of the most extensively documented implant systems available today. The system is designed for simplicity, versatility, and flexibility making it suitable in a number of situations and indications.

Straumann has developed a chemically modified implant surface, Straumann SLActive®, based on the well documented Straumann SLA topography. SLActive has a high surface free energy, and is hydrophilic.[20, 21] Sixty percent more bone to implant contact has been observed at the SLActive surface compared to Straumann's SLA® surface, with earlier formation of more mature bone in an animal study.[22]

The **characteristics of the SLA® and SLActive surface**, and their osseointegration properties, are discussed in chapter 1. These surface characteristics are designed to offer a new level of security and treatment predictability and to revolutionize the **timing of provisionalization**.

Chapter 2 focuses on studies that look at how the implant surface impacts the healing time and the time for provisionalization. Results are presented that show a reduction in healing times from 12 weeks to 6 weeks with SLA and a reduction to 3-4 weeks with SLActive, when the implants are used in the appropriate clinical circumstances. Studies are also reviewed that help demonstrate that safe and predictable early loading is possible, including immediate restorations with appropriate occlusal loading on the day of implant placement.

The various **implant designs** available within the Straumann Dental Implant System are outlined in chapter 3, including an overview of the clinical success with short implants, narrow- and wide-diameter implants, and Straumann Tapered Effect implants.

**Biomechanical aspects** of the implant design, including stability, distribution of stress forces and the influence of the implant abutment joint, are discussed in chapter 4.

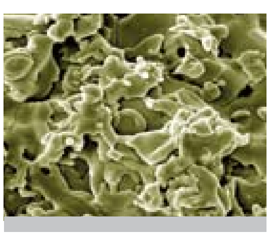
Chapter 5 focuses on the **prolonged success** of the implant system, as shown in several long-term studies. Chapter 6 then reviews the evidence for the excellent **peri-implant tissue effects**, demonstrating remarkable long term esthetic results. Chapter 7 then highlights the various successful functional **prosthetic elements** of the system.

Successful implant restoration is about more than just restoring function, and chapter 8 demonstrates the beneficial effects of implants on the wider aspects of **quality of life** for the patients.

Chapter 9 then shows the success of the implants in **special situations** such as sinus floor elevation and narrow ridge augmentation.

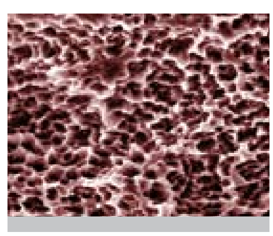
The intention of this document is to outline the key clinical evidence for the Straumann® Dental Implant System in various situations so that implant practitioners can treat patients with the knowledge that the implants they are using are scientifically tested and well-documented.

1974 – TPS



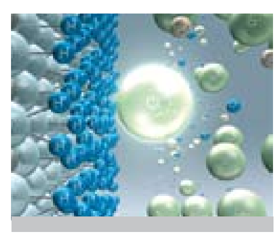
**Macro**

1994 – SLA



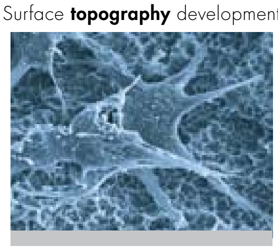
**Micro & Macro**

2005 – SLActive



**Molecular**

Surface **topography** development



Surface **chemistry** development

# 1. Surface characteristics and osseointegration

Roughened implant surfaces show advantages over machined (smooth) titanium surfaces, but not all roughened surfaces are equal. The topography chemistry and characteristics of the Straumann® SLA and SLActive surfaces, the advantages, and how these translate into improved osseointegration, are discussed here.

## Introduction

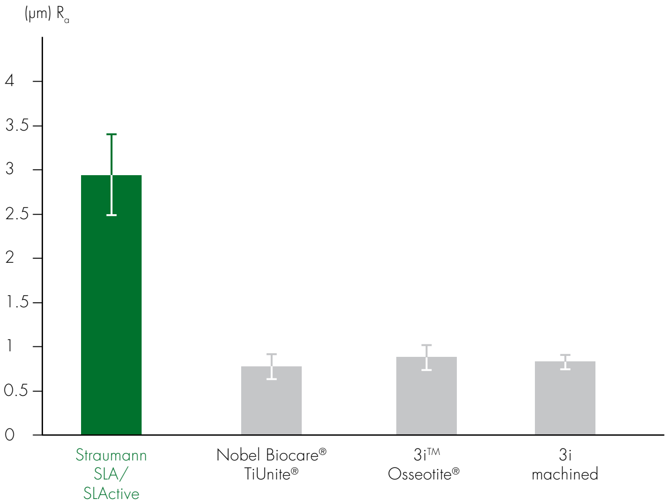
Studies are conducted in specific indications or patient groups show that implants with roughened surfaces have significant advantages over smoother surface implants. They show better osseointegration, enhanced bone-to-implant contact (BIC) and greater biomechanical and functional stability.[1]

The SLActive surface is the result of improved surface chemistry with the established SLA surface, designed to enhance osseointegration and the healing response. Cell culture and animal studies have demonstrated that the hydrophilic surface enhances cell activity and differentiation, bone healing and bone apposition, and increases implant stability, all of which are crucial factors in the osseointegration process. The reduction in healing time with SLA is reduced (from the conventional healing time of 12 weeks to 6 weeks), the enhanced response with SLActive further reduces the healing time to 3-4 weeks in the appropriate clinical circumstances. The surface properties of implants become particularly relevant to the chemical and biological interfacial processes in each healing stage, but first and foremost, in the early healing stages following implantation. It is generally accepted that these early stages of healing are likely to have an effect on the host response to the implant and therefore the long-term outcome and success of treatment.[29]

Morphometric analyses have shown that the extent of the bone-implant interface formed at the implant surface increases with increased surface roughness.[2, 3] However, problems have been noted with surfaces that are very rough. Therefore, there appears to be an optimum range of moderate surface roughness into which some modern implant surfaces fall.[4]

The SLA surface is sandblasted with large grit (250–500 μm), which produces macro-roughness of around 20–40 μm peak to-peak. Subsequent acid-etching with HCl/H2SO4 confers a micro-roughness of around 2–4 μm peak-to-peak. The Ra value, a standard parameter to describe average surface roughness, is 2.93 ± 0.46 (Figure 1 references the Ra value of major implant manufacturers in the US).[5]

**Fig. 1:** Implant surface $R_a$ values[5]

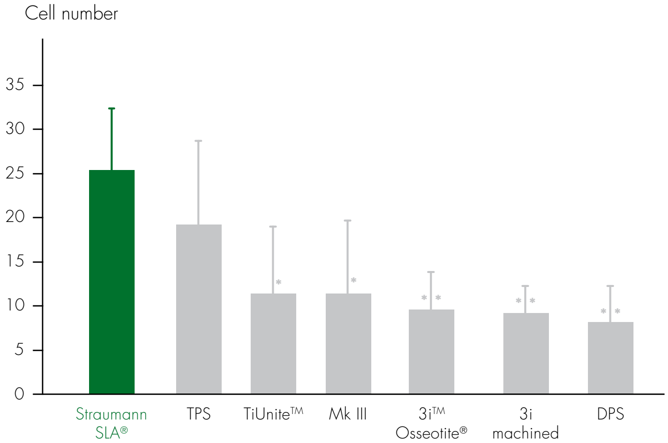



## Effects on osteogenic cells

The effect of micro-rough titanium surfaces on osteogenic cells has been evaluated in several *in vitro* studies. The microtopography influences cell differentiation and mineralization.[6]

For example, the production of osteoprotegerin, which is involved in bone remodeling, and 1,25(OH)2D3, which regulates osteoblast differentiation, are increased on micro-rough surfaces such as Straumann SLA and SLActive. Osteoblast differentiation is enhanced and osteoclast formation and activity is reduced.[7] Cells adhere and proliferate in cavities of 30–100 μm diameter, but do not recognize 10 μm cavities; nanotopography has little effect on cell morphology, but proliferation and morphology are enhanced with micro-rough topography.[8] Micro-rough surface topography also enhances the rate of cell spreading and the formation of a 3-dimensional cell matrix, and significantly increases the number of cells attached to the surface (Fig. 2).[5]

**Fig. 2:** Percentages of attached cells on micro-rough surfaces[5]




## Hydrophilicity

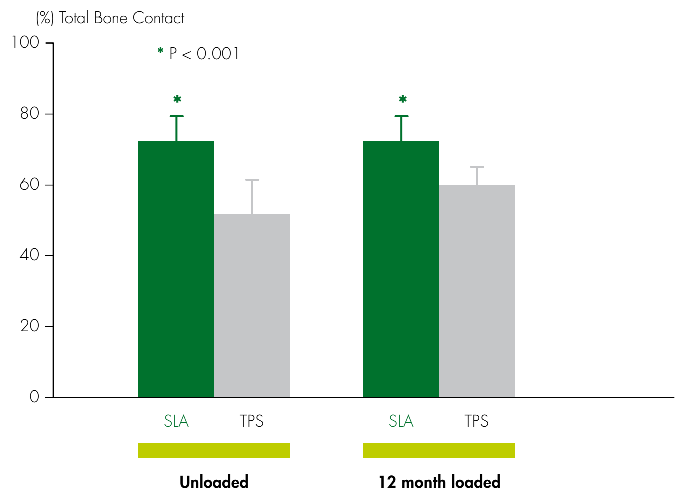
*In vitro* studies using dynamic contact angle analysis showed maximum hydrophilicity for Straumann SLActive in comparison to Straumann SLA (Fig. 3) that is preserved over the shelf life of the product.103 Water contact angles of 0° compared to 139.9° for SLA have been demonstrated. Investigations also showed an increased surface free energy for SLActive, and reduced atmospheric contamination.[21] This phenomenon allows immediate cell reaction for more bone-to-implant-contact in the early phase of bone healing.

**Fig. 3:** Immersion of Straumann SLA and Straumann SLActive implants in water demonstrates the wetting of SLActive and its meniscus at the water-air implant interface.


## Influence on new bone apposition

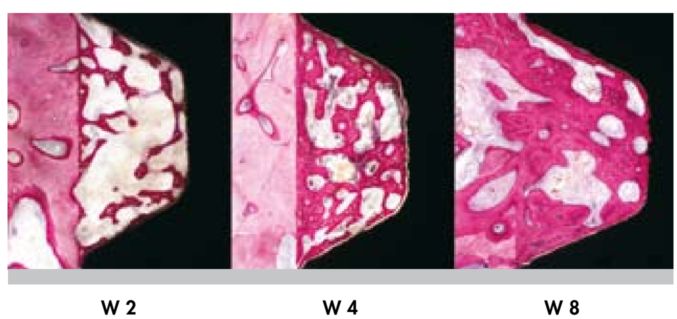
In comparison to the titanium plasma-sprayed (TPS) implant surface, Straumann's previous rough surface before the advent of Straumann SLA, analysis has shown the benefits of the SLA surface. A preclinical study by Cochran et al (1996) showed that loss of bone height was reduced (0.73 mm (SLA) versus 1.06 mm (TPS) after 3 months). The percentage of BIC with SLA implants has also been shown to be greater than with TPS implants after 3 months of unloaded healing and after 12 months of loading, indicating greater and earlier osseous contact (Fig. 4).[10]

**Fig. 4:** Percent BIC – Straumann SLA versus TPS[10]




The additional benefits of the enhanced surface chemistry of SLActive on BIC have also been demonstrated, with significantly greater BIC observed after 2 and 4 weeks compared to Straumann SLA surface (mean 49.30% versus 29.42% at 2 weeks and 81.91% versus 66.57% at 4 weeks). Bone apposition was therefore enhanced in the early healing stages (Fig. 5).[22]

**Fig. 5:** Bone formation on Straumann SLActive experimental implants after 2, 4 and 8 weeks

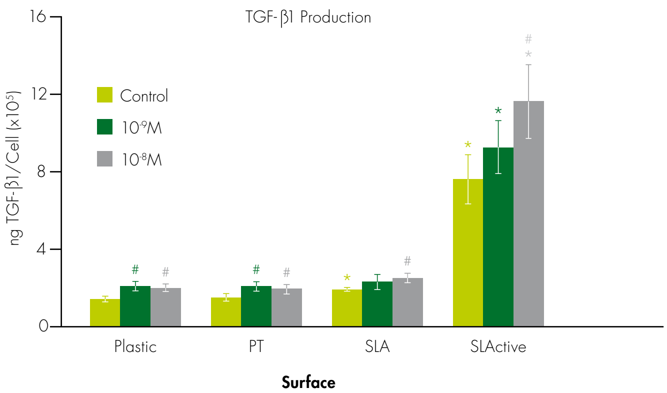


Implant stability, measured by removal torque in a preclinical study, was also higher with SLActive compared to SLA®. Removal torque value (RTV) increased for both surfaces to a peak at 4 weeks after implant placement, but the mean RTV was consistently higher for SLActive at all time points.[23]

## Enhanced cell activity

Studies on the osteoblast response to Straumann SLActive have shown that levels of alkaline phosphatase, osteocalcin and local growth factors (PGE2 and TGF-ß1, Fig. 6) are increased when osteoblasts are cultured on SLActive compared to Straumann SLA, plastic or pre-treated titanium. Osteoblast differentiation is also enhanced, as demonstrated by increased levels of 1α,25-dihydroxyvitamin D3.[20]

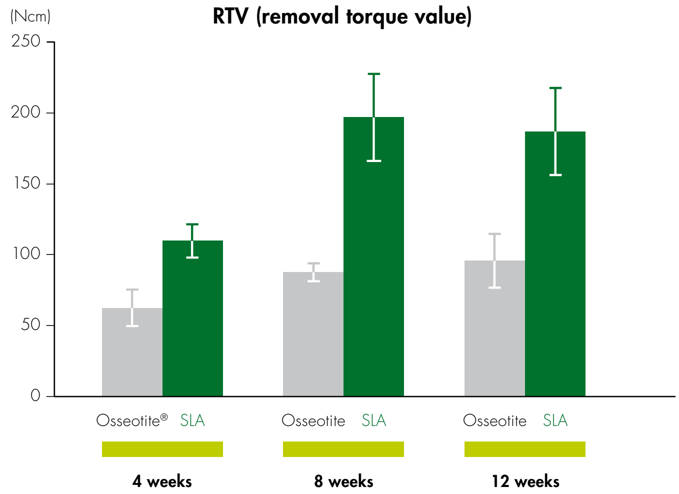
**Fig. 6:** Latent TGF-ß1 production by MG63 cells during culture on plastic or Ti disks. Values are the mean ± SEM of six cultures.




There were no significant differences in the shear strength of the bone-implant interface with SLA than with TPS after 4 weeks, although SLA implants demonstrated a slightly higher mean. SLA was significantly greater than machined surface implants at 12 weeks. (4-week mean removal torque values were 1.39 Nm, 1.14 Nm and 0.26 Nm for SLA®, TPS and machined surfaces, respectively).[11]

An in vivo study comparing the shear strength of the bone-implant interface of SLA versus the machined and acid-etched Osseotite also showed significantly greater removal torque values (75% to 125% higher; $p < 0.01$) for SLA® (Fig. 7).[12]

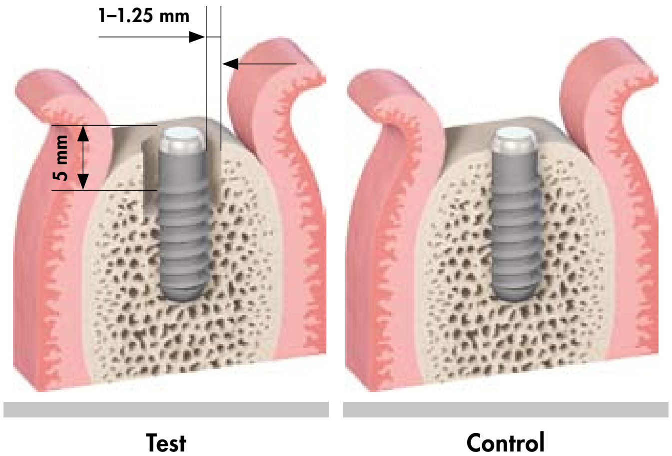
**Fig. 7:** Removal torque values (Ncm) for Osseotite and Straumann SLA implants at 4, 8 and 12 weeks.[12]




A later investigation compared SLA® and machine/acid-etched implants with the same implant design; in this study, removal torque values were again significantly greater for SLA (about 30% higher; $p = 0.002$). In addition, the SLA surface implants showed more than 5% greater stiffness than the machined/acid-etched surface implants. This may translate into a lower likelihood of micromovements, thus producing benefit for osseointegration.

In marginal defects in dogs, appositional bone formation was assessed with SLA implants, where implants were placed in defects 5 mm deep, with the bone walls 1–1.25 mm from the implant surface, compared to control implants where no further defect was created (Fig. 8). After 1 month, BIC around the test implants in the apical area and the defect area was 68.8% and 64.4%, respectively.[14] Within 2 months of implant placement, newly formed bone, beginning in the defect walls, filled the defect area around the test implants by distance osteogenesis, with BIC first established in the apical portion of the implant. Soft tissue, resembling 'late granulation tissue' attached to the implant was first formed, which underwent mineralization to form bone and increase the BIC.

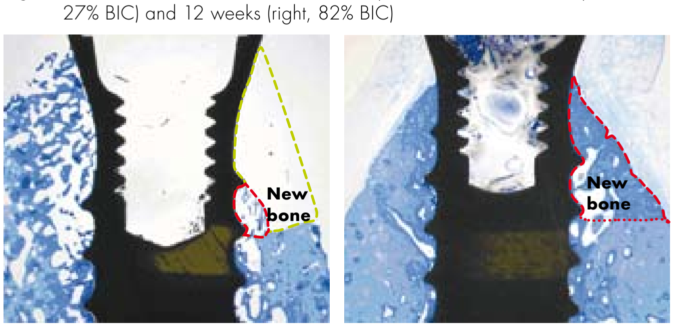
**Fig. 8:** Test and control sites in evaluation of appositional bone formation at experimental implants in marginal defects.[14]




In a similar canine study, the large defect around SLA® implants was filled with newly formed bone after 4 months, with equivalent BIC to that observed in conventionally placed implants.[15] Both of these studies showed that marginal defects >1 mm in width around SLA implants can heal with new bone and a high level of osseointegration.

The effect of the SLActive® surface in dehiscence defects in dogs showed new bone formed around SLActive implants after 12 weeks, compared to dense connective tissue around SLA® implants. The percentage of linear bone fill and BIC were also greater with SLActive (Fig. 9).[80]

**Fig. 9:** Bone fill around Straumann SLActive implants after 2 weeks (left picture, 27% BIC) and 12 weeks (right, 82% BIC)




## Enhanced bone healing[2]

Enhanced early tissue reactions in the early healing period (i.e. the first 14 days after implantation) have been demonstrated around Straumann SLActive implants. Faster blood vessel formation, osteocalcin synthesis, mineralized bone, and mature, parallel-fibered woven bone occurred around SLActive implants compared to Straumann® SLA (Fig. 10 and Fig. 11). BIC was greater with Straumann SLActive at all time points (Fig. 12).[104]

**Fig. 10:** Histology at Day 1; collapsed blood clots (Straumann SLA) versus stabilized blood clots (Straumann SLActive).

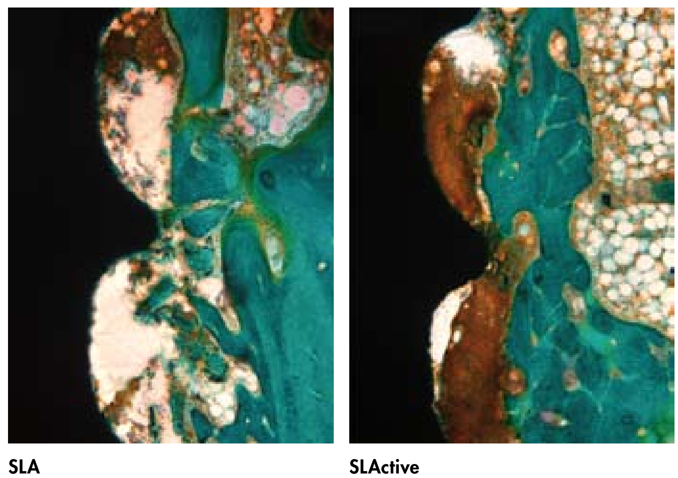
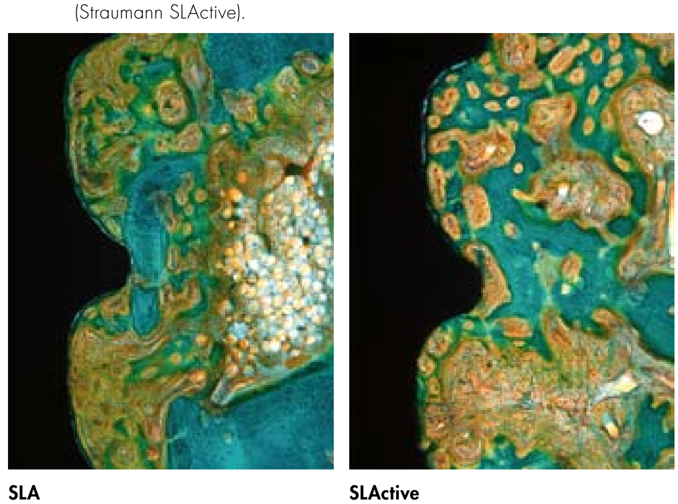
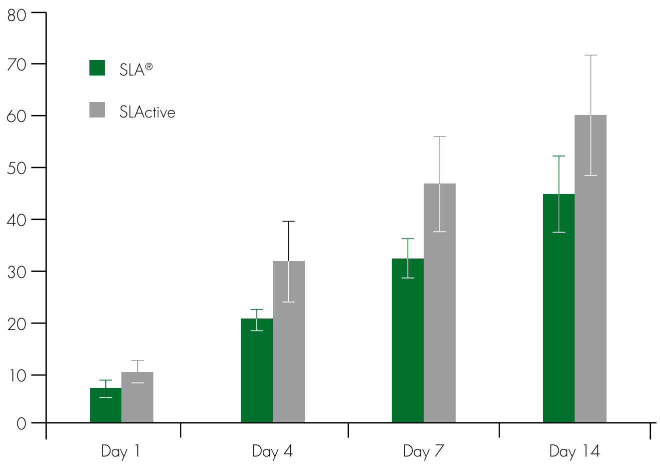



**Fig. 11:** Histology at Day 14; newly formed trabeculae (Straumann SLA) versus firmly attached, mature, parallel-fibered woven bone and primary osteons (Straumann SLActive).




[2]Shown in animal studies

**Fig. 12:** BIC was increased with Straumann® SLActive at all time points.

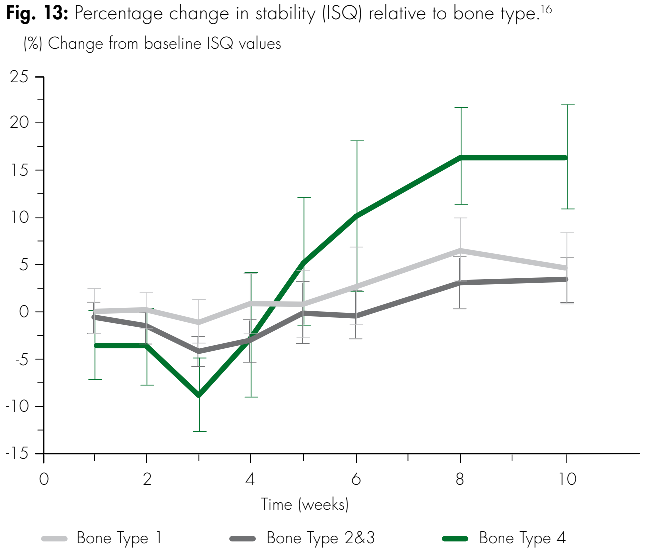



## Clinical application

Implant stability of Straumann SLA® implants in various bone types (1–4) in patients was evaluated by Barewal, et al (2003). Implant stability in all bone types, as assessed by resonance frequency analysis (RFA) using the Osstell® device, initially decreased and then increased after 3 weeks (Fig. 13); the biggest stability decrease at this time was in Type 4 bone (8.6% decrease).

There were no differences in stability between the various bone types from week 5 onwards. Implants in Type 1 bone exhibited no significant change in stability for the whole 10-week period.[16] The results correspond with the 'stability dip' identified by Raghavendra et al (2005), where primary stability decreases but has not yet been replaced by secondary stability.[17]

**Fig. 13:** Percentage change in stability (ISQ) relative to bone type.[16]

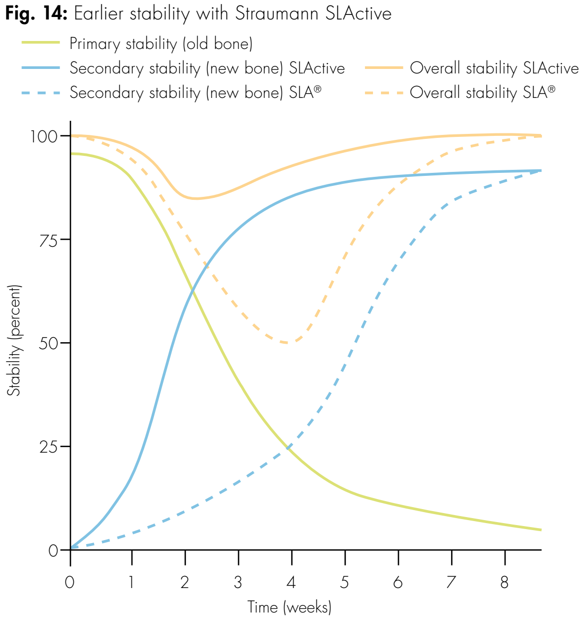



The stability of SLA implants is also similar in both immediate loading and standard delayed loading; no statistically significant difference in stability was observed between these procedures over the first 3 months. At 12 weeks the mean implant stability quotient (ISQ) values of 60.3 ± 4.8 for delayed loading and 60.3 ± 6.8 for immediate loading were observed. No decrease in stability was seen for either group over 3 months.[18]

Nedir et al (2004) showed that RFA was reliable in determining implant stability in implants with an ISQ≥47, and demonstrated that osseointegration was achieved in all delayed-loaded SLA® implants with ISQ≥49 and all immediately loaded SLA® implants with ISQ ≥ 54 in the study.[19]

A number of clinical studies are ongoing with Straumann SLActive implants. One of these is a large multicenter study involving over 260 patients and over 380 implants, evaluating survival rates and bone level changes for SLActive implants in time-critical (early and immediate) loading protocols. After 5 months the results indicate survival rates of 98% and 97% in the immediate and early loading groups, respectively.[106] In another study comparing implant stability between Straumann SLActive and SLA implants increased stability has been shown at an earlier stage, with the change in stability pattern (from primary to secondary stability) occurring earlier with SLActive (Fig. 14). These results suggest greater predictability in earlier loading procedures.[107]

**Fig. 14:** Earlier stability with Straumann SLActive



Further details on the scientific evidence of the SLActive® surface can be found in the latest version of the Straumann® document USLIT196, which can be ordered from your local subsidiary.

Bone apposition in a pig study also increased in the early healing stages, as shown by a 60% greater BIC at SLActive after 2 weeks, compared to SLA®. More mature bone was also formed earlier, with a scaffold of woven bone after 2 weeks and reinforcement of the bone with trabeculae after 4 weeks (Fig. 21).[22]

Greater early bone apposition has also been seen in another preclinical study in dogs after 2 weeks of healing.[105]

**Conclusions**

- SLA has biologically friendly topography and optimum roughness, with demonstrated benefits for the clinician.
- The proven SLA topography is the basis of Straumann® SLActive, the next generation in implant surface technology.
- When compared to SLA faster osseointegration with SLActive reduces the stability dip in the early healing period and there with may offer greater confidence when treating patients.
- SLActive surface technology may improve the implant survival rate by reducing the failure rate in the early phase.

# 2. Healing periods and timing of provisionalization

In traditional implant placement procedures, the implants are left to heal for several months after placement for osseointegration to take place. The advent of the Straumann® SLA® surface allowed this healing time to be cut in half, from 12 weeks (for TPS) to 6 weeks for SLA, and then 3–4 weeks with the advent of Straumann® SLActive® surface. Subsequent studies have provided evidence for even earlier loading times in the appropriate clinical circumstances including immediate loading; these studies are reviewed here.

## Introduction

Conventional dental implant treatment protocols dictate that the implants should be left undisturbed after placement, so that osseointegration can take place; loading the implant before the end of this traditional healing period was thought to inhibit the healing process and adversely affect osseointegration.[24] The traditional healing period for TPS surface implants was established at 12 weeks, or even longer in poor quality (Type 4) bone. The advantages of the Straumann SLA surface suggested that this traditionally extended healing period could be reduced with the same predictability.[25,26] Several clinical studies have since confirmed that the conventional healing time could be cut in half, to only 6 weeks (with adequate bone quality), by using implants with the SLA® surface; the properties of the Straumann® SLActive surface reduce the healing time further to 3–4 weeks.

## Reduced healing times

Cochran, et al (2002) evaluated the possibility of restoration of Straumann® SLA implants 6 weeks after placement in patients with bone quality 1–3 (implants in patients with Type 4 bone quality were restored after 12 weeks). The success rate (defined as no mobility, no persistent pain or infection, and no peri-implant radiolucency) for 329 implants at 12-months post-loading was 99.1%. No implants were lost after one year so the cumulative implant success rate for 138 implants remained unchanged at 99.1% at the 24-month post-loading evaluation. (Table 1).[27]

**Table 1:** Life table analyses for implants loaded after 6 weeks[27]

| Group | Interval (months) | No. of implants | No. of implants lost | Success rate for interval (in %) | Cumulative implant success rate |
|---|---|---|---|---|---|
| A, B, C | 0–12 | 329 | 3 | 99.1 | 99.1 |
| | 12–24 | 138 | 0 | 100.0 | 99.1 |
| A | 0–12 | 166 | 1 | 99.4 | 99.4 |
| | 12–24 | 61 | 0 | 100.0 | 99.4 |
| B | 0–12 | 35 | 0 | 100.0 | 100.0 |
| | 12–24 | 16 | 0 | 100.0 | 100.0 |
| C | 0–12 | 128 | 2 | 98.4 | 98.4 |
| | 12–24 | 61 | 0 | 100.0 | 98.4 |

A later study, which defined implant success as lack of persistent clinical symptoms and absence of inflammation or suppuration, mobility, or peri-implant radiolucency also showed that SLA® implants could be successfully loaded after 6 weeks.[28]

Longer-term results of SLA® implants loaded after 6 weeks also demonstrate the suitability of the procedure. Of 104 implants placed in 51 partially edentulous patients, a 3-year success rate of 99.03% was noted, with stable peri-implant soft tissue and bone crest levels, and no peri-implant radiolucency.[29] Soft tissues continued to be stable up to 5 years (last follow-up was 60 months), with no change in probing depths or mean attachment levels.

Ankylotic stability and stability of the bone crest levels were also demonstrated. The cumulative 5-year success rate was 99% (Table 2).[30] Loading after 6 weeks was therefore highly predictable, with favorable long-term results.

**Table 2:** Cumulative success rates of Straumann SLA implants loaded after 6 weeks.[30]

| Interval (months) | No. of implants | Drop-out implants | Implant failures | Success rate within period (%) | Cumulative success rate (%) |
|---|---|---|---|---|---|
| **Healing period** | 104 | 0 | 1 | > 99 | 99 |
| **0–3** | 102 | 1 | 0 | 100 | 99 |
| **3–12** | 102 | 0 | 0 | 100 | 99 |
| **12–24** | 102 | 0 | 0 | 100 | 99 |
| **24–60** | 100 | 2 | 0 | 100 | 99 |

A comparison of 68 SLA implants, loaded after 6 weeks, and 68 TPS implants, loaded after 12 weeks, showed no significant difference with respect to the presence of plaque, bleeding on probing, mean pocket depth or mean marginal bone loss (Table 3). The implant survival rate was 100% after 1 year in both groups.[31]

**Table 3:** Periodontal parameters measured at Straumann SLA and TPS implants after 1 year.[31]

| | Test (SLA®) n=68 | Control (TPS) n=68 | Statistical difference |
|---|---|---|---|
| **Healing period** (weeks) | 6 | 12 | |
| **Survival rate** (after 1 year) | 100 | 100 | N.S. |
| **PI** (in %) | 24 | 27 | N.S. |
| **BOP** (in %) | 24 | 31 | N.S. |
| **PD** (in mm) | 3.3 (1.3) | 2.9 (1.2) | N.S. |
| **BL** (in mm) | 0.65 (0.41) | 0.77 (0.49) | N.S. |

SLA® implants loaded with mandibular overdentures after 6 weeks (test) or 12 weeks (control) were compared. All implants (24 in each group) were still in place after 2 years, with no significant differences in implant stability (mean ISQ 64.77 and 62.0 for control and test implants, respectively) or peri-implant parameters (recession, probing depth, attachment levels, keratinized tissue width, plaque index and gingival index; Table 4).[32]

**Table 4:** Mean peri-implant parameters up to 2 years for Straumann® SLA implants loaded after 6 or 12 weeks.[32]

| | **Control group: 6 weeks healing, n=24** | | | **Test group: 12 weeks healing, n=24** | | |
|---|---|---|---|---|---|---|
| | **Base-line** (SD) | **1 year** (SD) | **2 years** (SD) | **Base-line** (SD) | **1 year** (SD) | **2 years** (SD) |
| **GR** (mm) | 2.28 (± 2.90) | 0.16 (± 1.60) | -0.62 (± 1.11) | 1.94 (± 2.47) | -0.57 (± 0.64) | -0.55 (± 0.43) |
| **PPD** (mm) | 1.30 (± 0.56) | 1.87 (± 0.43) | 1.78 (± 0.50) | 1.47 (± 0.59) | 2.10 (± 0.41) | 2.07 (± 0.21) |
| **CAL** (mm) | 3.58 (± 2.90) | 2.03 (± 1.82) | 1.16 (± 1.08) | 3.42 (± 2.22) | 1.46 (± 0.66) | 1.52 (± 0.36) |
| **PI** | 1.62 (± 0.59) | 0.96 (± 0.83) | 0.60 (± 0.78) | 1.71 (± 0.76) | 1.15 (± 0.85) | 0.63 (± 0.76) |
| **GI** | 0.54 (± 0.64) | 0.62 (± 0.44) | 0.23 (± 0.33) | 0.88 (± 0.84) | 0.46 (± 0.43) | 0.28 (± 0.36) |
| **Survival** | 100 % | | | 100 % | | |

***GR =*** *Gingival recession (mm),* ***PPD =*** *Pocket probing depth (mm),*
***CAL =*** *Clinical attachment levels (mm),* ***PI =*** *Plaque index,*
***GI =*** *Gingival index,* ***Survival =*** *Survival rate after 2 years*

The suitability of loading SLA® implants after 6 weeks in the trabecular bone of the posterior maxilla was demonstrated by Roccuzzo and Wilson (2002). To keep drilling to a minimum implant site preparation in this study was accomplished primarily by using osteotomes. Abutments were tightened to 15 Ncm and provisional restorations placed 43 (± 1 days) after surgery, with additional abutment tightening to 35 Ncm after an additional 6 weeks. Implant survival at 1 year for 36 implants placed was 97.2% (one implant was lost before final restoration).[33]

Recent studies have shown that the healing time with SLActive can be reduced further, to only 3–4 weeks. There are significant earlier stability improvements with SLActive over SLA®; the change in stability pattern (from primary to secondary stability) occurs earlier with SLActive (after 2 weeks versus 4 weeks for SLA®).[110]

## Early loading

From both the patient's and the clinician's point of view, earlier loading is desirable, as the patient achieves optimum function faster, with fewer surgical interventions. In a 1-year prospective controlled clinical trial to evaluate the effect of early loading of Straumann SLA implants clinical and radiographic outcomes of final single-tooth restorations were compared between those provisionalized 2 weeks after implant placement versus those provisionalized 6 weeks after implant placement. No statistically significant differences were found including probing depths, clinical attachment levels, bleeding on probing, keratinized mucosa width, Periotest values and crestal bone loss (Table 5). The implant survival rate was 100%.[34]

**Table 5:** Clinical and radiographic parameters of implants loaded after 2 weeks (test) or 6 weeks (control)3

| | **Test sites: 2 weeks healing n=31** | **Control sites: 4 weeks healing n=36** | |
|---|---|---|---|
| | **Baseline** (SD) | **Baseline** (SD) | **Statistical difference** |
| **PPD** (in mm) | 2.6 (± 0.5) | 2.7 (± 0.5) | N.S. |
| **CAL** (in mm) | 3.1 (± 0.4) | 3.2 (± 0.5) | N.S. |
| **BOP** (in %) | 9.7 | 8.3 | N.S. |
| **PTV** | 1.8 (± 0.4) | 1.9 (± 0.5) | N.S. |
| **BL** (in mm) | 0.57 (± 0.49) | 0.72 (± 0.50) | N.S. |
| **Survival** | 100 % | 100% | |

***PPD =*** *Pocket probing depth (mm),* ***CAL =*** *Clinical attachment level (mm),*
***BOP =*** *Bleeding on probing (%),* ***PTV =*** *Perio test value,* ***BL =*** *Crestal bone loss (mm),*
***Survival =*** *Survival rate after 1 year*

Similar results were shown in a study where Straumann® SLA implants were loaded with mandibular overdentures after 2 weeks.

In this study, SLA® implants were compared with Southern implants with a sandblasted and acid-etched surface. Southern implants showed a greater reduction in implant stability from baseline to six weeks compared to SLA® implants (Fig. 15); 1 year follow-up indicates that early functional loading with mandibular two-implant overdenture is possible.[35]

**Fig. 15:** Mean change in implant stability for Straumann® and Southern™ implants.[35]

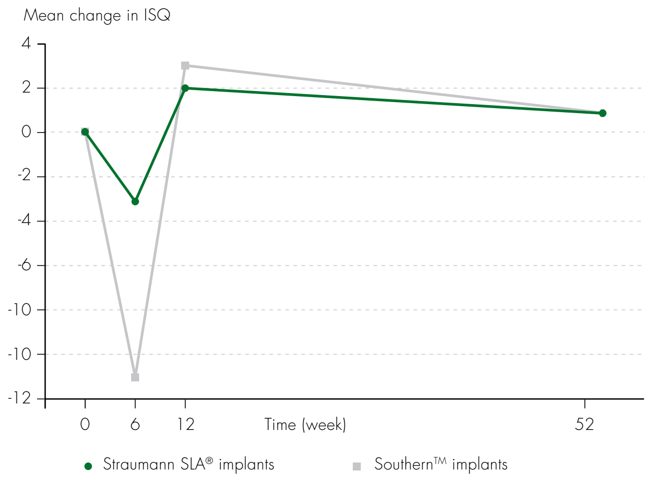
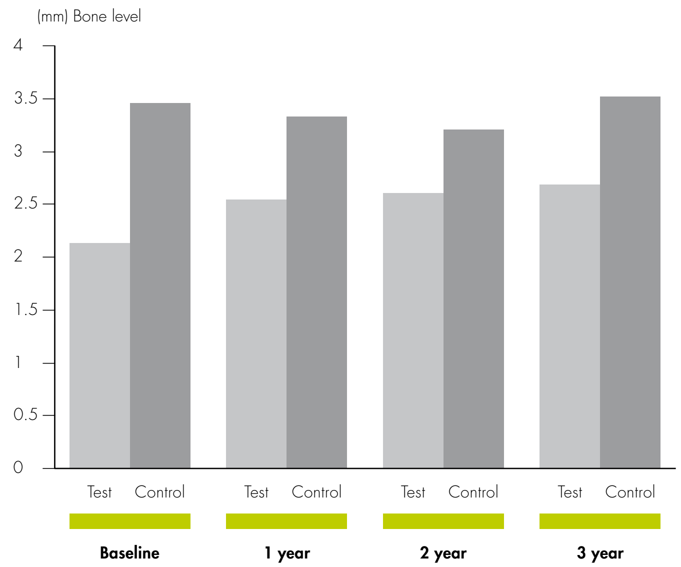



**Fig. 16:** Mean crestal bone levels (mm) up to 3 years for early (test) and conventional (control) loaded implants[37]




Loading of Straumann® SLA implants with maxillary full-arch prostheses after 9–18 days, in comparison to 2.5–5.1 months was investigated in a randomized clinical study; this was the first published randomized clinical trial to evaluate maxillary full-arch prostheses in this setting. After 1 year, the implant survival of the 139 implants loaded (94 test and 45 control) was 100%, and sulcus bleeding index and plaque index scores were significantly better for the earlier-loaded implants.[36] Cumulative implant success continued to be 100% after 3 years, and crestal bone levels (mean, distal and mesial) were better for the earlier-loaded implants (Fig. 16). The early loading protocol for maxillary full-arch prostheses was therefore confirmed as a viable alternative to conventional loading.[37]

Early loading in the edentulous maxilla and posterior mandible and maxilla was evaluated in 54 patients, who received a total of 234 implants; prostheses were loaded after a mean of 9 days.

After 1 year, the implant survival rate was 99.1% and the mean marginal bone loss was 0.75 ± 1.3 mm. In this study, 58 of the implants had been placed immediately after tooth extraction, but there were no significant differences between these and the implants placed in healed bone.[38]

One-year results from a 3-year study of early loading (mean 4.3 days) of splinted crowns or 3-unit fixed prostheses in the posterior mandible and maxilla showed an implant survival rate of 98.8% with mean bone loss of 0.52 ± 0.98 mm.[39]

### Immediate loading

The effects on the surrounding bone of immediate versus early loading were evaluated in an in vivo preclinical study, where Straumann® SLA implants were placed 2 days, 10 days, 21 days or 3 months before restoration. All 48 implants (12 per group) were osseointegrated, with no statistical differences in total BIC for any of the groups (75.2%, 74.6%, 71.3% and 69.1% for implants loaded after 2, days, 10 days, 21 days and 3 months, respectively). Similarly, there were no statistically significant changes in bone height for combined mesial and distal bone changes (Table 6).[41]

**Table 6:** Change in crestal bone height for combined mesial and distal aspects (mean ± standard error [SE])[41]

| Loading time | Follow up 1–2 months | 1–3 months | 2–3 months |
|---|---|---|---|
| **2 days** | 0.03 ± 0.09 | 0.02 ± 0.07 | -0.02 ± 0.05 |
| **10 days** | 0.30 ± 0.06 | 0.30 ± 0.08 | 0.00 ± 0.07 |
| **21 days** | 0.26 ± 0.07 | 0.15 ± 0.08 | -0.10 ± 0.06 |
| **3 months** | 0.04 ± 0.08 | 0.35 ± 0.18 | 0.31 ± 0.17 |

Implant stability has been demonstrated to be nearly the same between immediately-loaded and delayed-loaded implants restored with short-span or full-arch maxillary prostheses. An RFA analysis showed baseline mean ISQ values of 57.2 ± 7.0 and 56.8 ± 6.6 for immediately loaded and delayed loaded implants, respectively. After 12 weeks, mean ISQ values were 60.3 ± 6.8 in immediate-loading and 60.3 ± 4.8 in delayed-loading, indicating no difference between the loading protocols (Table 7). Survival rates after 1 year were 98.4% and 97.7% for immediate and delayed loading, respectively.[18]

**Table 7:** ISQ values of immediately and delayed loaded implants (mean ± SD)[18]

| | immediate | delayed |
|---|---|---|
| **Baseline** | 57.2 ±7 | 56.8 ±6.6 |
| **12 weeks** | 60.3 ±6.8 | 60.3 ±4.8 |

Wilson, et al (2003) demonstrated successful integration of Straumann® SLA® implants in extraction sockets with horizontal defect dimensions of > 4 mm; such osseointegration had previously only been demonstrated with TPS implants in extraction sockets with a bone-to-implant distance of < 2 mm. The BIC for implants in defects > 4 mm (64.72%) was similar to that for implants in defects 0–1.5 mm (69.29%) and was similar to the mean BIC for all evaluated surfaces (63.71%).[42]

Immediate loading of implants in the posterior mandible with single-tooth restorations showed an implant survival rate of 96.7 % (1/30 implants lost) after 1 year. Good primary stability was achieved, with no adverse change in stability over the evaluation period; mean ISQ at baseline was 70.6 ± 5.8, and at the 12-month evaluation was 76.7 ± 7.0, with no adverse changes in keratinized mucosa or bone level.[43]

A study evaluating the immediate loading of 40 Straumann® SLA implants with 3-unit fixed partial dentures showed no statistically significant changes in implant stability or peri-implant bone levels from baseline to 12 months; the success rate was 97.5% (1 implant lost). The results indicated satisfactory function with immediate loading.[44]

The immediate loading of implant-supported mandibular overdentures also showed the success and viability of this technique. Of 20 implants in 10 patients, there were no implant failures at the 24-month evaluation. Mean bone loss averaged 0.71 mm in the first 12 months, with only 0.08 mm additional bone loss from 12 to 24 months. At 92% of the measured sites, a bleeding index of 0 was recorded. Patient satisfaction was recorded as 10 (the highest score) on the Visual Analog Scale (VAS) for 8/10 patients.[45]

Evidence for the viability of immediate loading of Straumann SLA implants with fixed maxillary prostheses has also been demonstrated. A total of 168 implants were placed in 28 patients and immediately loaded with a fixed provisional prosthesis. The mean bone loss after 8 months was 1.6 mm, and the cumulative survival rate was 98% (Table 8).[46]

**Table 8:** Survival rates for implants immediately loaded with maxillary fixed prostheses.[46]

| Interval | No. surviving implants | No. failed implants | No. withdrawn implants | Survival rate for interval | Cumulative survival rate |
|---|---|---|---|---|---|
| **Placement – week 15** | 168 | 3 | 0 | 98.2 % | 98.2 % |
| **week 15 – 8 months** | 165 | 0 | 0 | 100.0 % | 98.2 % |
| **8 – 20 months** | 90 | 0 | 12 | 100.0 % | 98.2 % |

Interim results from a large multicenter clinical trial have suggested that immediate loading with SLActive implants may be as predictable as early loading, with survival rates of 98% and 97% for immediate and early loading, respectively, after 5 months, and no excessive change in bone level.[106]

**Conclusions**

- The Straumann® SLActive® surface can reduce healing times to 3–4 weeks in the appropriate clinical indications.
- Study results suggest that earlier loading (less than 3 weeks) can be as successful as conventional delayed procedures.
- The success of early and immediate loading with Straumann implants has been demonstrated with single crowns, 2–3 unit prostheses, mandibular overdentures and maxillary partial- and full-arch prostheses.
- When compared to SLA, faster osseointegration with SLActive reduces the stability dip in the early healing period.

# 3. Implant designs

The range of implant diameters and lengths available gives the clinician the opportunity to choose the best solution for every situation. The advantages and clinical performance of some of the 'non-standard' implants available (i.e. implants with a Narrow Neck or Wide Neck prosthetic platform or Straumann® Tapered Effect implants) are presented in this section.

**Introduction**

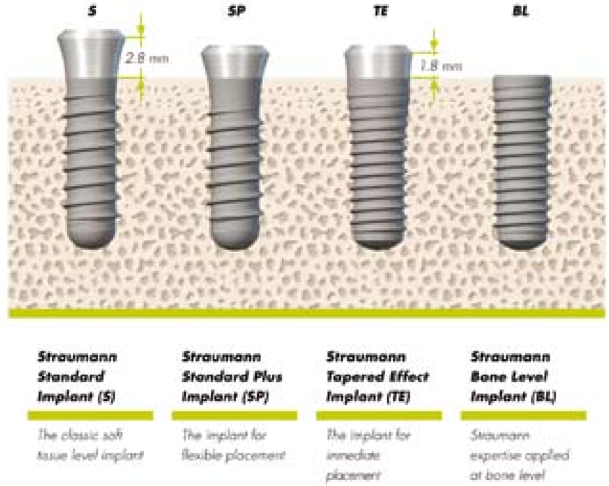
The Straumann® Dental Implant System offers four implant lines with diverse body and neck designs, ranging from the classic soft tissue level to the bone level implant. All implants can be placed with one surgical kit while using very similar surgical procedures. Preclinical and clinical research is critical to the long-term reliability of Straumann implants; more than 3,000 published articles on the Straumann® Dental Implant System exist to date. All Straumann® implants feature Bone Control Design,™ based on the five key biological principles in implant dentistry: osseoconductivity, control of the microgap, biomechanical implant design, biological distance, and the location of the surface margin. With the Bone Control Design™, Straumann® implants are designed to achieve optimal preservation of crestal bone and soft tissue stability.

Straumann® dental implants are available in three endosteal diameters: ∅ 3.3 mm, ∅ 4.1 mm, and ∅ 4.8 mm.

**Fig. 17:** Straumann Tissue Level implant platforms


The Straumann Tapered Effect (TE) implants, especially designed for immediate or early implantations, e.g. in extraction sockets, can also be obtained in  endosteal diameters of 3.3, 4.1 and 4.8 mm. Implants are available with two coronal collar types: Straumann Standard (S) implants have a 2.8 mm machined collar, while Straumann Standard Plus (SP) and Straumann Tapered Effect (TE) implants have a 1.8 mm machined collar (Fig. 18). The Tissue Level implants feature neck diameters of 3.5 mm (Narrow Neck [NN]), 4.8 mm (Regular Neck [RN]) and 6.5 mm (Wide Neck [WN]) (Fig. 17).

**Fig. 18:** Straumann implant types




In addition to the extensively documented evidence of the success of Straumann regular diameter implants, implants with a Narrow Neck or Wide Neck prosthetic platform and Straumann Tapered Effect implants have also been investigated in a number of situations.

**Small diameter implants**

It is a widely held belief that reduced-diameter implants are potentially more prone to failure possibly due to the reduced mechanical stability and are therefore not recommended for use in the molar region. A long-term prospective study of 298 small diameter (3.3 mm) implants in 149 patients used to support single crowns, fixed prostheses or overdentures showed that implant failures and biological complications were infrequent; the life table analysis of the 5-year cumulative implant survival rate was 98.7%. Prosthetic complications encountered were not serious and were related to screw or bar retainer loosening and sore spots resulting from the denture base.[47]

A longitudinal study, which followed 122 small diameter implants in 68 patients for 1–7 years, compared small diameter (3.3 mm) and standard diameter (4.1 mm) implants. The prosthetic restorations were single crowns or fixed partial dentures. A life table analysis showed cumulative survival rates of 98.1% and 96.9% in the maxilla and mandible, respectively. This study compared to survival rates of 96.8% and 97.9% in the maxilla and mandible for standard diameter implants; there was therefore no statistically significant difference between the two implant diameters used (Table 10). Likewise, there were no statistically significant differences in bone resorption, bleeding index or probing depth (Table 11).[48]

**Table 10:** Life table analysis showing cumulative survival rates of small diameter implants.[48]

| | Small Ø | Standard Ø | Statistical Reference |
|---|---|---|---|
| maxilla | 98.1 % | 96.8 % | N.S. |
| mandible | 96.9 % | 97.9 % | N.S. |

**Table 11:** Bone loss, probing depth and modified bleeding index for small and standard diameter implants at loading and last evaluation showed no differences.[48]

| Implants | Cum. suvival rate | | Marginal bone loss | Probing depth |
|---|---|---|---|---|
| | maxilla | mandible | last evaluation (mm) | last evaluation (mm) |
| Ø 3.3mm n = 122 | 98.1 % | 96.8 % | mean 1.5 ± 1.5 | mean 2.2 ± 1.6 |
| Ø 4.1mm n = 208 | 96.8 % | 97.9 % | mean 1.4 ± 1.1 | mean 2.1 ± 1.7 |

Zarone, et al (2006) conducted a study evaluating the use of Straumann® Narrow Neck platform implants for the treatment of maxillary lateral incisor agenesis in 30 patients. The follow-up period was 24–39 months. The cumulative survival rate was 97.06%, indicating the reliability and predictability of Straumann® Narrow Neck platform implants in this situation.[49]

A retrospective evaluation of Straumann® Narrow Neck platform implants used to replace mandibular incisors in 31 patients was performed. A total of 44 implants were placed in these patients, replacing single mandibular incisors, two adjacent incisors or 3–4 incisors, where 3–4-unit fixed partial dentures were used. After a mean follow-up period of 23 months, the implant survival rate was100%. High scores on the Visual Analog Scale (VAS) indicated excellent patient satisfaction, regardless of the type of restoration used.[50]

## Short implants

The use of short implants may reduce the necessity for complicated surgical or augmentation procedures, and may allow the placement of a prosthetically driven rather than a surgically driven restoration. Short implants, for purposes of this summary are considered to be implants that are 11 mm or less in length

Some studies have especially examined the use of short implants. For example, Nedir, et al (2004) reported a 7-year life table analysis on both TPS and Straumann SLA® implants (264 of each), where most of the implants (71.1%) were ≤11 mm in length. The implants were used to support single crowns and 2–4 unit fixed partial dentures, and the seven year cumulative success rate was 99.4% (Table 12). There was no difference in success between longer and shorter implants. Of the SLA implants used, 46.2% were loaded early (within 63 days); the three year rate for these implants was 97.4%.[51]

**Table 12:** Life table analysis of short and longer implants.[51]

| Time interval | No. of implants | Failures | Success rate on interval | Cumulative success rate |
|---|---|---|---|---|
| 7-year life table analysis of all implants | | | | |
| **0–1 years** | 502 | 2 | 99.6 % | 99.6 % |
| **1–2 years** | 499 | 1 | 99.8 % | 99.4 % |
| **2–3 years** | 277 | 0 | 100.0 % | 99.4 % |
| **3–4 years** | 156 | 0 | 100.0 % | 99.4 % |
| **4–5 years** | 105 | 0 | 100.0 % | 99.4 % |
| **5–6 years** | 78 | 0 | 100.0 % | 99.4 % |
| **6–7 years** | 40 | 0 | 100.0 % | 99.4 % |
| 3-year life table analysis of early loaded **SLA®** implants | | | | |
| **0–1 years** | 117 | 2 | 98.3 % | 98.3 % |
| **1–2 years** | 115 | 1 | 99.1 % | 97.4 % |
| **2–3 years** | 70 | 0 | 100.0 % | 97.4 % |

In another study, the clinical outcome of short (6–8 mm) implants was compared to that of longer implants in an observational study. Over a period of almost 10 years, 630 implants were placed in 264 patients. Most (72.1%) were 10-16 mm in length, while 22.4% were 8 mm and 5.5% were 6 mm. The two-year survival rates for the 6 mm, 8 mm and 10–16 mm implants were 94.3%, 99.3% and 97.4%, respectively. Life table analysis showed a cumulative 5-year survival rate of 94.2%, 99.2% and 96.2% for the 6 mm, 8 mm and 10-16 mm implants, respectively. The results of this observational study demonstrated the success of short implants without the need for ridge augmentation.[52]

## Large diameter implants

A life table analysis of 263 Straumann® Standard (S) and Straumann® Standard Plus (SP) Wide Neck platform implants (endosteal ∅ 4.8 mm) placed in 212 patients, mainly in the mandibular and maxillary molar areas, demonstrated 1- and 2-year survival rates of 98.8% and 97.7%, with a 5-year cumulative survival rate of 97.89% (Table 13). Prosthetic complications were infrequent, occurring in 5.7% and 3.8% of single crowns and fixed partial dentures, respectively.[53]

**Table 13:** Life table analysis of Wide Neck platform implants.[53]

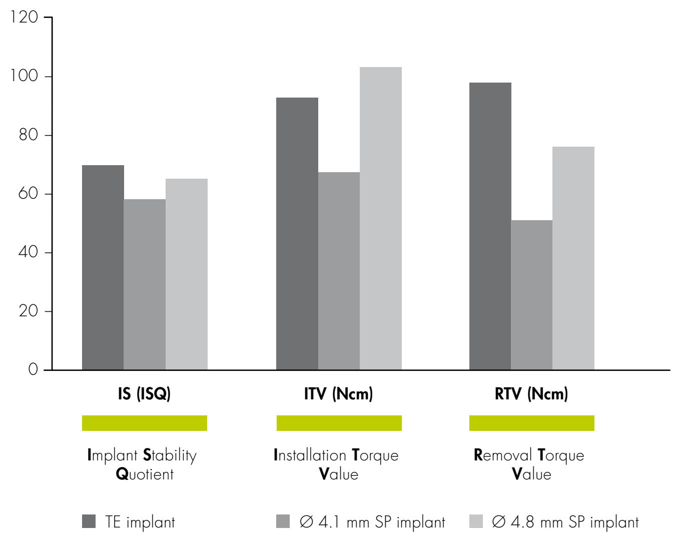
| Time interval | No. of implants | Failures | Success rate on interval | Cumulative success rate |
|---|---|---|---|---|
| **0–1 years** | 259 | 3 | 98.8 % | 98.8 % |
| **1–2 years** | 253 | 1 | 99.6 % | 98.5 % |
| **2–3 years** | 174 | 1 | 99.4 % | 97.9 % |
| **3–4 years** | 107 | 0 | 100.0 % | 97.9 % |
| **4–5 years** | 41 | 0 | 100.0 % | 97.9 % |

## Straumann® Tapered Effect implants

The mechanical stability of Straumann® 4.1/4.8 Tapered Effect (TE) implants placed in immediate extraction sockets has been demonstrated. In a cadaver model stability, as measured by RFA, was greater than SP ∅ 4.1 mm diameter implants and comparable to SP large diameter (∅ 4.8 mm) implants; analysis of insertion torque and removal torque values were also measured. (Fig. 20). [54]

Immediate placement of Straumann 4.8 mm/6.5 mm neck Tapered Effect implants at the time of maxillary molar extraction was studied. Primary soft tissue closure was obtained in all 83 cases, and this was maintained until 6 months after implantation in 81/83 implants, but neither the cover screw nor the implant were fully uncovered in the other two cases. At the time of uncovering, all implants were clinically stable and restored with single crowns. Successful (mean 12.4 months) function was maintained for 18 months follow-up.[55]

**Fig. 20:** ISQ, ITV and RTV values of TE ∅ 4.1 mm, SP ∅ 4.1 mm and SP ∅ 4.8 mm implants.[54]



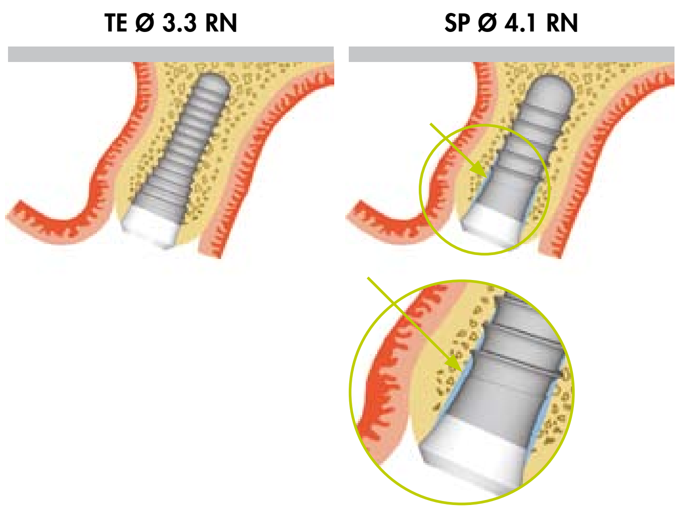

Because of their shape, Straumann® Tapered Effect implants can also be useful in clinically challenging situations. For example, their success has been shown in combination with the Extension Crest® device, which is designed to widen narrow edentulous alveolar ridges so that implants can be placed in horizontally atrophied sites. A total of 110 implants were placed in 45 patients; in 33 of the patients, the implants were placed at the time of alveolar ridge expansion, while implants were placed 1 week later in 12 patients. The mean follow-up time was 20.4 months, and the cumulative survival rate at the end of the observation period was 97.3% (Table 14).[56]

**Table 14:** Life table analysis for Straumann Tapered Effect implants in sites treated with Extension Crest®.[56]

| Time interval | Number of implants | Implants removed | Failing implants | Cumulative survival rate | Cumulative success rate |
|---|---|---|---|---|---|
| **Placement to loading** | 110 | 3 | 0 | 97.3 % | 97.3 % |
| **Loading to 1 year** | 106 | 0 | 2 | 97.3 % | 95.4 % |
| **1–2 years** | 106 | 0 | 0 | 97.3 % | 95.4 % |
| **2–3 years** | 61 | 0 | 0 | 97.3 % | 95.4 % |
| **3–4 years** | 18 | 0 | 0 | – | – |

Similar results have been found for TE implants placed after ridge augmentation with the split crest technique. In this study, Straumann Tapered Effect 3.3 mm Regular Neck implants were compared to Straumann Standard Plus ∅ 4.1 mm implants in 40 patients (42 TE and 40 SP implants). The TE implant showed certain advantages, such as reducing the risk of fracture of the labial plate. In addition, it was noted that the TE implants achieved excellent bone-to-implant vestibular contact in this particular situation, filling the triangular intra-bone space created by the split crest technique; with Straumann® Standard Plus implants, there was a possible risk of crestal fracture (Fig. 21). TE implants achieved a 100% overall success rate, compared to 95% for SP implants.[57]

**Fig. 21:** Bone-to-implant vestibular contact with TE and SP implants, showing the potential risk of fracture (arrows).[57]




### Conclusions

- Straumann implants with reduced areas for osseointegration (i.e. short or narrow implants) show survival and success rates comparable to standard implants.
- Straumann® Narrow Neck platform implants are particularly useful where space is limited. (e.g. single lateral incisors in the maxilla and central incisors in the mandible) with good predictability.
- Straumann® Tapered Effect implants are designed to achieve high initial mechanical stability and may be an advantage in situations where a narrow alveolar ridge is present.

# 4. Biomechanical aspects

The implants of the Straumann® Dental Implant System have demonstrated excellent stability in a number of preclinical and clinical investigations. This stability is not only due to the superior surface technology, but also to the estabilished biomechanical implant design. Important features of the implant design, in terms of stability and stress force distribution in the bone, are discussed in this section.

**Introduction**

In addition to the implant surface properties discussed in a previous chapter, the process and success of osseointegration is influenced by a number of biomechanical factors, both direct (e.g. primary stability, stress force distribution) and indirect (e.g. fatigue strength). The excellent stability of Straumann Dental Implant System implants has been amply demonstrated in several clinical studies,[16,18,32,35,43,54] and many studies also show the advantages of Straumann implants in the distribution of stress forces in the surrounding bone.

**Bone stress forces and stability**

*Ex vivo* bone tissue strains were measured around implants in the anterior maxilla (lateral incisor and first premolar regions) supporting bar-retained overdentures. Installation torque, Resonance Frequency Analysis and removal torque were assessed, and strain measurements were performed.Absolute strain values in the axial direction around posterior implants approximately ranged between 100 and 550 µε were generally below 50 µε under 25 N. Strain forces were higher for implants in premolar than lateral sites. The results indicated that the maximum strains recorded for distal implants fell within the physiological range.[58]

*Ex vivo* forces were also compared around implants and natural teeth, with strain measurements performed at 10 kHz under a maximum load of 100 N. Prostheses evaluated were single-tooth (unsplinted), unilateral splinted canines, lateral and central and incisors (1–3 splinted), and one-piece splinted restoration of bilateral canines and lateral and central incisors (all-splinted) Installation torque and RFA were also measured. The microstrains observed around teeth and implants supporting fixed prostheses were comparable, in the bilateral canines with significantly lower strains for implants placed in central and lateral incisor sockets. For both teeth and implants, the strains around canine sites were higher than for lateral and incisor sites. The results suggested deformation of the premaxilla due to loading, with not much load transferred to labial marginal bone; the strains caused in this area were therefore purely due to deformation of the premaxilla under load.[59]

The size of the stress forces around implants are influenced and complicated by a number of factors, as demonstrated by a finite element analysis of the effect of inter-implant distance on stress distribution. In this investigation, different inter-implant distances and different directional loads were applied, and the main stress forces calculated. Tensile stress values recorded at the cortical bone were seen to increase with increasing inter-implant distance under vertical and oblique loading. The compressive stress values recorded at the cortical and cancellous bone increased with decreasing inter-implant distance.. An inter-implant distance of 1 mm was suggested to be optimum in terms of force distribution for two fixture implantation.[60]

Stress forces are greater in poor quality, predominantly trabecular bone, since this type of bone is weaker and less resistant to deformation. However, a finite element analysis showed that in type 1 and 2 bone, the von Mises stress distribution patterns at the neck of the Straumann implants are similar, with a homogenous distribution throughout the bone. Stress forces were higher in type 3 and 4 bone because trabecular bone is weaker and less resistant to deformation.[61]

**Influence of the implant-abutment joint**

Together with proper design of the occlusion and stable osseointegration, a reliable connection between implant and abutment is an important precondition for the appropriate functioning and stability of implant restorations, especially cemented ones. External hex configurations seem to be prone to abutment screw loosening, while the conical connection of the ITI Morse Taper compares clinically very favorably. There is no form lock or positive locking by the external hex, which determines the rotational position but does not absorb any lateral loading (Fig 22a). The ITI Morse Taper connection features form lock and friction that prevents the abutment from tilting off. This geometric locking mechanism also protects the abutments threads from excessive functional load (Fig 22b). The Finite Element study shows that, under similar conditions, the stress at abutment screw reaches far higher levels than in the taper joint.

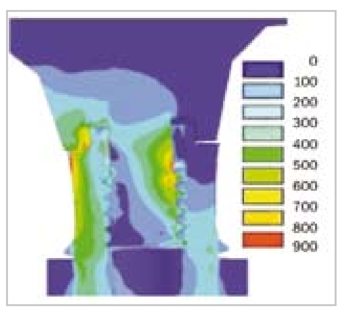



**Fig. 22a:** Distribution of equivalent stress (MPa) in the butt joint under 30-degree off-axis loading of 380 N. The stress levels on the tension side are high and spread over a large area. Therefore, supporting effects are nearly irrelevant. On the compression side, very punctual loads are found in the butt joint area, while the abutment is separated from the implant shoulder on the tension side.

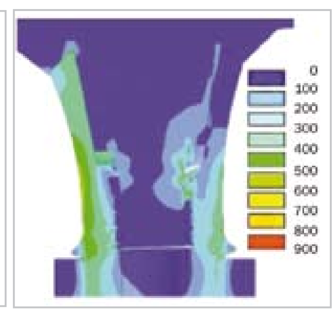



**Fig. 22b:** Distribution of equivalent stress (MPa) in the ITI Morse Taper under 30-degree off-axis loading of 380 N. The thread is still largely protected by the conical joint. The areas with critical stress levels in the abutment thread are extremely limited and small. Therefore, supporting effects come into action.

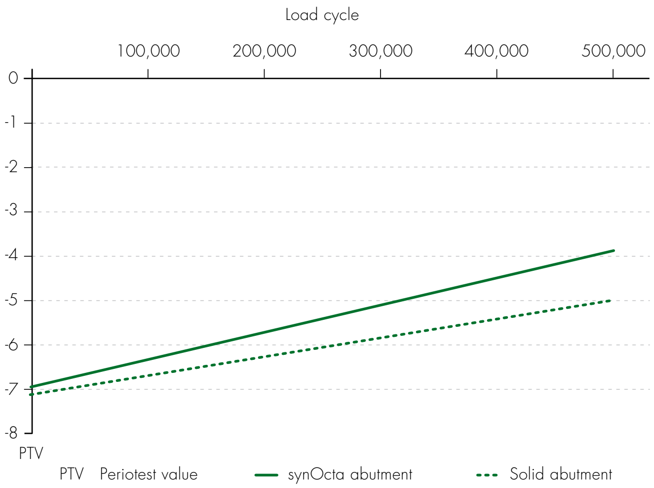
The mechanics of the implant-abutment joint have an important effect on the fatigue strength of the implant. Internal conical abutment connections are suggested to be stronger than more conventional flat-top or butt-joint connections. This was confirmed in a comparison of the fatigue strength of implants with an 8° conical interface (Straumann®) and hex-mediated butt-joint interface (Brånemark). Fatigue resistance was investigated over a simulated 6-year functional period (1,800,000 cycles with a cyclic load of 100N). The abutment screw of the Brånemark implants all failed between 1,178,023 and 1,733,526 cycles with a standard deviation of 224,477 cycles, but there were no failures with the Straumann Dental Implant System over the full period of 1,800,000 cycles (Table 15); the difference between the two implant types was statistically significant ($p = 0.000582$) within the limits of this *in vitro* study, The results indicate enhanced fatigue resistance for a conical implant-abutment joint interface under controlled loads.[63]

**Table 15:** Fatigue test results – Straumann® Dental Implant System versus Brånemark implants.[63]

| Cycles to failure | | |
|---|---|---|
| **Dental Implant System** | **Branemark System** | **Straumann System** |
| **Sample 1** | 1,543,927 | No failure |
| **Sample 2** | 1,178,023 | No failure |
| **Sample 3** | 1,733,526 | No failure |
| **Sample 4** | 1,289,631 | No failure |
| **Sample 5** | 1,240,196 | No failure |
| **Sample 6** | 1,436,427 | No failure |
| **Sample 7** | 1,713,196 | No failure |

Fatigue resistance of Straumann Solid versus Straumann synOcta® abutments have also been studied. A combination of cyclic dynamic axial and lateral peak loads at 75 N ± 5N with a compressive sine wave were applied on the implants for 500,000 cycles at 0.5 Hz and at an angle of 20° simulating a worst case. There were no signs of mechanical failure in any of the implant/abutment combinations, and the increase in Periotest values was similar for all implants tested, with no difference between implants (Fig. 23).[64]

**Fig. 23:** Trend of increase in Periotest values for abutments in consecutive loading cycles.[64]




## Conclusions

- The Straumann® implant design distributes stress forces homogenously throughout the surrounding bone.
- Stress forces surrounding the internal 8° Morse Taper connection are much lower than with conventional external butt-joint connections.
- The internal 8° Morse Taper connection used for Straumann® Solid abutments and Straumann® synOcta abutments demonstrates fatigue resistance on the implant system.

# 5. Long-term survival

Long-term clinical data on dental implants are particularly important to show the predictability and successful application of a given implant system. Several clinical and private practice studies have evaluated the long-term success of Straumann® Dental Implant System implants; in a number of different clinical situations. These studies are the subject of this section.

### Introduction

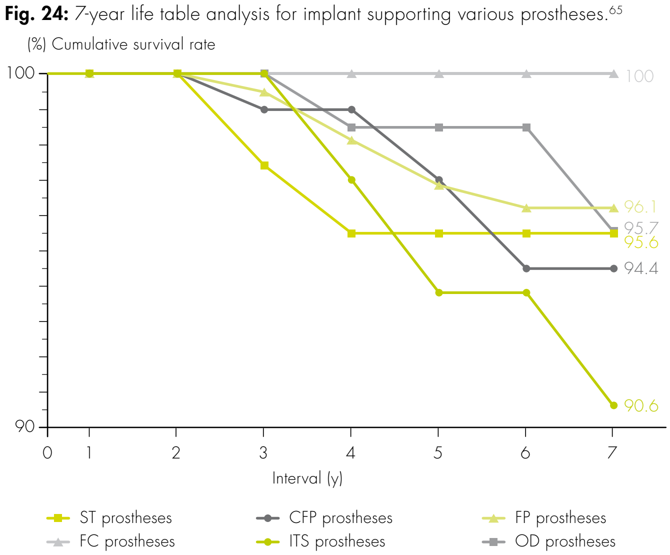
For any implant system, long-term clinical data are crucial, since patients and clinicians expect their implants to function for as long as possible. Long-term investigations help to show the prolonged success of implants, and give clinicians more confidence when choosing and using a particular implant system.

### Life table analyses

As previously noted, a 7-year life table analysis of predominantly short implants demonstrated a cumulative survival rate of 99.4% (Table 12)51 and a 5-year life table analysis of Straumann Standard (S) and Straumann Standard Plus (SP) Wide Neck implants showed a cumulative survival rate of 97.89 % (Table 13).[53] The latter study showed excellent survival rates even in poorer quality soft bone (96.4% versus 98.3% survival in soft and normal bone, respectively).

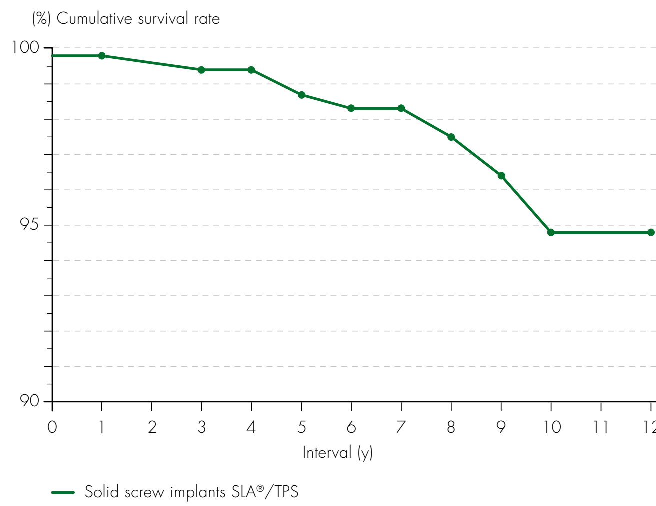
A 7-year prospective study (mean follow-up time 3.85 years) evaluated Straumann implants used to support single-tooth prostheses (ST), cantilever fixed prostheses (CFP), fixed partial prostheses (FP), fixed complete prostheses (FC), implant/tooth-supported prostheses (ITS) or overdentures (ODs). Cumulative survival rates as shown by life table analysis were similar between the implants supporting the various prostheses (Fig. 24), and there was no difference between survival in the maxilla or the mandible, and implant size had no adverse influence on survival rate.[65]

**Fig. 24:** 7-year life table analysis for implant supporting various prostheses.[65]




A 12-year life table analysis was also performed using data from implants placed in 323 patients in conjunction with maxillary sinus floor elevation. In this study, most of the 588 implants placed were solid screw implants, but only 234 had the Straumann SLA® surface; the remaining implants were TPS-surfaced. The combined cumulative 12-year survival rate for the implants placed was 94.8% (Fig. 25). In addition, it was noted that the incidence of perforation of the Schneiderian membrane was very low, at only 2.2%. The procedure was therefore judged to be safe and predictable.[66]

**Fig. 25:** 12-year life table analysis for 588 implants.[66]




### Long-term survival in special situations

Pinholt (2003) evaluated the use of 80 Straumann SLA implants (13 patients) and 78 machined-surface Brånemark implants (12 patients) in bone-augmented sites in the maxilla followed for up to 67 months post-implantation. Straumann SLA implants demonstrated a significantly higher survival rate (98% versus 81% for Brånemark implants) in this clinical situation.[67]

Early loading of implants has no adverse effect on the long-term survival rates, as shown by a 5-year cumulative success rate of 99% with 104 Straumann SLA implants loaded after 6 weeks. Stable soft tissues and crestal bone levels were also demonstrated over the 5-year assessment period.[30] Arlin (2006) also demonstrated the long-term success and survival of short implants, with cumulative 5-year survival rates of 94.2%, 99.2% and 96.2% for implants 6 mm, 8 mm and 10–16 mm in length, respectively.[52]

The non-submerged placement of implants in narrow alveolar ridges has been shown to give excellent long-term results. In a prospective study, 16 implants were placed in 13 patients with buccal bone dehiscences between 3 and 9 mm. Exposed implant threads were covered with a deproteinized bone mineral xenograft and a non-resorbable membrane, which was removed after membrane exposure or a maximum of 24 weeks after surgery. The follow-up period ranged from 12 to 114 months, and all implants except one were successful. Plaque index and bleeding on probing were low for all patients and with the exception of implant, there was no mesial or distal bone resorption.[68]

### Long-term survival in private practice

Most implant studies evaluate implants under very controlled conditions in clinical trials, often performed in large universities and clinics; however, the results when the implants are placed in private practices in a more diverse range of clinical situations may be different. Survival rates for Straumann® dental implants in private practice situations have demonstrated to be as good as those under more strictly controlled conditions. For example, a study that followed 5,526 implants in three private practices for 72 + months showed a cumulative success rate of 96.1% (94.8% and 97.5% for implants in the maxilla and mandible, respectively). Success rates for implants in particular clinical applications can be seen in Table 16.[69]

**Table 16:** Success rates for implants in private practice by clinical application.[69]

| Indication | Implants placed | Absolute success rate (%) |
|---|---|---|
| **Single-tooth** | 2,717 | 98.9 |
| **Fixed prosthesis** | 922 | 99.1 |
| **Fixed prosthesis (implant/ tooth-supported)** | 33 | 95.0 |
| **Pier abutments** | 21 | 100.0 |
| **Orthodontic anchorage** | 10 | 80.0 |
| **Removable partial prosthesis** | 71 | 91.5 |
| **Maxillary overdentures** | 681 | 96.0 |
| **Mandibular overdentures** | 482 | 96.9 |
| **Full-arch fixed prosthesis** | 589 | 95.4 |

A prospective, multicenter, observational field trial evaluated implant survival and success in predominantly private practice settings in 16 countries. A total of 509 patients with 990 implants met all inclusion criteria. Most (87%) of the implants were placed in type II or III bone; with 73% of the implants placed in the mandible and 27% placed in the maxilla. The results showed a cumulative 5-year survival rate of 99.26% (Table 17) and 5-year cumulative success rate of 97.38%.[111]

**Table 17:** Success rates for implants in private practice by clinical application.[69]

| Interval (month) | Implants at baseline | Dropouts | Implants estimated at risk | Failures | Interval failure rate (%) | Interval survival rate (%) | CSR |
|---|---|---|---|---|---|---|---|
| 0 to 12 | 990 | 177 | 901.5 | 4 | 0.44 | 99.56 | 99.56 |
| 12 to 24 | 809 | 123 | 747.5 | 0 | 0.00 | 100.00 | 99.56 |
| 24 to 36 | 686 | 83 | 644.0 | 0 | 0.00 | 100.00 | 99.56 |
| 36 to 48 | 603 | 141 | 532.5 | 0 | 0.00 | 100.00 | 99.56 |
| 48 to 60 | 462 | 259 | 332.5 | 1 | 0.30 | 99.70 | 99.26 |
| 60 to 72 | 202 | 191 | 106.5 | 0 | 0.00 | 100.00 | 99.26 |
| > 72 | 11 | 11 | 5.5 | 0 | 0.00 | 100.00 | 99.26 |

CSR = Cumulative survival rate

* Calculation based on median of dropouts

**Conclusions**

- Straumann® dental implants document excellent long term success.
- Excellent survival has also been demonstrated in more difficult clinical situations, such as narrow alveolar ridges or augmented maxilla.
- Success rates in private practice were equivalent to that of a University setting.

# 6. Bone and soft tissue effects

The influence of dental implants on the surrounding soft and hard tissue is crucial in defining the implant's functional and esthetic success. The behavior of soft tissue and bone around Straumann® dental implants, a combination of the implant design and the surface, is described here.

## Introduction

Implant survival is obviously a crucial factor in implant dentistry, but is only one of many criteria that define a successful implant. How the implant influences the bone and surrounding soft tissue is an important factor in implant success criteria, particularly in achieving a good esthetic result. Straumann® implants have amply demonstrated a low incidence rate of adverse effects on bone and soft tissue, designed to give excellent esthetic results to satisfy both patients and clinicians. Further outstanding results have been observed with Straumann SLActive® on the surrounding peri-implant tissues.

## Soft tissue

An early preclinical soft tissue in canines with Titanium Plasma Sprayed (TPS) and Straumann SLA® implants examined the effect of experimental TPS and SLA implants on the biological width, i.e. the composition and dimensions of the soft tissue around the implant. Measurements of the sulcus depth, junctional epithelium and connective tissue contact showed that the soft tissue dimensions around loaded and non-loaded implants were similar at various time points, and were no different to those around natural teeth.70 A more recent investigation in canines showed that the soft tissue attachment around titanium implants is adequately established several weeks after surgery. Fibroblasts predominated in the connective tissue interface after 2 weeks, decreasing in density by 4 weeks. The organization of collagen fibers was seen after 4–6 weeks, and epithelial proliferation was evident after 1–2 weeks, with mature epithelial tissue after 6–8 weeks.[71]

The favorable soft tissue effects of Straumann implants have been demonstrated in several clinical studies in conventional, early and immediate loading in a number of different situations.[31,34,37,43,49,50] Long-term stability of peri-implant soft tissues, with no significant adverse changes in mean probing depths or clinical attachment levels, has been demonstrated, and biochemical and microbiological parameters also show no significant changes over long periods of observation.[72] Patient satisfaction is also very high; in a study where 10 patients received overdentures supported by Straumann SLA implants, 80% of patients rated their satisfaction with treatment as 10 on the Visual Analog Scale (VAS), which records satisfaction on a scale of 1 (very bad) to 10 (excellent). VAS scores for the remaining patients were 6 and 8.[45]

## Crestal bone

Some well-known canine studies have evaluated the effects of the microgap between the implant and abutment, or the interface between the roughened and smooth titanium surfaces, on crestal bone levels. In non-submerged one-piece transgingival implants, it was found that the position of the rough/smooth titanium surface interface relative to the crestal bone level determines the position of the first bone-to-implant contact; greater crestal bone resorption occurs if the interface is placed below the level of the crestal bone. Likewise, the position of the microgap relative to the crestal bone level in two-piece implants determines the extent of bone resorption; greater resorption occurs when the microgap is placed below the crestal bone level (Fig. 26 and Fig. 27).[73] This occurs regardless of the size of the machined coronal collar.[74] Changes in crestal bone around implants may be more related to possible movements around implants and abutments than the size of the microgap.[75, 76]

**Fig. 26:** Schematic representation of implants placed with rough/smooth border at different levels relative to the bone crest.[73]

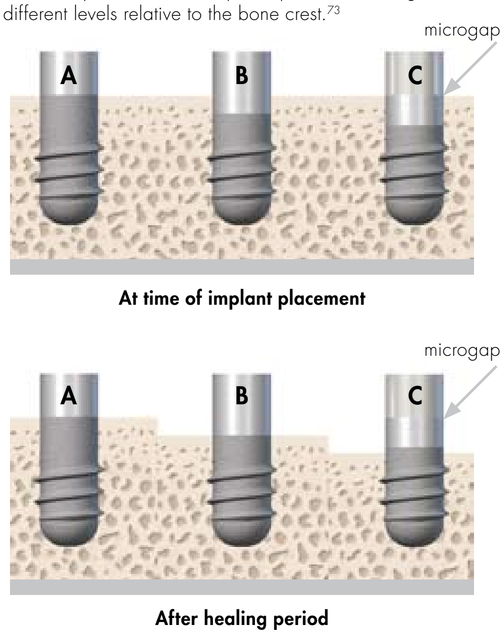
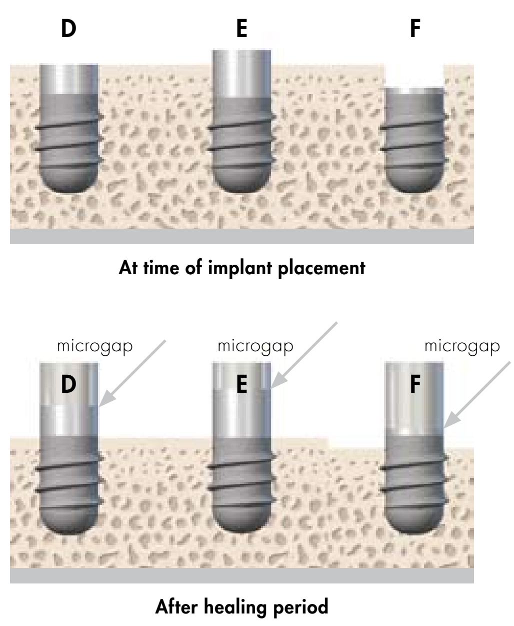



**Fig. 27:** Schematic representation of bone tissue at endpoint for implants placed with the microgap at different levels relative to the bone crest.[73]



Exposure of the metal implant margin may be a concern in some esthetically sensitive areas, particularly if the patient has a thin gingival biotype. The Straumann® Standard Plus implant, with a machined coronal collar of 1.8 mm compared to 2.8 mm for Straumann® Standard implants, was introduced to reduce this risk in esthetic areas. Clinical studies have shown that these implants cause no additional bone loss.[77]

### Bone remodeling

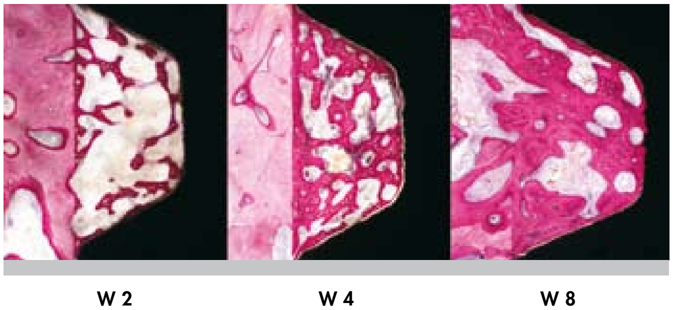
Straumann SLA® implants placed in the predominantly trabecular bone of the posterior maxilla have shown excellent results.
One-year results of implants placed in this manner gave a survival rate of 97.2%, despite the implants having been loaded after 6 weeks.[33]

Dental implant placement in conjunction with alveolar distraction osteogenesis has also been shown in a clinical study to be a reliable technique. The mean bone gain after distraction was 7 mm (range 5–9 mm), with an implant survival rate of 100% for 20 implants placed. The mean bone area fraction in the distraction region was 38.5 ± 11.7%.[79]

### Straumann SLActive® effects

Results from published studies with Straumann SLActive have demonstrated the additional benefits of enhanced surface chemistry on bone; no differences in surface topography could be demonstrated An early study using SLActive implants in 6 miniature pigs revealed significantly greater BIC after 2 and 4 weeks compared to the Straumann SLA surface (mean 49.30% versus 29.42% at 2 weeks and 81.91% versus 66.57% at 4 weeks). Bone apposition was therefore enhanced in the early healing stages. At 8 weeks, no differences were apparent.(Fig. 28).[22]

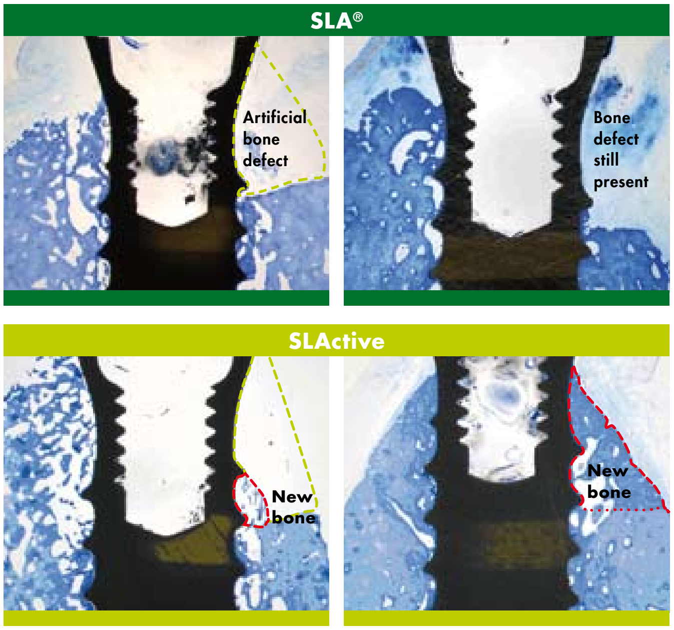
**Fig. 28:** Bone formation on Straumann SLActive experimental implants after 2, 4 and 8 weeks




In a recent dog study, where SLA® and SLActive implants were placed in dehiscence defects, new bone was observed around the SLActive implants after 12 weeks, compared to only dense connective tissue around the SLA® implants. Linear bone fill and BIC with SLActive implants were 98 % and 82 % (Fig. 29), respectively.[80]

In addition, preliminary results from an ongoing clinical study have indicated that SLActive implants may be restored at 3 weeks in the appropriate clinical circumstances after implant placement.[81,82]

**Fig. 29:** Bone fill around Straumann SLA and SLActive implants after 2 weeks (left picture 27% BIC) and 12 weeks (right, 82% BIC)




### Conclusions

- Excellent peri-implant soft tissue parameters, which are stable long-term, are evident with Straumann® implants.
- Biological distance of microgap to bone level has been demonstrated and are respected with Straumann implant design.
- Excellent bone-to-implant contact can be achieved.
- Preclinical investigations have shown 60% more bone to implant contact with Straumann® SLActive after 2 weeks compared to Straumann® SLA.
- A preclinical study shows the complete filling of certain type of bone defect using SLActive implants without the addition of bone substitute material.

# 7. Prosthetics

Prosthetic reconstruction is a crucial part of successful implant-based therapy. Moreover, there are a number of factors to consider before deciding on the most appropriate prosthesis. In the following section, the relative success of various types of prostheses, potential complications and strain forces are discussed.

## Introduction

Successful implant therapy is not solely a result of a well-osseointegrated implant. A large degree of success, especially in terms of esthetics and patient satisfaction, depends on the functional prosthetic elements, such as single-tooth crowns, full or partial prostheses, or overdentures.

## Prosthetic investigations

The successful use of telescopic crowns on Straumann® dental implants has been reported. Telescopic crowns provide good accessibility for oral hygiene procedures, have good retention and abutment connection, and are suggested to avoid many of the potential disadvantages of screw-retained superstructures. The use of telescopic crowns on implants was shown to be a suitable treatment option to support overdentures in a case series where the treatments of 7 subjects were in function for up to 4.5 years. [83]

Fixed prostheses have also been clinically studied. Resin-metal prostheses (fabricated from previously manufactured prostheses) were immediately loaded on 36 Straumann® dental implants in nine patients with edentulous mandibles.. The implant survival and success rates in this investigation were 100% at 24 months, with no signs of mobility, bleeding or inflammation.[84]

Cantilever fixed partial dentures, which have shown inconsistent results when supported by natural teeth, have been shown to be a viable treatment option when supported by Straumann dental implants. In a retrospective study of 60 cantilever prostheses supported by 115 implants in 35 patients over 10 years, there were no incidences of implant or abutment fracture, prosthesis fracture, soft tissue recession or radiographic bone loss. Screw loosening occurred with one prosthesis, and two prostheses required re-cementation, within 1 month of placement. All patients were satisfied with the treatment over the study period.[85]

Cement-retained versus screw-retained crowns on Straumann dental implants have been evaluated in a prospective clinical study in 80 patients. On 152 implants, 38.82% of the crowns were cement-retained and 61.18% were screw-retained. Over the 3-year evaluation period, plaque index (MPI) and sulcus bleeding index (SBI) around cement-retained crowns tended to worsen, while these parameters tended to improve around screw-retained crowns. (Fig. 30 and Fig. 31);.The MPI scores at 12 and 36 months and the SBI scores at 6, 12 and 36 months were significantly greater for cement-retained crowns than for screw retained crowns. There was no change in keratinized mucosa or gingival level. Sulcus bleeding was significantly affected by plaque accumulation, prophylaxis and depth of crown margin; while control of plaque accumulation was mainly due to prophylactic measures. Clinicians tended to prefer cement retention, but patient satisfaction was equal for both types of crown retention.[86]

**Fig. 30:** Modified plaque index scores for cement- and screw-retained crowns over 3 years.[86]

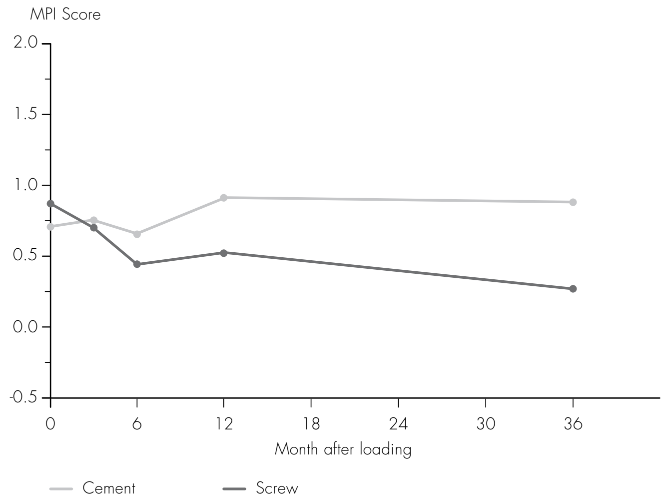
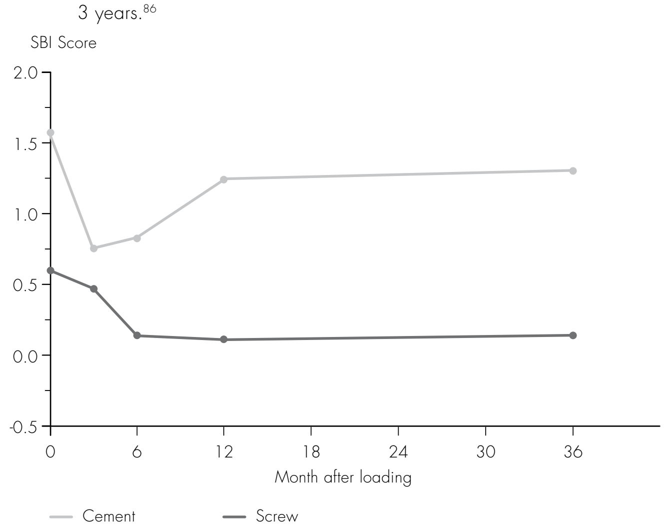



**Fig. 31:** Sulcus bleeding index scores for cement- and screw-retained crowns over 3 years.[86]



## Prosthetic complications

The long-term survival and success of implants supporting single-tooth prostheses, cantilever fixed prostheses, fixed partial or complete prostheses, overdentures, or prostheses supported on teeth and implants has been studied. Implant survival rates were similar for each of these types of prostheses.

Prosthetic complications were few: for example, loss of cementation occurred only in single-tooth and fixed partial prostheses (3.8% and 3.7%, respectively); abutment connection screw loosening occurred in 2.2% of fixed partial prostheses; veneer fracture was seen with 1.9% of single-tooth and 2.9% of fixed partial prostheses; and overdenture complications noted were retention failure (8.1%)/ screw loosening (5.4%) and overdenture fracture (5.4%).[65]

Complication rates, types of complications, and the costs associated with the complications were investigated for fixed implant-supported reconstructions (single crowns and fixed partial dentures [FPDs]) in 105 patients with 172 reconstructions on 283 Straumann® dental implants. The minimum follow-up time was 40 months, with a mean follow-up time of 65.2 ± 25.3 months.
Some prosthetic intervention was required on 25% of all reconstructions; the majority (74%) of these were screw tightening or recementing. Only 14% of the interventions were classed as major (involving >1 hour chair time and additional costs).

Complications occurred most frequently in FPDs with an extension and least frequently in single crowns. Llonger reconstructions appeared to be at higher risk for complications (Table 18). The rate of complications was significantly higher in bruxers compared to non-bruxers.[87]

**Table 18:** Presence or absence of complications in different groups of reconstructions

| Type of reconstruction | No | | Yes | | Total | |
|---|---|---|---|---|---|---|
| | | (%) | | (%) | | (%) |
| **Single crown** | 60 | 51.3 | 20 | 36.4 | 80 | 46.5 |
| **Two-connected crowns** | 25 | 21.4 | 14 | 25.5 | 39 | 22.7 |
| **Three-to-four-unit FPD** | 21 | 17.9 | 17 | 30.9 | 38 | 22.1 |
| **FPD with extension** | 4 | 3.4 | 4 | 7.3 | 8 | 4.7 |
| **Tooth/implants FPD** | 7 | 6.0 | 0 | 0.0 | 7 | 4.1 |
| **Total** | 117 | 100.0 | 55 | 100.0 | 172 | 100 |

Information on prosthetic complications has also been gleaned from private practice, using data from 236 patients with 528 implants over an 8-year period; 265 FPDs and 55 overdentures were evaluated in this study. It was found that removable prostheses had a significantly higher complication rate than fixed prostheses (66% versus 11.5%) and that prostheses in the posterior area had more complications than those in the anterior, but the difference was not significant. The majority of complications/ adjustments (58.8%) with the removable prostheses involved changing the attachment or overdenture relining; other involvements were reactivation of the attachment or clip (13.2%), fracture (7.4%) and rotation (5.9%); most complications were foreseeable and easy to manage. In contrast, the most common complications/ adjustments with fixed prostheses were veneer fracture (55%) and remaking the prosthesis (27%). As with the previous study, prostheses with an extension were more prone to complications. Most complications with FPDs occurred within the first 2 years and did not recur. Among the overdentures, those that were ball-retained had significantly more complications than those that were bar-retained.[88]

**Stress analyses**

Finite element analyses have been utilized to investigate the bone loading that occurs with 5-unit implant-supported FPDs. Using a variety of 5-unit restorations supported by three implants each, researchers found stresses between 5 and 30 MPa in the cortical region, compared to between 2 and 5 MPa in trabecular bone. The lowest stress forces were observed with cementable FPDs fabricated on master casts obtained from repositioning technique impressions. Axial loading of a single implant with 200 N produced similar stress forces. The results demonstrated that superstructure fixation on Straumann® dental implants alone does not represent a risk of bone damage.[89]

The effects of superstructure misfit on the strains induced have also been investigated. Two different impression techniques and impression materials were used to create impressions from a master cast with four Straumann implants. Four superstructures were then cast in gold alloy and evaluated. Strains were increased when the superstructures were connected to the implants, compared to the casts that they were made from. The difference in strains was less for superstructures made using an indirect impression technique with snap-on impression caps and Straumann® synOcta positioning cylinders than with a direct impression technique.[90]

**Conclusions**

- Various types of prostheses have been evaluated on Straumann Dental Implant System implants and found to result in excellent esthetic and functional outcomes.
- Finite element analysis and strain gauge measurements provided evidence of the precision fit of superstructures of Straumann implants.

# 8. Quality of life with implants

Successful implant treatment, especially in edentulous patients, involves more than just restoring the patient's masticatory function. It is also about restoring their confidence in eating certain foods, making appropriate nutritional choices and dealing with certain social situations. This section reviews several of the studies showing the positive impact that implant treatment can have on the patients' quality of life.

### Introduction

For many patients, particularly those that are fully edentulous in one or both jaws, receiving dental implants is about more than just restoring function. Edentulism is considered a chronic condition, and conventional treatment (i.e. dentures) is often unsatisfactory for patients, as it does not allow them to eat the range of foods they used to. For many, conventional dentures are uncomfortable, inconvenient and embarrassing, and this affects their quality of life and psychological well-being. There are, therefore, many factors to consider besides general quality of life, including esthetics, phonetics, psychological impact and nutritional aspects. Implant treatment has been shown to have tremendous benefits on patients' quality of life.

### Overall patient satisfaction

Several studies have demonstrated that implant-retained overdentures are better than conventional dentures, for a number of reasons.

A study where 60 patients received either conventional dentures or implant-based ball-retained overdentures evaluated the effects on comfort, stability, chewing ability, speech esthetics and ease of cleaning, as well as general satisfaction using the Oral Health Impact Profile (OHIP). General satisfaction, comfort, stability and chewing ability were all rated as significantly higher with the overdenture treatment, and these patients also experienced significantly fewer oral health-related quality of life problems.[91]

Another study evaluated patient satisfaction and quality of life using OHIP and the SF-36 general health questionnaire. Patients with overdentures had excellent results in assessments of functional limitation, physical pain, disability and psychological disability (Table 19), with significant positive changes for assessments of emotion, vitality and social function (Table 20).[92]

**Table 19:** OHIP-20 scores for patients with conventional dentures and implant based overdentures.[92]

| | Conventional | | Implant | |
|---|---|---|---|---|
| | Pre-treatment | 6 Months | Pre-treatment | 6 Months |
| **OHIP subscale** | Mean | | Mean | |
| **Functional limitation** | 11.56 | 10.36[b] | 10.67[a] | 8.10[ab] |
| **Physical pain** | 15.48[a] | 12.36[ab] | 14.00[a] | 8.07[ab] |
| **Psychological discomfort** | 5.96[a] | 4.60[a] | 5.27[a] | 3.33[a] |
| **Physical disability** | 10.88 | 9.48[b] | 10.50[a] | 6.50[ab] |
| **Psychological disability** | 5.00 | 4.40[b] | 5.03[a] | 3.13[ab] |
| **Social disability** | 4.20 | 3.88 | 4.20[a] | 3.47[a] |
| **Handicap** | 3.24 | 2.76 | 3.83[a] | 2.40[a] |
| **Total** | 56.32 | 47.84[b] | 53.50[a] | 35.00[ab] |

*[a] Significant differences between pre- and 6-months OHIP-20 scores within treatment group (paired t-test, $P < 0.05$).*

*[b] Significant differences between conventional and implant treatment , 6-months OHIP-20 scores (independent t-test, $P < 0.05$).*

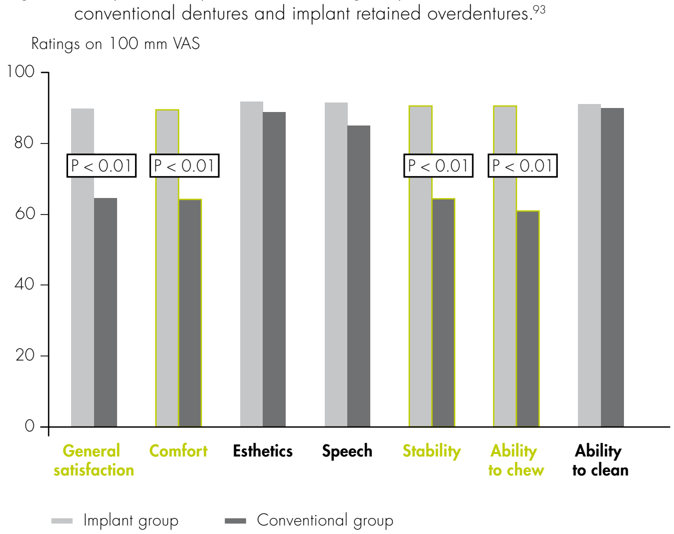
**Table 20:** SF-36 scores for patients with conventional dentures and implant-based overdentures.[92]

| | Conventional | | Implant | |
|---|---|---|---|---|
| | Pre-treatment | 6 Months | Pre-treatment | 6 Months |
| **SF-36 subscale** | Mean | | Mean | |
| **Physical function** | 81.60 | 83.40 | 83.89 | 85.00 |
| **Role physical** | 80.00 | 82.00 | 83.33 | 79.63 |
| **Role emotional** | 96.00 | 88.00 | 93.83[a] | 79.01[a] |
| **Bodily pain** | 68.84 | 75.80 | 76.78 | 71.07 |
| **Vitality** | 71.80 | 75.60 | 78.52[a] | 71.30 |
| **Mental health** | 82.88 | 82.24 | 82.52 | 80.89 |
| **Social function** | 88.00 | 92.00 | 93.98[a] | 84.26[a] |
| **General health** | 83.76 | 82.72 | 82.85 | 80.89 |
| **Physical component score** | 51.00 | 52.92 | 52.95 | 52.81 |
| **Mental component score** | 52.88 | 52.12 | 53.49 | 49.01 |

*[a] Significant differences between pre- and 6-months SF-36 scores within treatment group (paired t-test, $P < 0.05$).*

The VAS measurement has also proved to be a useful indicator of quality of life. In a randomized trial with 102 patients who received either conventional dentures or implant-retained overdentures, mean general satisfaction proved to be significantly greater with the implant overdenture treatment. Scores were also significantly higher for three additional measurements: comfort, stability and ease of chewing (Fig. 33). Patients also reported that various potentially problematic foods were easier to eat with implant overdentures; these included bread, cheese, apple, lettuce and carrot.[93]

**Fig. 33:** Comparison of post-treatment ratings of patient satisfaction between conventional dentures and implant retained overdentures.[93]




Patient general satisfaction (as measured by VAS) was shown to be approximately 36% greater in patients receiving implant retained overdentures compared to conventional dentures in another study. Here also, certain foods such as sausages, apples, carrots, lettuce, bread and cheese were reported to be easier to eat for patients with overdentures.[94]

## Additional benefits – nutrition and social impact

Studies of improved digestion by patients with implant retained overdentures suggest that better nutritional health has led to investigations of diet and nutrition, to assess whether nutrition is improved.[93] Patients with implant retained overdentures were seen to gain more weight and increase their percentage of body fat (Table 21), something that is beneficial for elderly patients. Increased skin-fold thickness at the biceps, scapularis and abdomen, and significant reductions in waist circumference and waist-hip ratio showed that the patients were gaining fat in the healthy parts of the body. In addition, serum albumin, hemoglobin and vitamin B12 were all significantly increased in the patients with implant retained overdentures (Table 20). Concentrations of nutritional parameters and nutrients are often reduced in elderly patients, and such reductions have been associated with increased risk of stroke, hematological diseases and neurological disorders.[95]

**Table 21:** Comparison of post-treatment ratings of patient satisfaction between conventional dentures and implant retained overdentures.[95]

| | Conventional | | Implant | |
|---|---|---|---|---|
| | Post-treatment Mean | Mean Difference | Post-treatment Mean | Mean Difference |
| **Patient characteristics** | | | | |
| **Age** | 70.1 | 0.48 | 69.6 | 0.50 |
| **Weight** (kg) | 72.5 | 0.92 | 77.7 | -0.40 |
| **Height** (cm) | 162.1 | -0.01 | 165.4 | -0.17 |
| **Anthropometric data** | | | | |
| **% Fat** (SFT) | 36.6 | 0.33 | 35.7 | 1.10 |
| **Biceps SFT** (mm) | 13.0 | 1.81 | 12.5 | 1.36 |
| **Subscap. SFT** (mm) | 21.9 | 0.48 | 21.2 | 1.82 |
| **Abdom. SFT** (mm) | 29.4 | 1.30 | 32.1 | 3.28 |
| **Waist circumference** (cm) | 92.7 | -0.59 | 93.2 | -2.97 |
| **Waist/hip ratio** | 0.9 | 0.00 | 0.9 | -0.02 |
| **Blood parameters** | | | | |
| **Hgb** (g/L) | 141.9 | 2.33 | 144.4 | 3.21 |
| **Albumin** (g/L) | 42.9 | 0.85 | 43.8 | 1.14 |
| **B12** (pmol/L) | 291.8 | 22.07 | 269.3 | 27.62 |

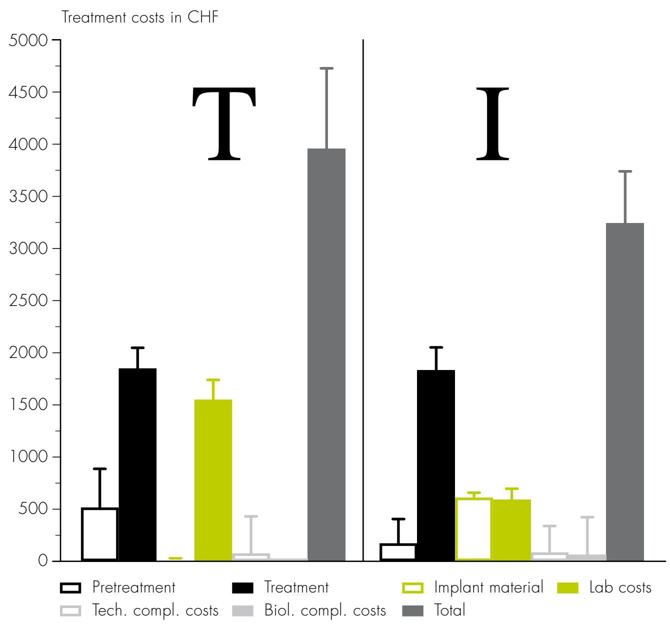
The restoration of normal function involves more than just the ability to chew and eat more nutritional foods, however, and the wider social impact that implant-retained overdenture treatment can have has also been evaluated. In one study, a Social Impact Questionnaire was used as well as OHIP to assess more detailed quality of life aspects, specifically the impact on social and sexual activity. These included avoiding conversation, refusing social invitations, avoiding sport and unease when kissing and in sexual relationships. Significant improvements were reported in the implant retained overdenture group compared to those with conventional dentures only a short time (2 months) after delivery of the prosthesis.

Post-treatment looseness of the prosthesis was much lower, and there were significant improvements for looseness during eating, speaking, kissing and yawning. Patients also reported feeling less uneasy with kissing and sexual relations. Implant retained overdenture treatment therefore had a substantially positive impact on these aspects of quality of life.[96]

**Cost-effectiveness of implant therapy**

Some patients may perceive implant therapy to be expensive, but economic analyses of implant treatment supporting single-tooth restorations and overdentures have shown that this is not the case. A private practice assessment of economic aspects of restorations with either conventional three-unit FPDs or single crowns supported by Straumann® dental implants demonstrated that cost-effectiveness was greater for the implant-based treatment, despite the total treatment times being almost the same (mean 5.1 h for FPDs and 4.8 h for implant treatment). Laboratory costs and total costs were found to be significantly lower for the implant-based treatment (Fig. 34), even when 'opportunity costs' (i.e. financial losses due to lost work time, compensation, transportation, etc.) were taken into consideration. The costs for the treatment of complications were the same between both types of treatment.[97]

**Fig. 34:** Comparison of costs (in CHF) for conventional FPDs (T) and implant supported single crowns (I) [97]




In a comparison of economic aspects of conventional versus implant-supported overdenture treatment, it was found that, although costs were higher for overdenture treatment, the increase in oral-health- related quality of life (using the 20-point OHIP [OHIP-20]) was significantly greater (Table 22). The differences in equalized annual value between the two groups were $226 and 15.7 OHIP-20 points, which translate into an additional cost of only $14.41 per OHIP point per year.[98]

**Table 22:** Comparison of OHIP-20 scores for conventional dentures and implant supported overdentures

| OHIP Category | CD Mean | IOD Mean | Mean Difference |
|---|---|---|---|
| Functional limitation | 10.0 | 6.8 | 3.20 |
| Physical pain | 12.0 | 7.5 | 4.48 |
| Psychological discomfort | 4.8 | 2.9 | 1.86 |
| Physical disability | 9.5 | 5.7 | 3.80 |
| Psychological disability | 3.9 | 2.8 | 1.07 |
| Social disability | 4.0 | 3.1 | 0.92 |
| Handicap | 3.2 | 2.2 | 0.97 |
| Total | 47.3 | 31.0 | 16.30 |

**Conclusions**

- Straumann's edentulous solutions may improve quality of life and patient satisfaction compared to conventional treatment.
- Implant treatment in edentulous patients may lead to improved nutritional health.
- Implant treatment may have a positive impact on social aspects of quality of life.
- Implant treatment may be more cost-effective than conventional treatment.

# 9. Special cases and high-risk patients

In the real world beyond controlled clinical studies, patients receiving dental implant treatment may have a number of associated health conditions that may influence the success of the implant procedure. The use of Straumann® dental implants in such patients, has been reported. This section deals with the evidence for treatment in these cases.

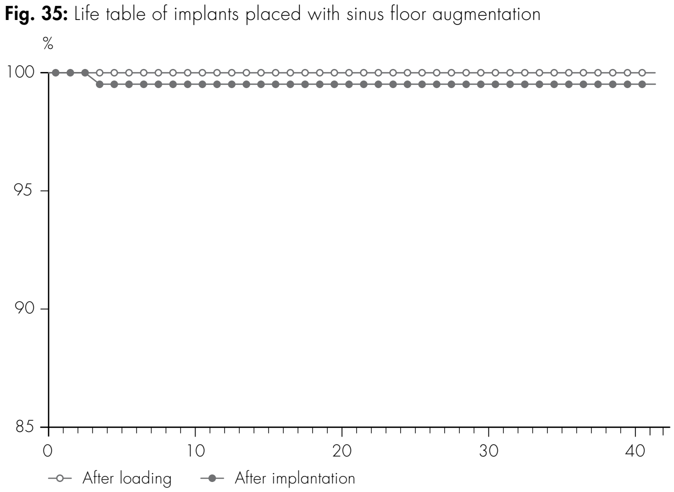
## Introduction

For most clinical investigations into implant success and survival, the patient population evaluated is carefully chosen according to strict study inclusion criteria. These patients therefore represent an 'ideal' patient population in many ways, i.e. no periodontal disease, no diabetes, no local or systemic diseases, etc. However, patients in the real world often have associated health conditions (e.g. periodontitis, diabetes, etc.) or habits (e.g. smoking, bruxism, etc.) that may put implant success at risk, or implants may need to be used in special situations (e.g. sinus augmentation, narrow alveolar ridges). It is therefore important to know how safe and predictable implant therapy can be in such situations.

## Sinus floor elevation

Placement of Straumann dental implants in conjunction with sinus augmentation using autogenous bone was evaluated in 41 patients who received 183 Straumann SLA® implants. The implants were loaded after an average of 4.1 months, with a follow-up time ranging from 15 to 40 months after placement. The implants were placed either simultaneously with augmentation or after an average healing time of 4.9 months. A total of 61% implants were loaded by fixed bridges, 11% bar reconstructions, 22% single crowns and 6% temporary. The 2-year implant survival rate was 99.5% (Fig. 35), with a mean marginal bone loss of 0.26 mm in the first year. This study demonstrated the safety and predictability of SLA implants in this setting.[99]

**Fig. 35:** Life table of implants placed with sinus floor augmentation




A 12-year life table analysis (mean follow-up of 59.9 months) from a study of 588 implants placed in conjunction with sinus floor elevation in 323 patients also demonstrated the success of Straumann implants in this situation.

A cumulative 12-year survival rate of 94.8% and success rate of 90.8% were calculated, with a very low incidence of Schneiderian membrane perforation (2.2%). In this study, cumulative success was slightly higher for longer (12 mm) implants compared to implants of 10 mm and 8 mm lengths (success rates 93.4%, 90.5% and 88.9%, respectively).

The results for short implants are considered good, since these implants tended to be placed in the posterior segment, where bone quality and quantity tended to be reduced.[66]

Predictable implant function was also demonstrated when SLA implants were placed in an osteotome sinus floor elevation procedure without the addition of a bone grafting material. The mean residual bone height was 5.4 ± 2.3 mm. A total of 25 implants placed protruding into the maxillary sinuses (mean protrusion of 4.6 mm and 5.2 mm at the mesial and distal sides, respectively) of 17 patients and left to heal for 3–4 months before abutment insertion; 96% of the implants resisted the torque. All implants were clinically stable at 1 year. The endo-sinus bone gain was 2.5 ± 1.2 mm (Table 23), which correlated well with implant penetration into the sinus. This procedure with SLA implants resulted in predictable bone formation without the use of grafting material.[100]

**Table 23:** Endo-sinus bone gain with implants placed in the maxillary sinus without grafting material.[100]

| **Gain** (mm) | **Mesial side** | **Distal side** | **Sum** |
|---|---|---|---|
| **0 – 1** | 3 (12 %) | 0 (0 %) | 3 (6%) |
| **1 – 2** | 8 (32 %) | 8 (32 %) | 16 (32%) |
| **2 – 3** | 5 (20 %) | 9 (36 %) | 14 (28%) |
| **3 – 4** | 7 (28 %) | 6 (24 %) | 13 (26%) |
| **> 4** | 2 (8 %) | 2 (8 %) | 4 (8%) |
| **Sum** | 25 (100 %) | 25 (100 %) | 50 (100%) |

## Narrow alveolar ridges

Straumann® Dental Implant System implants are also successful and predictable when placed in narrow alveolar ridges, as demonstrated by a study where implants (in conjunction with bovine bone mineral and covered with a membrane) were placed in patients with bone dehiscences of between 3 and 9 mm. Of the 16 implants placed, 15 were successful, with a follow-up period ranging from 12 to 114 months. Only one implant showed mesial and distal bone resorption, and previously exposed implant threads were covered with vascularized tissue; coverage was 100% in all implants except two, where the coverage was 63% and 87% respectively.[68]

**Conclusions**

- Straumann® dental implants have demonstrated excellent results in sinus floor elevation, even without the use of bone augmentation material.
- Successful results can be achieved in narrow alveolar ridge cases with the use of Straumann dental implants in conjunction with bovine bone and a membrane.

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