Clinical Performance of a Method for the Fabrication of Implant-Supported Precisely Fitting Titanium Frameworks: A Retrospective 5- to 8-Year Clinical Follow-Up Study

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ABSTRACT

Background: The CrescoTi Precision® (CTiP) method (CrescoTi Systems, Lausanne, Switzerland) has been introduced as an alternative method for the fabrication of precisely fitting titanium frameworks. The method is supposed to be used with all major implant systems, without the need for abutments.

Purpose: The objectives of this clinical and radiographic retrospective follow-up study were to report the clinical performances of "CTiP-fabricated" frameworks that are screw retained directly to Brånemark implants as opposed to Brånemark implant/abutment assemblies (Nobel Biocare AB, Gothenburg, Sweden) and to compare the clinical outcomes of these two modalities.

Materials and Methods: Thirty-six patients were provided with 46 fixed prostheses supported by 207 Brånemark regular-platform implants. Twenty-seven prostheses were placed on implant/abutment assemblies, and 19 were placed directly at "implant level." The prostheses had been in function for 5 to 8 years at the time of the final examinations.

Results: Three patients did not attend the final examination. All 43 prostheses in the 33 examined patients were still in function. No major mechanical framework complications were observed during the observation period. One implant was lost after loading. There was no difference in bone loss around the abutment-free implants when compared with the implants provided with abutments.

Conclusions: This long-term clinical test demonstrated that the CTiP technology constitutes a reliable prosthetic treatment concept in combination with Brånemark implants. The results also revealed that the frameworks could be connected directly to the implants without any negative consequences.

KEY WORDS: abutment-free, Cresco, dental implant, precision of fit, retrospective clinical study, titanium, welding

As osseointegrated implants do not have the same resilience in the bone as teeth have, the precision of fit between the superstructure framework and the supporting implants seems especially important. For example, because of distortion arising from the casting procedure,[1] eventually combined with improper handling in the laboratory, a framework as cast does not fit on the implant analogs in the master cast as precisely as the original wax-up did. This means that screw tightening of an as-cast framework to "nonresilient" implants causes uncontrolled stress and strains that are transmitted to the periimplant bone, the implant components, and the framework.[2,3] The classic way to correct the misfit of gold alloy frameworks is by sectioning and soldering, even if the method does not lead to an "absolute" fit.[4] To compensate for a lack of precision of fit between the superstructure metal framework and the implants, the original implant prosthodontic concept also included a strong recommendation to build into the system a shock-absorbing and misfit-compensating abutment assembly.[5,6]

In recent years inexpensive and biocompatible titanium—which, however, cannot be soldered in the

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same way as gold alloys—has become more frequently used as a framework material. Titanium has to be welded. Several modifications of systems have been introduced, including the assembling of prefabricated titanium components by laser welding.[7–9] Some of the earlier tests of laser-welded titanium frameworks reported a high incidence of fractures.[10] However, later studies showed that the clinical performance of laser-welded titanium frameworks was similar to that of conventionally fabricated gold alloy frameworks.[11,12] During the last few years computer-aided design (CAD) and computer-aided manufacturing (CAM) milling[13–15] and spark erosion[16] methods for the fabrication of titanium frameworks from a solid piece of titanium have become of interest. Welding and distortion problems are eliminated by the use of these fabrication methods. Recently an alternative method for the fabrication of abutment-free titanium frameworks with a high precision of fit was presented: the CrescoTi Precision® (CTiP) method (CrescoTi Systems, Lausanne, Switzerland).[3,17,18] This method is based on the lost-wax casting technology followed by laser welding in a horizontal plane.

The objectives of the present retrospective study were to report the clinical performances of "CTiP-fabricated" titanium superstructure frameworks when supported by Brånemark regular-platform (RP) implants (Nobel Biocare, Gothenburg, Sweden) directly (ie, abutment free) or by Brånemark implant/abutment assemblies (Nobel Biocare AB) and to report possible differences in the clinical outcomes of the two treatment modalities.

MATERIALS AND METHODS

CrescoTi Precision Method

The CTiP method for the fabrication of abutment-free screw-retained precisely fitting superstructure frameworks has been presented and described in detail elsewhere.[3,17,18] In this article the description of the method is therefore limited to the schematic illustrations in Figure 1. The technology is adaptable to most implant platforms on the market and to a wide range of alloys besides titanium. Even if the fabrication technology is based on an abutment-free prosthesis concept, the technology can also be used on abutments if so desired. Because of the various designs of the platforms, the proper components fitting the actual implant platform must be used. As Brånemark RP implants (3.75 mm in diameter) with or without abutments supported the fixed prostheses in the present study, components fitting this type of implant and abutment platform were used (Figure 2).

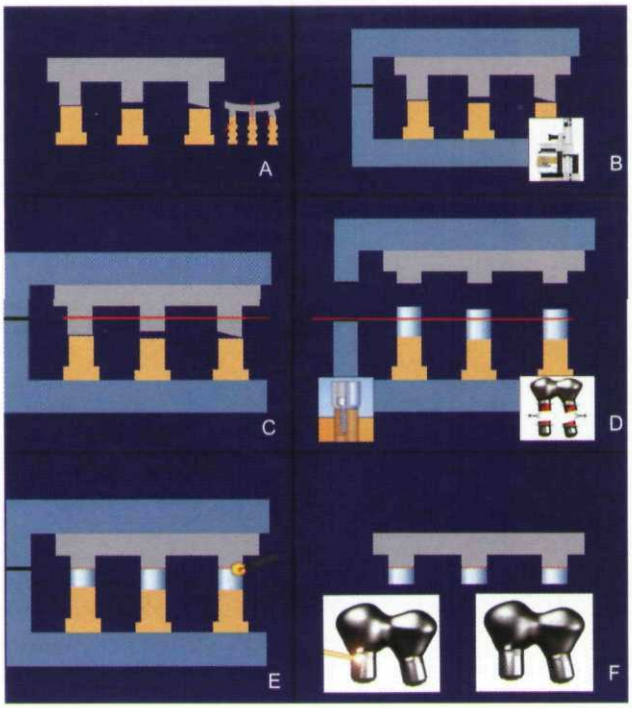

Figure 1 Schematic illustration of the CrescoTi Precision method for fabrication of passively fitting frameworks. *A*, Misfit framework placed on the implant analogs. Screw tightening causes uncontrolled stress (*inset*). *B*, Master cast and framework mounted in an articulator-like "fixator" (*inset*), which secures the relation between master cast and framework. *C*, Framework "legs" are cut in a defined horizontal plane. *D*, Prefabricated "bridge supports" (*left inset*) are connected to the implant analogs by screws and are then cut in the same horizontal plane as the framework "legs." *E*, "Passive fit" between framework and "bridge supports." Assembly is done by laser welding. *F*, Abutment-free framework.

Retrospective Clinical Study

Patient and Implant Distribution. The actual clinical follow-up study comprises all the implant-supported prosthetic treatments (single-tooth implant restorations not included) performed between 1994 and 1998 in a Swedish general private practice. Altogether 36 patients had restorations with 46 fixed prostheses (FPs) supported by a total of 207 Brånemark RP implants. Seven of the patients had restorations with two FPs, and one patient's restoration was with three FPs. The distribution of gender, type of prosthesis, and number of supporting implants with reference to patient age is presented in Table 1.

Surgical Procedure. The surgical installation of the implants was performed by a trained oral surgeon (one of the authors [T. M.]), and all prosthetic treat-

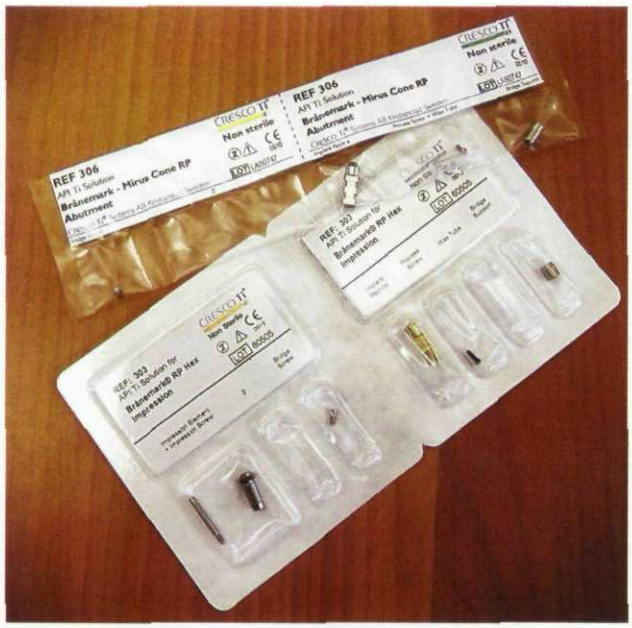

Figure 2 All-parts-included (API) packets for Brånemark regular-platform implants (Ref: 303) and Brånemark corresponding abutment platform (Ref: 306). Each packet includes all parts needed for the prosthodontic and laboratory procedures (ie, impression element, bridge retention screw, burnout plastic tube, laboratory screw, and prefabricated titanium "bridge support").

ments were carried out by a general practitioner (another of the authors [L. H.]). The two-stage surgical protocol[19] was followed (ie, the implants healed in a submerged position).

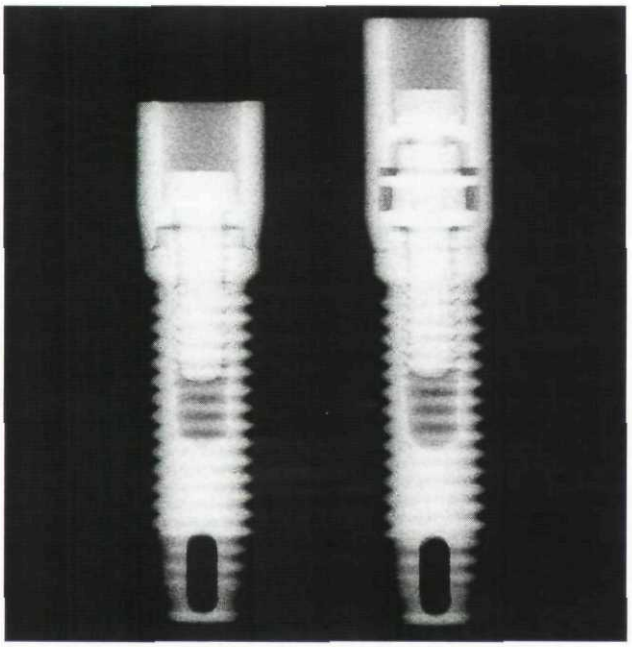

Figure 3 Radiographic demonstration of the screw connection between the Cresco "bridge support," the Brånemark regular-platform implant (shown at left), and the Brånemark implant/abutment assembly (shown at right).

TABLE 1 Distributions of Fixed Prostheses by Patient Age and Gender, Type of Prosthesis, and Number of Implants

	Gender		Type of Prosthesis		No. of
Age (yr)	Male	Female	FFP	FPP	Implants
40–49	1	0	0	2	6
50–59	5	7	11	5	81
60–69	6	6	10	4	61
70–79	5	4	5	6	48
≥ 80	1	1	1	2	11
Total	18	18	27	19	207

FFP = fixed full prosthesis; FPP = fixed partial prosthesis.

Prosthodontic Treatment. All 46 superstructure frameworks were cast in titanium and then subjected to the CTiP procedure to correct the misfit. Twenty-seven of the prostheses (in 19 patients) were "built" on 117 Brånemark implant/standard-abutment assemblies whereas 19 prostheses (in 17 patients) were "built" directly on the implants (90 implants) (ie, abutments were excluded) (Figure 3).

The clinical control of the fit between the implants and the frameworks was accomplished with the available radiographs and by tightening one distal retention screw and then observing the eventual gap spaces between the remaining implants and the framework. In one case the fit was inaccurate. In that case a new impression was taken, and a new master cast was fabricated. The CTiP procedure was then repeated on the existing framework but was based on the new master cast.

Clinical Data Collection at Final Follow-Up Examination. To collect actual clinical information, all patients were called for a follow-up examination. Three of the patients, who had restorations with 3 fixed full prostheses supported by 17 implants, had moved away from town and did not attend the final examinations (the dropout rate was 8%; 2 patients attended the checkup control examination at 6 months, and the third patient was observed for 2 years). Thus the results presented in this article are based on 33 patients (43 restorations supported by 190 implants). The number and types of prostheses, the number of examined implants, and the distribution of abutment-supported versus abutment-free prostheses with reference to observation times are presented in Table 2.

The examinations followed a defined protocol including radiography of all implants. The superstruc-

TABLE 2 Number and Type of Restorations and Number of Supporting Brånemark Implants, with Reference to Observation Time

Observation Time (yr)	Restorations*	FFPs*	FPPs*	Implants†	Implant Failures
8	5 (0)	5 (0)	0	28 (0)	—
7	11 (0)	5 (0)	6 (0)	44 (0)	—
6	10 (4)	6 (2)	4 (2)	46 (18)	—
5	17 (13)	8 (8)	9 (5)	72 (61)	1
Total	43 (17)	24 (10)	19 (7)	190 (79)	1

FFP = fixed full prosthesis; FPP = fixed partial prosthesis.
*Figures within parentheses denote number of abutment-free restorations and number of their supporting implants, respectively.
†Figures within parentheses denote number of implants supporting abutment-free restorations.

tures were removed if any sign of implant disintegration or periimplantitis was observed clinically or by radiography. Periimplantitis was defined as loss of periimplant bone as observed on radiographs, in combination with suppuration from the implant "sulcus." Adverse events that had occurred during the observation periods (from delivery of the prosthesis to last examination) were registered from the patients' records. According to the clinical routines in the office, every patient was seen by the dentist 6 and 12 months after delivery of the prosthesis and then once yearly. The patients also received treatment from a dental hygienist at intervals based on individual needs.

Radiographic Analysis. The distance between the mesial and distal crestal bone level and a defined marking on the implant (lateral border of the implant platform) was measured for each supporting implant from the initial radiographs (made on the day of functional loading) and from the final radiographs (made at follow-up reexaminations) to the nearest tenth of a millimeter, with the use of a loupe (×7 magnification). The radiography was performed "freehand." Efforts were made to get the x-ray projection as perpendicular to the implant as possible. The differences between the measurements representing the bone level variation during the observation periods were calculated as mean values (± standard deviation [SD]) and as the frequency distribution of all measured sites, grouped in intervals of 0.5 mm. An independent examiner made all the measurements. The intra-individual reproducibility based on 200 measurements was 89%. If a radiograph was not good enough for accurate measurements, the site was denoted as "not measurable" and was excluded from the final calculations.

Statistical Analysis. *t*-Tests were used to analyze possible differences in crestal bone loss whether related to the use of abutments or not. As the observation time for the abutment-free FPs did not exceed 6 years (see Table 2), the analysis was based on the measurements around the implants loaded for 5 and 6 years.

RESULTS

All 43 restorations in the 33 examined patients were still in function at the final follow-up examinations. Telephone contacts with the three nonattending patients (dropouts) revealed that their restorations and the supporting implants were in function. Six of the originally placed 207 implants did not osseointegrate, that is, were "lost" during the healing phase between surgical installation and "implant exposure surgery." This corresponds to an initial implant failure rate of 2.9%. One implant was lost after loading (see Table 2), resulting in a total implant survival rate (after loading) of 99.5%.[20] In the same jaw, one implant fractured. Two prostheses were temporarily removed, one to gain access for treatment of periimplantitis and one for removal of the disintegrated implant and the coronal part of the fractured implant. As can be seen from Table 3, very few complications were observed.

TABLE 3 Presentation of Complications

Complication	No. of Cases
Implant failure before loading	6
Implant failure after loading	1
Implant fracture	1
Resin fracture	6
Porcelain fracture	1
Periimplantitis	3
Soft tissue hyperplasia	1

The results from the measurements of the crestal bone changes for each observation interval (together with the percentage of "nonmeasurable sites") appear in Table 4 whereas Table 5 presents the frequency distribution analysis. No statistically significant difference in bone loss around implants with abutments (mean, 0.3 mm ± 0.5 SD) as compared to abutment-free restorations (mean, 0.4 mm ± 0.5 SD) can be observed.

DISCUSSION

The absence of mechanical complications of the superstructure is in agreement with results from a prospective 5-year multicenter study recently reported by Helldén and colleagues.[21] The present 5- to 8-year follow-up study can therefore be considered a decisive test of the mechanical strength and fatigue properties of frameworks fabricated according to the CTiP method.

As the lack of periodontal ligament renders the implant more or less unable to modify its position, Nobel Biocare early established the rule that abutments are needed between framework and implants in order to prevent mechanical and biologic complications.[6] The rationale behind this rule was that the resilience in the implant/abutment assembly should (similarly to the periodontal ligament) counteract uncontrolled stress forces that otherwise might develop during and after the tightening of the retention screw of a misfit superstructure. The logical conclusion of this reasoning might be that abutments could be excluded if precision of fit exists between the superstructure and the supporting implants. The results from the present comparative study (in which the superstructures were fabricated according to a method meeting the highest demands in regard to precision of fit)[3] did not reveal any clinical and radiographic differences around the abutment-free implants when compared with the implants provided with abutments. This should not be interpreted as indirect support for the expressed conclusion above since neither animal experiments nor clinical studies have so far demonstrated major negative biologic effects of misfit-induced stresses.[22–24] The trend toward shortened healing periods and even immediate loading of the implants might, however, suggest that the degree of precision of fit could be a potential discriminating factor for implant success and failure. From that aspect it seems essential to have access to standardized, simple, and reliable methods for the fabrication of frameworks, methods meeting high demands of fit between implant components and superstructure.[25]

Today the CTiP method is in routine clinical and laboratory use for the fabrication of titanium frameworks, as is the Procera® Implant Bridge method (Nobel Biocare AB). Even if these methods are based on quite different technologies, both were developed with specific focus on rational routine fabrication of frameworks and superstructures with maximal precision of fit to the supporting implants. The Procera method is based on the three-dimensional computer numeric controlled (CNC) milling of a bulk base material[13–15] whereas the CTiP method is based on the conventional lost-wax technology. Örtorp and Jemt[14] compared the clinical experiences with CNC-milled titanium frameworks with experiences with conventionally fabricated gold alloy cast frameworks; no mechanical complications were reported for either group. Their conclusion after 3 years' follow-up was that CNC-milled titanium frameworks can be used as an alternative to conventional gold alloy frameworks. As the favorable results from this study are based on 5 to 8 years of function, it seems justified to assume that the same conclusion is valid also for titanium frameworks fabricated according to the CTiP method. Even if both methods lead to very high levels of precision between the framework and the analogs in the master cast, this does not imply that the same precision is occurring in the mouth. Such differences can be caused by inaccurate impressions and/or

TABLE 4 Crestal Bone Loss around Implants with and without Abutments*

Observation Time	With Abutments (Mean ± SD)	Without Abutments (Mean ± SD)	Difference
8 yr	0.4 ± 0.6 mm (20%)	—	—
7 yr	0.3 ± 0.5 mm (18%)	—	—
5 and 6 yr	0.4 ± 0.6 mm (10%)	0.4 ± 0.5 mm (4%)	NS

NS = no statistically significant difference.
*Figures within parentheses denote percentage of nonmeasurable sites.

TABLE 5 Frequency Distribution (in Percentages) of Measured Periimplant Sites, Related to Crestal Bone Loss/Gain after 5 Years' Functional Load, with Comparison between Abutment-Free Implants and Implants with Abutments

	Crestal Bone Level Changes				Nonmeasurable Sites
	– (> 1.5 mm)	– (1.0–1.5 mm)	– (0.5–1.0 mm)	± 0.5 mm	
Abutment-free implants (%)	3	5	16	72	4
Abutment/implant assemblies (%)	4	2	8	76	10

by inaccurate handling in the laboratory during the fabrication of the master cast. It is therefore of utmost importance to spend time and effort examining the fit while in the clinic. Various examination methods have been suggested, but none of these methods have gained full acceptance as an accurate clinical standard test. Single tightening of a retention screw in "distal" position and then observation of gap spaces between the remaining implants and framework still seem to be the most common method for the evaluation of misfit. This method can be used in laboratory settings but is not as easy to use intraorally, where the metal contact zones are mostly subgingivally located. Complicated techniques for the assessment and measurement of misfit have been presented,[26] but these methods are not designated for routine clinical use. An easy and objective method for assessment of fit in the laboratory as well as in the clinic is therefore desirable.

CONCLUSIONS

The results from the radiographic assessment of marginal periimplant bone loss were in accordance with clinically accepted values for both implant groups (with or without abutments).[20] It can therefore be concluded, both from a biologic and from a mechanical (ie, the absence of major mechanical complications during a period of 5 years) aspect, that superstructures fabricated according to the CTiP method and Brånemark implants constitute a reliable combination. This statement seems to apply also to other brands of implant having the same external hexagon design and dimensions as the Brånemark implant as it has recently been reported that the Brånemark/Procera abutment with its screw can be universally applied to other implant platforms and internal screw bores.[27]

ACKNOWLEDGMENT

The patients who kindly participated in the study are greatly appreciated and acknowledged.

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