Title: A retrievable metal-ceramic acrylic implant supported fixed prosthesis with titanium framework and all-ceramic individual crowns. Retrospective clinical study with up to 10 years of follow-up.

Short title: Retrievable definitive implant supported fixed prosthesis

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SUMMARY

Objective. The purpose of this study was to report on the outcome of a metal-ceramic implant supported fixed prosthesis with a titanium framework and all-ceramic crowns.

Methods. The clinical study included 108 patients (67 women and 41 men), with a mean age of 58.6 years (range:34-82), followed between 9 months and 10 years, with a mean follow-up time of 5 years. The data was divided into 2 groups (development and routine groups). One-hundred-twenty-five prosthesis were manufactured, 66 prosthesis (28 in the maxilla and 38 in the mandible) manufactured using the first generation laboratory protocol, distributed by 52 patients (development group); and 59 prosthesis (49 in the maxilla and 10 in the mandible) manufactured using the second generation laboratory protocol, distributed by 56 patients (routine group). Survival estimates were calculated on patient level through the Kaplan-Meyer product limit estimator with 95% confidence intervals (CI). Data were analyzed with descriptive and inferential analyses.

Results. At patient level, the estimate of survival of the implant supported fixed prosthesis were 92.4% for the development group at 10 years and 100% for the routine group at 5 years (Kaplan-Meyer). In the development group, univariate analysis of logistic regression “opposing dentition” as a risk factor for crown fracture; while in the routine group, the same factor was not found to be significant in the outcome of the rehabilitations.

Conclusions. The results indicate that, within the limitations of this study, the present protocol is valid for the definitive prosthetic rehabilitation with good prognosis on the long term.

INTRODUCTION

Implant supported fixed prosthesis have been increasingly the first choice treatment on the rehabilitation of edentulous areas,[1-3] with the substitution of removable dentures by fixed prosthesis over implants achieving predictable high success results. The focus of research should be on types of frameworks and their reliability, with the development of new prosthetic solutions allowing performing total rehabilitations with higher quality of the materials and finish, higher aesthetics, customization of the fixed dental prosthesis (avoiding "same look smile"), better biomechanics, facilitation of hygienic maintenance, retrievability and better prognosis as endpoints.

It has also been of great importance to develop fabrication technical procedures that can be performed in a production line in order to lower costs, reduce manufacturing time, guarantee consistent high quality and minimize human error. The main goals to achieve when developing a new type of fixed dental prosthesis should be the use of state of the art dental technology, reliable materials in the long term basis, and the solution of problems posed previously with other types of fixed dental prosthesis. An infrastructure should have a number of characteristics such as: biocompatibility, good mechanical properties, passive fit to the implants and abutments [4] and compatibility with other laboratorial materials (ceramic and acrylic).

Two major concepts for the production of a fixed rehabilitation are the conventional waxing-casting technique (Gold)[5]; and the Cadd-Cam with the grinding of a metal block (Procera; Titanium, Zirconia).[6] For the conventional waxing-casting technique, several advantages can be applied, such as high aesthetics due to well developed ceramics,[7] high biocompatibility if only gold alloy is used,[8,9] or the fact that any dental laboratory can manufacture it due to its non-expensive, low-technology standard equipment requirements.

For the Cadd-Cam system (Titanium + ceramic baked over it), [6,10,11] several advantages can be enumerated such as: biocompatibility, the very high precision of fit, the possibility of an extended cantilever length (due to characteristics of titanium/zirconia allowing this way the use of less implants), the resistance (due to the fact that it constitutes one block structure with no welding points), and that it is machine manufactured, thus less susceptible to human error. However, the number of disadvantages should also be taken into consideration for both concepts. For the conventional waxing-casting technique, one category of difficulty is the achievement of high precision fit in large structures.[12-14] This requires the welding of sections in full arch structures in order to achieve passive fit,[15-17] with the welded sections representing weak points. Another potential disadvantage might be the metal characteristics, which renders limited cantilever length, an expensive price if gold alloys are used (for the waxing-casting technique), and impossibility to correct insufficient metal support (for both concepts).

For both concepts, the management of ceramic properties is also a concern, due to the technique sensitivity characteristics,[18] with these techniques requiring a very good ceramist (to complete a situation with fewer backings, without oxidation, keeping high aesthetics and passive fit).

The unsatisfactory remedy of ceramic fractures is a disadvantage present in both concepts. Fractures can only be repaired by adding more ceramics and baking again the whole structure, increasing the probability of destroying the welding points (in the conventional technique) and damaging irreversibly the ceramics due to too many baking cycles (in both concepts).[19] The difficulty to hide the access of a prosthodontic screw if that happens in a visible aspect of the prosthesis (ex: buccal/vestibular aspect) is another disadvantage present in both concepts. The poor bonding of ceramics over the titanium is a disadvantage identified in the cad-cam system.[20]

There is evidence that supports the choice of full ceramics on all prosthesis.[21,22] The constant evolution of ceramics provided several advantages for its use including: Better aesthetics,[22] higher resistance to fracture; maintenance of vertical dimension, longer longevity,[23] more hygienic;[24] more stain resistant,[25] and more customized.[26]

The theoretical rationale for developing this new prototype of implant supported fixed prosthesis, consisted in using an infrastructure produced by the Cadd-cam system (Procera), and individualized crowns, taking the advantages of both systems and avoiding their disadvantages. By using an infrastructure produced by the Cadd-cam system (Procera), the authors aimed at the following advantages: High precision of fit;[27] longer length of cantilever due to the characteristics of metal, allowing this way the use of less implants (less bone volume for a total rehabilitation);[1] biocompatibility; one block structure with no welding, thus very resistant; machine made thus less susceptible to human error; independent from technique sensitivity (not dependable on the skills of the laboratory technician) and allowing a standardized production. By using individualized Procera crowns the authors aimed at the following advantages: High aesthetics; [28,30,31] customized prosthesis avoiding "same smile" patients; high capacity of repair, having no need to bake the structures in case of fracture (because it is manufactured crown by crown, it can be baked individually as many times as necessary); by cementing individually the crowns it is possible to repair without removing the whole structure. This way benefitting from: Repairability (reapiring without removing the whole structure); cushion effect; if any misjudgement is made in the vertical dimension or position of the teeth, it is easily solved by the double reading characteristic of the Procera system;[29] good prognosis on the medium and long term. [21, 32]

Several reports, including a review focused on the prosthodontic survival outcome of these types of rehabilitation, with survival rates ranging between 87% and 92.1% with a follow-up between 5 and 15 years.[33-38]

This new prototype was thought to be a rehabilitation solution for a full metal-ceramic implant supported fixed prosthesis that gathered the advantages of all the different concepts and materials to ensure a consistent high quality, a capacity of quick and simple repair and retrievability (the capacity to easily remove and reconnect the prosthesis). The aim of this prospective cohort study was to document the clinical and laboratorial procedure to fabricate an implant supported standardized fixed metal ceramic prosthesis. The research hypothesis was that the outcome of the rehabilitations using the current protocol gives high success rates in the long term.

MATERIAL AND METHODS

This clinical study was performed in a private center, and included 108 complete edentulous patients (67 women and 41 men) rehabilitated with 125 dental prosthesis (77 in the Maxilla and 48 in the Mandible). The average age was 58.6 years (range:34-82). A total of 634 implants (Branemark system, Nobel speedy; Nobel Biocare AB, Göteborg, Sweden) were inserted. Multi-unit straight and 30 degrees angulated abutments (Nobel Biocare) were used in the rehabilitations. The same team performed the surgical and prosthodontic treatment. The first prosthesis was placed on January 2000 and the last on February 2007. The patients were followed between 9 months and 10 years, with a mean follow-up of 5 years.

Patients were included in the study provided they were rehabilitated surgically and prosthetically at our Rehabilitation Center, in need of a definitive full arch ceramic dental

prosthesis and a written informed consent to participate in this study. The data was divided into 2 groups, with a development group and a routine group. The development group, consisted of patients with a prosthetic rehabilitation manufactured using the first generation laboratory protocol). This group included 52 patients (23 women and 29 men), with an age range of 38 to 81 years (mean 59.5 years) with 66 prostheses (28 in the maxilla and 38 in the mandible).

The routine group, consisted of patients with the prosthesis manufactured using the second generation laboratory protocol. This group included 56 patients (35 women and 21 men), with an age range of 34 to 82 years (mean 57.6 years) with 59 prosthesis (49 in the maxilla and 10 in the mandible).

Regarding the laboratory protocol, the prosthesis on the development group had the following characteristics: 12 to 14 individual Procera crowns (alumina copings) (Nobel Biocare AB, Gothemburg, Sweden) cemented over a Procera Titanium infrastructure (Nobel Biocare AB) with pink ceramic that imitated the natural gingival.

In the routine group, the changes implemented were not only related with the materials used [alumina copings were replaced by zirconia copings with Nobel Rondo Zirconia Ceramic (Nobel Biocare AB) and also pink acrylic (Unifast TRAD, GC Co, Tokyo, Japan) was used in the place of pink ceramic], but also taken into consideration the type of opposing dentition (partial/ complete implant supported fixed prosthesis using ceramic crowns), that influenced the final design of the implant supported fixed prosthesis. On the other hand, when full acrylic implant supported fixed prosthesis, total / partial denture, natural dentition or teeth-supported ceramic crowns were present then the prosthesis design was kept unchanged.

Regarding the protocol, no differences existed between the clinical procedures used on the patients of both groups. A clinical situation illustrates the protocol (Figs. 1 through 14). In

order to accomplish the laboratory demands, some aspects of these clinical procedures were respected by the clinicians such as: a stable definitive impression at abutment or fixture level (Fig. 4), an aesthetical and functional provisional implant supported fixed prosthesis (following the rules of a Edentulous rehabilitation planning protocol presented in Table I) with a compressive bullet shape contact between the prosthesis and the mucosa, a good emergence of the screw exits, a correct inter-arch relation and a correct bite registration.

All new provisional acrylic implant supported fixed prosthesis were aesthetically and functionally adapted to each patient with a compressive contact with the natural tissues in order to achieve a final convex inter-implant surface. By this the authors aimed at achieving a bullet shape prosthesis, with the objective of making it easier to perform the dental hygiene procedures (Fig. 5).

The screw exits were always positioned as most palatal as possible in order to avoid the compromise of the ceramic crowns either for aesthetical or resistance reasons. In the situations that was not possible, the exit was on the occlusal surface of the posterior teeth or on the false palatal papilla of the anterior teeth. In some situations, the misdirection of some implants led to the connection of angulated abutments (17 degrees or 30 degrees multi-unit angulated abutments, Nobel Biocare AB) in order to accomplish this rule.

All definitive impressions were achieved in two steps. The first step was to splint together the Multi-Unit impression copings (Nobel Biocare AB) or Fixture level impression copings (Nobel Biocare AB) with stainless-steel bars and a low contraction acrylic (Pattern Resin GC Co, Alsip, IL, USA). The second step was the impression itself using customized open trays and addition silicones of two different consistencies (Light Body and Putty soft fast setting; Zhermack Co, Rovigo, Italy) (Fig. 6).

The dental laboratory needed to respect some aspects prior to start the prosthetic fabrication protocol, such as: a correct mounting on the articulator and cross-linking of the models (ensuring the maintenance of the vertical dimension and inter-arch/inter-dental relation); a new provisional acrylic implant supported fixed prosthesis (Fig. 7); and a correct abutment study (corresponding to the teeth arrangement on the provisional implant supported fixed prosthesis, allowing a good prosthetic screw exit position).

All the implant supported fixed prosthesis included in this study were fabricated following the same protocol:

First, an acrylic screw retained duplicate of the provisional implant supported fixed prosthesis was done over the definitive model in order to plan the future titanium infrastructure. This acrylic duplicate was trimmed tooth-by-tooth achieving therefore the 12 to 14 individual preparations that accommodated the correspondent Procera ceramic crowns (Nobel Biocare AB) (Fig. 8). After the trimming was finished, the acrylic duplicate was ready to be read by the Procera software (Nobel Biocare AB) and consequently, transfered digitally all the information for the titanium infrastructure fabrication, aiming at an accurate and consistent passive fit.

Once the titanium infrastructure was received, the next step focused on the Procera crowns: After a silicone impression of the preparations / infrastructure, the laboratory asked for the individual Procera copings. In some situations in which there was a lack of support, a customized waxing of the future coping was done together with a double-scanning using the Procera software.

The ceramic was applied individually over each coping (for the development group: Triceram Esprident GmbH, Inspringen, Germany; and Duceratin, Ducera Dental, Rosbach, Germany; for the routine group: Nobel Rondo Zirconia Ceramic, Nobel Biocare). Every tooth form, size, volume and all other aspects related to the set-up respected the model of the

provisional and the silicone matrix that have been performed previously (this silicone matrix allowed a double evaluation of the positioning of the incisal edges, buccal aspects of each crown, and inter-dental relation on an inner and inter-arch base).

Finally, after all the crowns were glazed, the implant supported fixed prosthesis was completed (Fig. 9). The crowns were cemented over the preparations using a definitive cement (Fig. 10), the screws' access holes were opened and the customized acrylic gingiva (Unifast TRAD, GC Co, Tokyo, Japan) (the shade guide has 6 different types of colour) was applied around the crowns and underneath the infrastructure, polymerized over pressure and under a temperature controlled environment in order to achieve a compression of the natural tissues in a similar way as the provisional implant supported fixed prosthesis (Fig. 11).

For the routine group, all the implant supported fixed prosthesis were placed without try-ins or any other type of extra visits apart from the final connection of the prosthesis (Fig. 12). All the prosthetic screws were given a final torque of 15N/cm, the prosthetic screw access holes were sealed using cotton pellets and composite material (Fig. 13) and the occlusion was evaluated respecting the following patterns: canine guidance on lateral eccentric movements, incisive guidance on protrusive movements and balanced contacts in maximum inter-cuspidation (Fig. 14). The follow-up examinations were scheduled at the connection of the prosthesis and after 2 and 6 months, 1 year and thereafter each year.

The following complication parameters were assessed: Mechanical complications: fracture or loosening of mechanical and prosthetic components, lack of passive fit; Biological complications: soft tissue inflammation, fistula formation, pain or peri-implant pathology; Aesthetic complications: aesthetic complaints of the patient or dentist; Functional complications:

phonetic complains, masticatory complains and comfort complains; and Oral hygiene complications: low levels of oral hygiene.

The survival estimate was calculated on patient level through the Kaplan-Meyer product limit estimator with 95% Confidence Intervals (CI) with comparison of survival between development and routine groups through complementary statistics (Tarone-Ware).

The difference in the incidence of mechanical complications between the development and routine groups was investigated through the Pearson Chi-square test.

The association between the variables "opposing dentition", "crown perforation" and the outcome variable "incidence of fractured crowns" was evaluated by unconditional logistic regression to estimate odds ratios (ORs) and corresponding 95% confidence intervals (CIs). The effect of each variable was assessed both in univariate (crude) analysis and after adjustment for the other variables of interest. The level of significance considered was 5%.

RESULTS

Twelve patients were lost to follow-up during the completion of this study, representing 11% of the sample size.

The overall survival rate of the implant supported fixed prosthesis were 96% (at 10 years of follow-up), with 92.4% (at 10 years of follow-up) and 100% (at 5 years of follow-up) for the development and routine groups, respectively (Kaplan-Meyer) (Table II and III; Fig. 15), with no significant difference between both groups (p=0.163). On the development group, 5 prostheses were replaced by all-acrylic prosthesis due to recurrent crown fractures. The overall survival estimate for the implant supported fixed prosthesis was 120.9 months 95% CI: 115.5–126.3 months (maximum follow-up registered was 127 months).

The difference between both groups regarding the incidence of mechanical complications was significant (development group: 29 incidences; routine group: 15 incidences; p=0.04).

The incidence of complications registered in the development group was: Mechanical complications: occurred in 29 prosthesis, ranging from crown fracture (28 in 29 prosthesis between 1 month and 91 months of follow-up; anterior crowns- 15 prosthesis; posterior crowns- 15 prosthesis; anterior and posterior crowns-5 prosthesis), abutment loosening (2 in 29 prosthesis) and chipping of the ceramic gingiva (2 in 29 prosthesis). In 2 patients, more than one incidence of mechanical complications occurred. At patient level, from the 29 prosthesis that were diagnosed with crown fractures, 24 had a metal ceramic implant supported fixed prosthesis as opposing dentition. The logistic regression (Table IV) presents the OR with 95% CI for the effect of the opposing dentition (ceramic vs. acrylic) and the crown status (perforated crowns vs. non-perforated crowns) in the incidence of mechanical complications. In univariate analysis, significant differences were found for opposing dentition (OR= 2.0), which remained significant after adjusting for the crown perforation, representing a possible risk factor for the incidence of mechanical complications (OR=1.97) (Table IV).

Regarding the routine group, the incidence of mechanical complications occurred in 15 patients, consisting of crown fractures (between 4 months and 54 months of follow-up; anterior- 8 prosthesis; posterior- 2 prosthesis; anterior and posterior crowns-2 prosthesis); abutment loosening (1 patient) and abutment substitution (1 patient).

In the logistic regression analysis to assess the effect of the variables “opposing dentition” (ceramic vs. acrylic) and the “crown status” (perforated crowns vs. non-perforated crowns) in the incidence of mechanical complications, the univariate analysis revealed no significant effects for

opposing dentition or perforation status, which remained non significant when both variables were included in the model (Table IV).

For both groups, the ceramic fractures that implicated removing the crown were repaired immediately in the mouth by the Dentist with a provisional crown, and later a ceramic crown was manufactured and cemented. The Procera software saves the files of previous scanned dyes, making it possible to produce a new coping with the exact same characteristics. The implant supported fixed prosthesis were never removed from the mouth nor baked again during this process. The repairing process ended with the manufacture of a night-guard. The abutment loosening was solved by adjusting the patients' occlusion and manufacturing an occlusal night-guard.

The chipping of the ceramic gingiva (that created a gap on the affected prosthesis) was repaired by the clinician using a special pink-colored resin composite (Gradia Gum, GC Company, Japan). No further mechanical complications were registered during the follow-up of this study.

The incidence of biological complications registered in the development group occurred in 18 patients, ranging from peri-implant pathology (9 patients), soft tissue inflammation (6 patients), and implant loss (2 patients). The peri-implant pockets were solved through non-surgical therapy (removal of the superstructure, mechanical debridement and pocket irrigation with a chlorhexidine gel- in 5 patients) and surgical therapy (open flap debridement and soft tissue repositioning- 1 patient); while 2 patients were waiting for the outcome of the interventions (1 non-surgical and 1 surgical interventions). In 1 patient the situation led to the loss of the implants and suprastructure, with a new prosthesis manufactured to connect to both the remaining

implants and the new implants inserted. In another patient that lost implants the prostheses was attached to the remaining implants without further insertion of implants.

The incidence of biological complications registered in the routine group occurred in 15 patients, ranging from peri-implant pathology (10 patients) to soft tissue inflammation (5 patients). The peri-implant pockets were solved through non-surgical therapy (10 patients) as described in the development group. No implants were lost after the connection of the Metal-ceramic bridges in the routine group.

Oral hygiene complications: Apart from the cases of peri-implant pathology, poor oral hygiene and soft tissue inflammation was diagnosed in another 6 patients of the development group and 5 patients in the routine group. These patients received mechanical debridement and chemical therapy (chlorhexidine) together with reinforcement of the oral hygiene recommendations.

Common to all therapeutics for solving the biological complications was the possibility to remove and reconnect the prosthesis (retrievability of the prosthesis), possible due to the existing screw access holes in the definitive crowns.

No functional, aesthetic or oral hygiene complications were registered during the follow-up of this study both in the development and routine groups.

DISCUSSION

The survival of the structures in the both the development and routine groups are comparable to other implant frameworks used in the rehabilitation of complete edentulous arches, [33-38] supporting the research hypothesis. The lower survival rate achieved in the development group is related to the incidence of mechanical complications (most of them crown fractures). This finding influenced the treatment planning in the routine group, where with the

introduction of zirconia crowns, adjusting the occlusion and controlling for the possible effect of the opposing dentition (a metal-acrylic or an all-acrylic and not metal-ceramic implant supported fixed prosthesis), led to a decrease in the number or fractures occurred and therefore to a higher survival rate. It was possible to identify the absence of a negative effect of perforating the crowns on the outcome of the rehabilitations. It is important to stress the importance of this finding for the field of prosthetic rehabilitation, in order to maximize the probability of success. The survival of the crowns can be compared with other reports on all ceramic crowns that analyzed survival in the medium and long-term.[21,32] The concept's independence from technique sensitivity (allowing a standardized production), accounts for a higher probability of success and increased predictability in the clinical setting [18] with consistent reliability.

The excellent precision of fit in these rehabilitations is related to the welded titanium framework used in this concept, achieving superior results when compared to the frameworks made with cast gold-alloy as previously reported.[27] By using all-ceramic crowns with Procera laminates, a superior aesthetical level can be achieved with this concept when compared to the metal-ceramic crowns.[30,31] The ceramic fractures occurred were easily repaired due to the concepts flexibility. Those fractures that implicated removal of the crown where repaired immediately in the mouth by the Dentist with a provisional acrylic crown and later a ceramic crown was made and cemented. The Procera software saves the files of previous scanned dyes, making it easy to manufacture a new coping. The prosthesis were never removed from the mouth due to ceramic fractures and most important, not baked again, which would have bring negative consequences for the ceramic. Also, this capacity of repair demonstrated by the structure was an important factor for the patient, as the protocol applied assured a rapid and comfortable repairing, superior to both titanium-ceramic, and gold-ceramic conventional structures.

The method for repairing the chipping of the ceramic gingiva (that created a gap on the affected prosthesis) using a special pink-colored resin composite (Gradia Gum, GC Co) is not satisfactory in terms of longevity, and future research should focus on better methods to resolve these problems.

The necessity of removing the structure due to inflammation of the soft tissue or hygienic reasons further expresses the need for easy retrievability of these structures, creating an easier access to the implants for accurate diagnosis or therapeutic interventions.

The fact that no equal prostheses were manufactured, as each one was different from each other, allowed for customization without loosing the advantage of a standardized production.

The limitations of the study are related to only 1 clinic being involved, the shorter follow-up time of the routine group, and the lack of randomization. The methodology implemented with a development and a routine group, was integrated in a concept of rehabilitation with several phases of conception, experiment, evaluation, re-conception and re-experiment, allowing the second generation protocol to perform better than the first generation protocol, judging by the survival estimate in the first 5 years of function.

The twelve patients lost to follow-up (11% of the sample) account for good methodological quality of the study, representing less than 20% of the sample size,[39] and this way reducing the probability of bias.

Future research should focus on the documentation of the routine group protocol with a follow-up of 10 years.

CONCLUSIONS

Within the limitations of this study, the outcome of a metal-ceramic implant supported fixed prosthesis with a titanium framework and all-ceramic crowns is valid, with a survival estimate of 96.4% overall, 92.4% for the development group at 10 years and 100% for the routine group at 5 years.

This type of structure has high aesthetics and excellent mechanical properties. The precision of fit, biocompatibility, independence from technique sensitivity (allowing a standardized production), customization, retrievability and capacity of repairing characteristics represent important advantages for achieving a successful prosthetic rehabilitation.

This type of structure should be further investigated to evaluate its survival with 10-years of follow-up using the current protocol.

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REFERENCES

1. Malo P, Rangert B, Nobre M. All-on-4 Immediate-function concept with Branemark system implants for completely edentulous mandibles: A retrospective clinical study. Clin Implant Dent Relat Res 2003;5:S2-S9.

2. Malo P, Rangert B, Nobre M. All-on-4 Immediate-function concept with Branemark system implants for complete edentulous maxillae: A 1-year retrospective clinical study. Clin Implant Dent Relat Res 2005;7:S88-S94.

3. Friberg B, Raghoebar GM, Grunert I, et al. A 5-year prospective multicenter study on 1-stage smooth-surface Brånemark System implants with early loading in edentulous mandibles. Int J Oral Maxillofac Implants 2008;23:481-6.

4. Mericske-Stern R. Prosthetic considerations. Aust Dent J 2008;53:S49-59

5. Puri S. Techniques used to fabricate all-ceramic restorations in the dental practice. Compend Contin Educ Dent 2005;26:519-25;

6. Jemt T, Petersson A. Precision of CNC-milled titanium frameworks for implant treatment in the edentulous jaw. Int J Prosthodont 1999;12:209-15.

7. Segal BS. Spective assessment of 546 all-ceramic anterior and posterior crowns in general practice. J Prosthet Dent 2001;85:544-50.

8. Craig RG, Hanks CT. Cytotoxicity of experimental casting alloys evaluated by cell culture tests. J Dent Res 1990;69:1539-1542.

9. Kansu G, Aydin AK. Evaluation of the biocompatibility of various dental alloys: Part I--Toxic potentials. Eur J Prosthodont Restor Dent 1996;4:129-36.

10. Ortorp A, Jemt T, Clinical experiences of CNC-milled titanium frameworks supported by implants in the edentulous jaw: 1-year prospective study. Clin Implant Dent Relat Res 2000;2:2-.

11. Ortorp A, Jemt T. Clinical experience of CNC-milled titanium frameworks supported by implants in the edentulous jaw: a 3-year interim report. Clin Implant Dent Relat Res 2002;4:104-9.

12. Carr AB, Stewart RB. Full-arch implant framework casting accuracy: preliminary in vitro observation for in vivo testing. J Prosthodont 1993;2:2-8.

13. Tan KB, Rubenstein JB, Nicholls JL, et al. Three-dimensional analysis of the casting accuracy of one-piece, osseointegrated implant-retained prostheses. Int J Prosthodont 1993;6:346-63.

14. Jemt T, Lie A. Accuracy of implant-supported prostheses in the edentulous jaw: analysis of precision of fit between cast gold-alloy frameworks and master casts by means of a three-dimensional photogrammetric technique. Clin Oral Implants Res 1995;6:172-80.

15. Hobo, Summiya and Ichida, Eiji and Garcia, Lily T. Osseointegration and Occlusal Rehabilitation. Chicago: Quintessence; 1989. p. 176.

16. Klineberg IJ, Murray GM. Design of superstructures for osseointegrated fixtures. Swed Dent J 1985;28:S63-S69.

17. Parel S. Modified casting technique for osseointegrated fixed prosthesis fabrication: a preliminary report. Int J Oral Maxillofac Implants 1989;4:33-40.

18. Cho CG, Donovan TE. Rational use of contemporary all-ceramic crown systems. J Cal Dent Assoc 1998;2:1-11.

19. Yanikoglu N. The repair methods for fractured metal-porcelain restorations: a review of the literature. Eur J Prosthodont Restor Dent 2004;12:161-5.

20. Suansuwan N, Swain MV. New approach for evaluating metal-porcelain interfacial bonding. Int J Prosthodont 1999;12:547-52.

21. Fradeani M, D'Amelio M, Redemagni M, et al. Five-year follow-up with Procera all-ceramic crowns. Quintessence Int 2005;36:105-13.

22. Lang BR, Malo P, Guedes CM, et al. Procera All Ceram Bridge. Appl Osseointegration Res 2004;4:13-21.

23. Ödman P, Andersson B. Procera AllCeram crowns followed for 5 to 10.5 years: a prospective clinical study. Int J Prosthodont 2001;14:504-9.

24. Sundh B, Köhler B. An in vivo study of the impact of different emergence profiles of procera titanium crowns on quantity and quality of plaque. Int J Prosthodont 2002;15:457-60.

25. Koksal T, Dikbas I. Color stability of different denture teeth materials against various staining agents. Dent Mater J 2008;27:139-44.

26. Graha L. The essence of restorative care: long-term tooth preservation. Compend Contin Educ Dent 2005;26:S28-S33.

27. Takahashi T, Gunne J. Fit of implant frameworks: an in vitro comparison between two fabrication techniques. J Prosthet Dent 2003;89:256-60.

28. Hegenbarth E. Quintessence Dental Technology. Chicago: Quintessence; 1996. p. 23-34.

29. Andersson M, Razzoog ME, Oden A, et al. Procera: a new way to achieve an All-Ceramic crown. Quintessence Int 1998;29:285-296.

30. Hager B, Oden A, Andersson B, et al. Procera AllCeram laminates: a clinical report. J Prosthet Dent 2001;85:231-2.

31. Chu FC, Andersson B, Deng FL, et al. Making porcelain veneers with the Procera AllCeram system: case studies. Dent Update 2003;30:454-8, 460.

32. Zarone F, Sorrentino R, Vaccaro F, et al. Retrospective clinical evaluation of 86 Procera AllCeram™ anterior crowns on natural and implant-supported abutments. Clin Implant Dent Relat Res 2005;7:S95-S103.

33. Parel SM. The single-piece milled titanium implant bridge. Dent Today 2003;22:96-9.

34. Jemt T, Bergendal B, Arvidson K, et al. Implant-supported welded titanium frameworks in the edentulous maxilla: a 5-year prospective multicenter study. International Journal of Prosthodontics 2002, 15:544-8.

35. Jemt T, Johansson J. Implant treatment in the edentulous maxillae: a 15-year follow-up study on 76 consecutive patients provided with fixed prostheses. Clinical Implant Dentistry and Related Research 2006; 8:61-9.

36. Ortorp A, Jemt T. Early laser-welded titanium frameworks supported by implants in the edentulous mandible: a 15-year comparative follow-up study. Clinical Implant Dentistry and Related Research 2009; 11:311-22.

37. Gualini F, Gualini G, Cominelli R, et al. Outcome of Branemark Novum implant treatment in edentulous mandibles: a retrospective 5-year follow-up study. Clinical Implant Dentistry and Related Research 2009; 11:330-7.

38. Lambert FE, Weber HP, Susarla SM, et al. Descriptive analysis of implant and prosthodontic survival rates with fixed implant-supported rehabilitations in the edentulous maxilla. Journal of Periodontology 2009; 80:1220-30.

39. NCBI » Bookshelf » U.S. Preventive Services Task Force Evidence Syntheses, formerly Systematic Evidence Reviews » Screening for Human Immunodeficiency Virus »Appendix 1. Quality Rating Criteria.

http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=es46&part=A34812. Assessed on November 2nd 2010.

40. Baba K, Tsukiyama Y, Clark GT. Reliability, validity, and utility of various occlusal measurement methods and techniques. J Prosthet Dent 2000;83:83-9.

TABLES

Table I. Edentulous rehabilitation planning protocol

Variable	Procedure
Occlusal Vertical Dimension (OVD)	Willis aesthetic method and Thompson functional method [40]
Lip Support (LS)	Upper lip retraction to the base of the nose in the sagital plan. Severity of wrinkled appearance.
Smile Line (SL)	Digital photograph registration of visible natural gingival level without removable prosthesis in maximum smile
Arch relation	Patient arch relation was classified according Kennedy classification. Vertical and horizontal overlap
Occlusion	Canine protected vs, group function Presence of occlusal prematurities and interferences
Harmony and esthetics of the complete arch prosthesis	Shade and shape of the prosthetic teeth, artificial gingiva, papilla occlusal plane/compensating curve and esthetic harmony selected according to the patients' demands and esthetics of face.

Table II: Estimated fractions for survival using the Kaplan-Meier product limit estimator for the prostheses in the development group

Time (months)	Status (0=non failure; 1=failure)	Cumulative Proportion Surviving at the Time		N of Cumulative Events	N of prostheses at risk
		Estimate	Std. Error		
0	0	.	.	0	66
12	0	.	.	0	64
13	1	,984	,016.	1	63
24	0	.	.	1	63
30	1	,968	,022	2	61
36	0	.	.	2	60
48	0	.	.	2	57
53	1	,952	,027	3	56
60	0	.	.	3	52
72	0	.	.	1	45
73	1	,930	,034	4	44
84	0	.	.	4	22
89	1	,883	,056	5	19
96	0	.	.	5	11
108	0	.	.	5	3
120	0	.	.	5	2
122	0	.	.	5	1
127	0	.	.	5	0

Table III: Estimated fractions for survival using the Kaplan-Meier product limit estimator for the prostheses in the routine group

Time (months)	Status (0=non failure; 1=failure)	Cumulative Proportion Surviving at the Time		N of Cumulative Events	N of prostheses at risk
		Estimate	Std. Error		
0	0	.	.	0	59
12	0	.	.	0	59
24	0	.	.	0	56
36	0	.	.	0	52
48	0	.	.	0	25
60	0	.	.	0	4
61	0	.	.	0	2
62	0	.	.	0	1
67	0	.	.	0	0

Table IV. Odds ratio (OR) with 95% confidence intervals (CI) for opposing dentition and crown status

Development group						
Factor	OR	Sig.	95% CI	OR¥	Sig.	95%CI
Opposing dentition						
Acrylic	1.0					
Ceramic	2.04	0.01	1.18-3.54	1.97	0.016	1.14-3.43
Crown status						
Not perforated	1.0					
Perforated	1.53	0.100	0.92-2.54	1.45	0.156	0.87-2.41
Routine group						
Factor	OR	Sig.	95% CI	OR¥	Sig.	95%CI
Opposing dentition						
Acrylic	1.0					
Ceramic	0.36	0.163	0.08-1.52	0.36	0.165	0.08-1.53
Crown status						
Not perforated	1.0					
Perforated	1.65	0.204	0.76-3.59	1.65	0.207	0.76-3.59

¥ OR from logistic regression analysis with opposing dentition and crown status included as explanatory variables.

In the Development group, the univariate and analysis disclosed a significant effect for opposing dentition as a risk factor for the incidence of mechanical complications, which remained significant after adjusting for crown status effect.

In the Routine group, no relevant effects were found in the univariate or adjusted analysis, meaning that variable (opposing dentition or crown status) had a relevant effect in the model.

ACKNOWLEDGEMENTS

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FIGURE LEGENDS

Fig. 1. Preoperative extra oral view.

Fig. 2. Preoperative intraoral view.

Fig. 3. Immediate provisional implant supported fixed prosthesis.

Fig. 4. Impression at abutment or implant level.

Fig. 5A. Intra-oral photograph with occlusal view of the rehabilitation. In order to adapt the prosthesis aesthetical and functionally to the patients, the anatomy needs to be taken into consideration. Note the concavities marked by the arrows

Fig. 5B. Aesthetical and functional adaptation of the prosthesis to the patients' anatomy achieved through a compressive contact with natural tissues. This is achieved by creating convex points to adapt to the concavities identified in the patients' anatomy.

Fig. 6. Impression using customized open tray and addition silicone. Multi-unit impression copings are splinted together with stainless-steel bars and low contraction acrylic.

Fig. 7. New provisional acrylic implant supported fixed prosthesis.

Fig. 8. Production of titanium infrastructure. A: Rough titanium infrastructure; B: Acrylic duplicate prepared to be scanned; C: titanium infrastructure finished and polished.

Fig. 9. Procera crowns are manufactured according to provisional prosthesis and dentist specifications.

Fig. 10. Crowns are cemented to structure extra-orally.

Fig. 11. Metal-ceramic implant supported fixed prosthesis with individual Procera crowns and customized gingiva over titanium CAD-CAMM structure. Intra oral view.

Fig. 12. Extra-oral photography of patient smiling. Same patient as in Figure 11.

Fig. 13. Occlusal view of the prosthesis. Same patient as in Figures 11 and 12.

Fig. 14. Intra-oral view of the maxillary prosthesis at maximum inter-cuspidation. Same patient as in Figures 11 to 13.

Fig. 15. Implant supported fixed prosthesis survival at patient level using Kaplan-Meier product limit estimator.

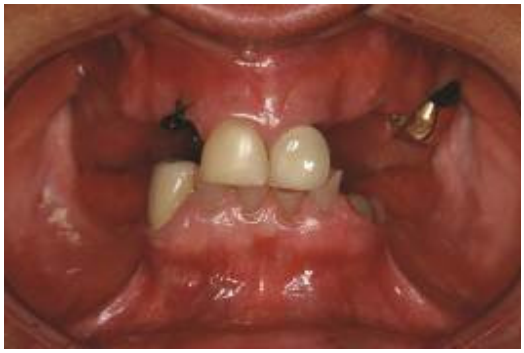


Figure 1

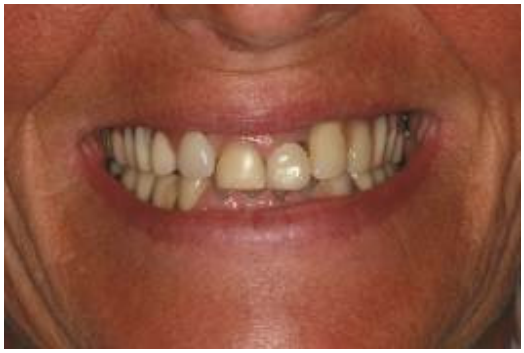
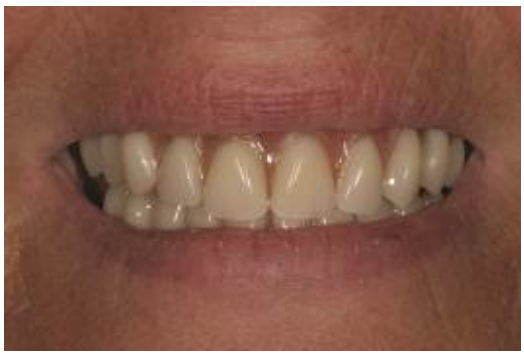


Figure 2



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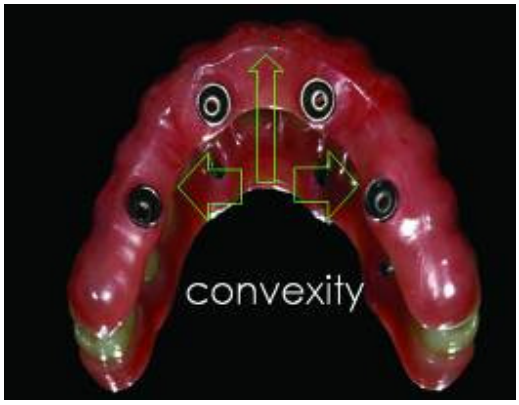


Figure 4

Figure 5a

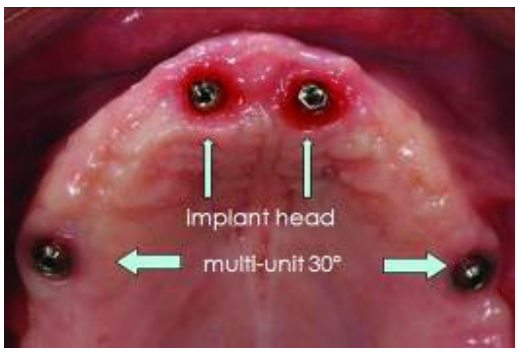
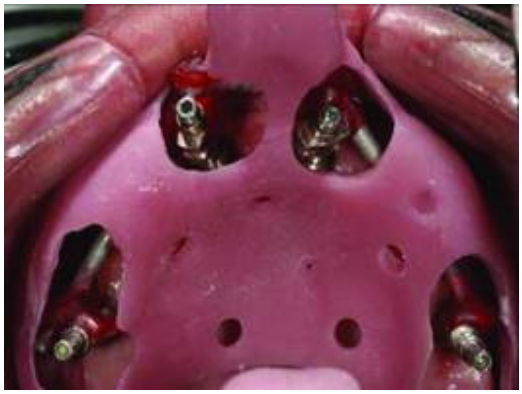


Figure 5b



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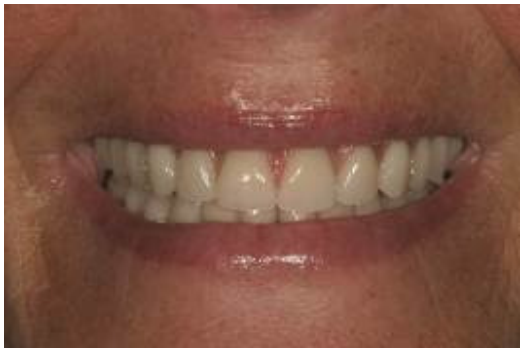

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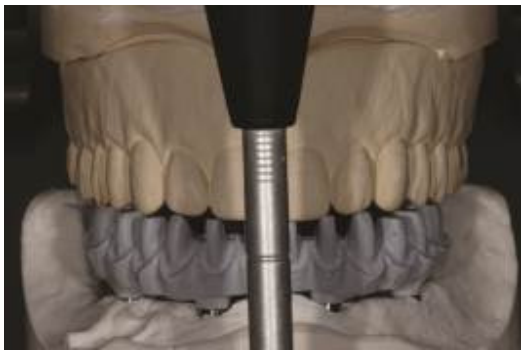
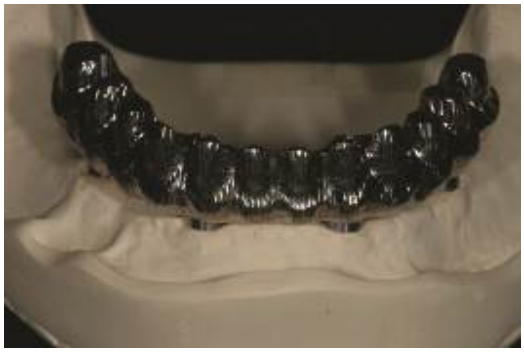


Figure 8A



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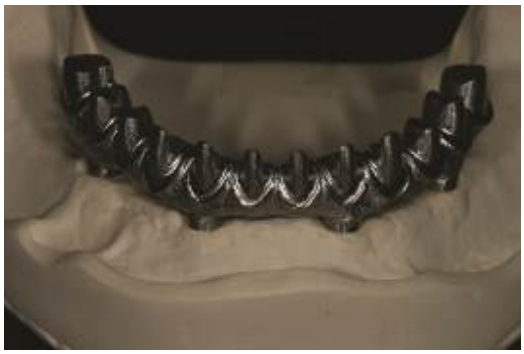

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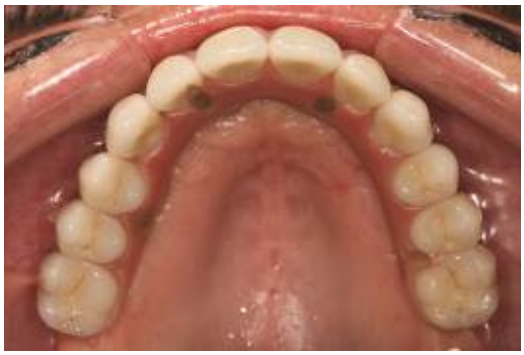

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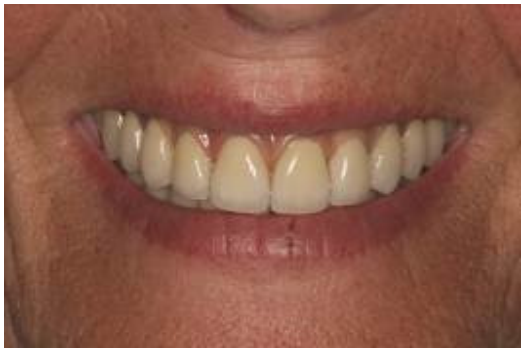
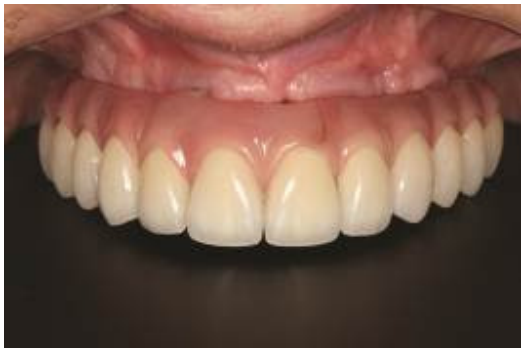


Figure 10



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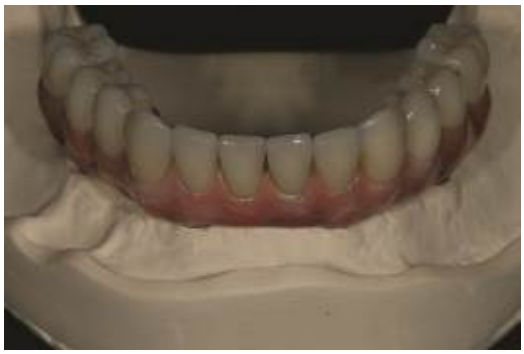

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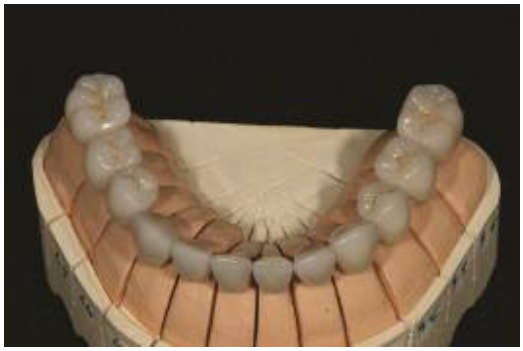

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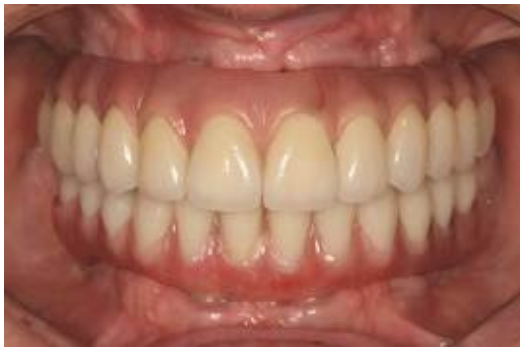

Figure 14

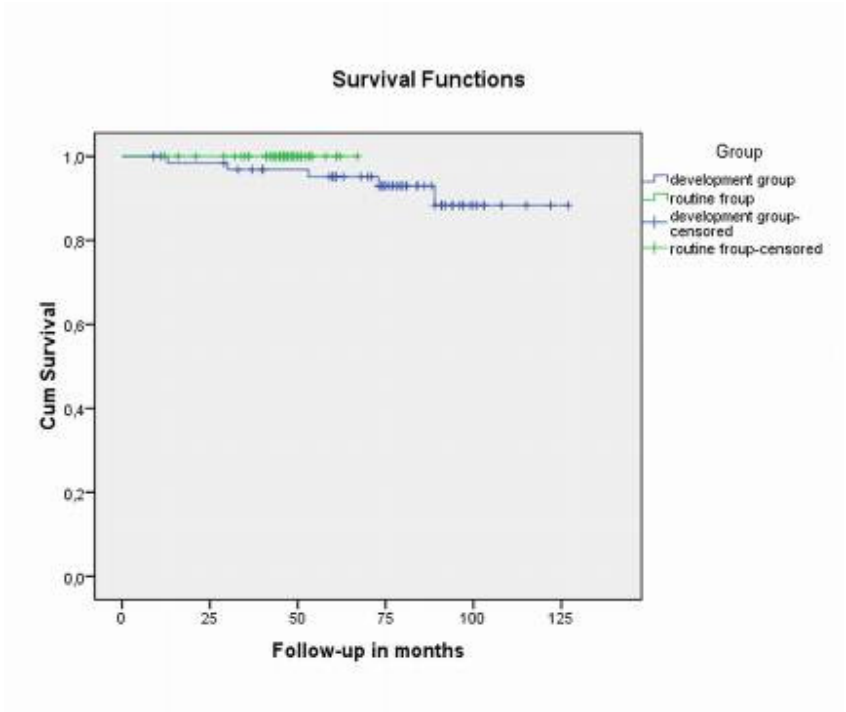

Figure 15