Esthetic outcome of two different veneering procedures based on zirconia implant abutments – 1-year follow-up of a randomized controlled clinical trial

GAVRIC, Jelena

Abstract
Comparaison des performances cliniques et esthétiques de couronnes implantaires maxillaires antérieures basées, soit sur un pilier préfabriqué en zircone sur lequel la céramique cosmétique est pressée (groupe test), soit sur un pilier individualisé (CAD/CAM) sur lequel le cosmétique est stratifié (contrôle). 20 patients avec implant et couronne provisoire ont été recrutés et randomisés après empreinte définitive. Une semaine après insertion des couronnes définitives, des paramètres cliniques, radiographiques et esthétiques ont été enregistrés et puis réévalués pour les deux groupes après une année. Les paramètres examinés n’ont pas montré de différences statistiquement significatives entre les deux modalités de fabrication. En revanche, l’analyse du temps de fabrication des couronnes s’est avérée différente entre les groupes, clairement moins importante pour le groupe test. Il a été démontré que les deux approches atteignent un bon niveau esthétique, mais sont significativement différentes quant à leur complexité, leur temps de fabrication et en conséquence, leur coûts.

Reference

URN : urn:nbn:ch:unige-390220
DOI : 10.13097/archive-ouverte/unige:39022

Available at:
http://archive-ouverte.unige.ch/unige:39022

Disclaimer: layout of this document may differ from the published version.
Esthetic outcome of two different veneering procedures based on zirconia implant abutments – 1-year follow-up of a randomized controlled clinical trial

Thèse
présentée à la Faculté de Médecine
de l'Université de Genève
pour obtenir le grade de Docteur en Médecine Dentaire
par

Jelena GAVRIC

de
Wallisellen (ZH)

Thèse n°

Genève
2014
Remerciement

Mes premiers remerciements vont au Prof. Urs Belser qui m'a fait l'honneur de présider ce travail de thèse, pour sa disponibilité et ses encouragements qui m'ont motivée, ses qualités pédagogiques et scientifiques, sa franchise et sa sympathie tout au long de ce travail de recherche.

Je désire également remercier :

Le Prof. Irena Sailer pour ses remarques pertinentes et son ouverture d'esprit lors de la phase terminale de la rédaction de la thèse.

Le Dr Julia Wittneben-Matter pour son implication dans l'étude. Elle m'a donné des conseils avisés et a été une grande ressource pour le développement de cette thèse.

Le Dr Michael Bornstein pour son aide précieuse sur le plan de l'analyse statistique.

Un grand merci :

Au Dr Linda Grütter, Léo Brazzola, Dr Christian Robin et Dr Philippe Mojon d'avoir partagé leurs idées, ainsi que pour leur soutien et leur gentillesse.

Au Dr Anja Zembic pour ses implications dans le projet, notamment sur le plan de l'analyse radiologique.

A Mr Dominique Vinci pour ses superbes travaux de laboratoire odonto-technique.

A tous les collaborateurs de la Division de Prothèse fixe et Biomatériaux pour leur collégialité ainsi que pour l'excellente ambiance de travail qui y règne.

«Last but not least» je tiens à remercier ma famille et mes proches pour leur encouragement constant et leur soutien tout au long de la thèse.
TABLE DES MATIÈRES / TABLE OF CONTENTS

1. PARTIE FRANÇAISE .............................................................................................................................. 4
   1.1 RÉSUMÉ ETENDU .......................................................................................................................... 4
       1.1.1 Introduction ........................................................................................................................... 4
       1.1.2 Objectif ................................................................................................................................ 5
       1.1.3 Matériels et Méthodes .......................................................................................................... 6
       1.1.4 Résultats ............................................................................................................................... 8
       1.1.5 Discussion ............................................................................................................................ 10
       1.1.6 Conclusions .......................................................................................................................... 11

2. ENGLISH PART .................................................................................................................................. 13
   2.1 ABSTRACT ..................................................................................................................................... 13
       2.1.1 Objectives .............................................................................................................................. 13
       2.1.2 Material and Methods ........................................................................................................ 13
       2.1.3 Results .................................................................................................................................. 14
       2.1.4 Conclusions .......................................................................................................................... 15

   2.2 INTRODUCTION ......................................................................................................................... 16

   2.3 MATERIAL AND METHODS ...................................................................................................... 21
       2.3.1 Study Design ........................................................................................................................ 21
       2.3.2 Study Objectives .................................................................................................................. 21
       2.3.3 Study Population and Randomization .................................................................................. 22
       2.3.4 Inclusion Criteria ................................................................................................................ 23
       2.3.5 Exclusion Criteria ................................................................................................................ 24
       2.3.6 Clinical Examination ......................................................................................................... 26
       2.3.7 Time Analysis ....................................................................................................................... 29
       2.3.8 Subjective Measurements ...................................................................................................... 29
       2.3.9 Statistics ................................................................................................................................ 30

   2.4 RESULTS ..................................................................................................................................... 31
       2.4.1 Esthetic Parameters: PES/WES ............................................................................................ 31
       2.4.2 Cast Analyses ........................................................................................................................ 32
       2.4.3 Presence / Absence of Technical / Mechanical Complications ......................................... 32
       2.4.4 Radiographic Findings / DIB Values .................................................................................... 33
       2.4.5 Analysis of the Fabrication Time (in minutes) of the Restorations ........................................ 33
       2.4.6 Questionnaires / VAS .......................................................................................................... 34

   2.5 DISCUSSION .................................................................................................................................. 35
       2.5.1 Time / Effectiveness Analysis ............................................................................................... 41

   2.6 CONCLUSIONS ............................................................................................................................. 44

3. REFERENCES ....................................................................................................................................... 45

4. ANNEXES .......................................................................................................................................... 53
1. PARTIE FRANÇAISE

1.1 RÉSUMÉ ETENDU

1.1.1 Introduction

Après plus de trois décennies d’utilisation clinique chez des patients partiellement édentés, les implants dentaires sont actuellement une option de traitement largement acceptée pour remplacer les dents manquantes. Le taux élevé de succès et de fiabilité de cette modalité thérapeutique a motivé les chercheurs et les fabricants à proposer des protocoles de traitement plus innovants et accessibles pour un grand nombre de patients, tout en maintenant un résultat de traitement prédictible. Le pilier implantaire, qui représente la partie intermédiaire entre l’implant et la couronne dentaire artificielle, a ainsi connu récemment des évolutions marquées tant dans le dessin de la pièce que dans le matériau utilisé. Le titane reste actuellement le matériau standard utilisé, notamment parce qu’il a d’excellentes propriétés physiques et biologiques (Andersson et al. 1995, Andersson et al. 1998). Cependant, les piliers en titane, caractérisés par une couleur gris foncée, peuvent donner une apparence grisâtre à la muqueuse péri-implantaire vestibulaire, particulièrement en présence d’un biotype gingival fin (Jemt 1987; Yildrim et al. 2000; Henrikson & Jemt 2003; Jung et al. 2007; Park et al. 2007). Dans ce contexte, des piliers implantaires en zircone de couleur claire ont récemment été développés afin d’apporter une solution à ce problème. Selon d’études préliminaires, ces piliers démontrent une excellente biocompatibilité, tout en pouvant améliorer sensiblement le résultat esthétique. En revanche, leur
stabilité mécanique à long terme en milieu clinique reste à être confirmée. Sur le plan pratique, plusieurs méthodes de fabrication de couronnes implantaires basées sur des piliers zircone ont été proposées, qui varient sur le plan de leur complexité intrinsèque de mise en œuvre, de leur temps de fabrication, ainsi que de leur coût.

À ce jour, aucune étude a comparé directement la performance clinique et esthétique de deux des méthodes les plus prometteuses de réalisation d'une couronne implantaire unitaire dans le secteur maxillaire antérieur, à savoir l'utilisation, soit d'un pilier zircone préfabriqué, soit d'un pilier zircone généré par technique « conception et fabrication assistées par ordinateur (CAO / FAO) ».

1.1.2 Objectif

Le but de cette étude randomisée et contrôlée était d'évaluer et comparer la performance clinique en général et le résultat esthétique en particulier de deux différents types de couronnes céramiques unitaires implanto-portées, situées dans la région maxillaire antérieure. Le premier type de couronne était basé sur un pilier préfabriqué en zircone sur lequel la majeure partie de la céramique cosmétique avait été appliquée par technique pressée, puis complétée par une stratification superficielle individualisée (groupe test). Le deuxième type, correspondant au «gold standard», était basé sur un pilier zircone individualisé, conçu et usiné par technique assistée par ordinateur (CAO / FAO) sur lequel la totalité de la céramique cosmétique avait été stratifiée de manière traditionnelle (groupe contrôle). L'hypothèse de travail à vérifier stipulait qu'on ne pourra pas mettre en évidence de différences statistiquement significatives entre les deux
types de couronnes implantaires en ce qui concerne leurs performances cliniques et esthétiques.

1.1.3 Matériels et Méthodes

Vingt et un patients porteurs d’un implant dentaire du type «bone level implant» (BLI Ø 4.1 mm, Regular CrossFit [RC] connection, longueur 8, 10 ou 12 mm, Institut Straumann S.A., Bâle, Suisse) au niveau maxillaire antérieur, restauré d’une couronne provisoire vissée, ont été recrutés, après prise d’empreinte définitive, selon des critères d’inclusion prédéterminés. L’attribution à l’un ou l’autre des deux groupes a été effectuée par méthode de randomisation, afin de minimiser tout risque de bias. Par la suite, chaque implant a été équipé d’une couronne définitive vissée, confectionnée soit sur un pilier zircone IPS anatomique préfabriqué («pre-fabricated abutment» PFA couleur M1, droit) en utilisant le procédé d’application du cosmétique par pressage (fluor vitrocéramique apatite, IPS e.max ZirPress) et la technique du «cut-back» (groupe test), soit sur un pilier zircone individualisé (pilier CAO / FAO) sur lequel la méthode traditionnelle de stratification cosmétique (céramique nano-fluoro apatite, IPS e.max Ceram) était utilisée (groupe contrôle).

Une semaine après la mise en bouche des couronnes («baseline appointment»), ainsi qu’après 6 et 12 mois, la documentation suivante a été effectuée :

- les paramètres péri-implantaires standard, enregistrés aux quatre faces des implants, à savoir l’indice gingival modifié (mod GI), l’indice de plaque modifié (mod Pl), la profondeur de sondage (PD), ainsi que le saignement après sondage (BOP) ;
• une radiographie apicale standardisée de l’implant, permettant de mesurer aux niveaux mesial et distal la distance entre l’épaule de l’implant et le premier contact osseux (DIB value) ;
• l’enregistrement des contacts occlusaux en intercuspidation maximale (IM) et lors des excursions mandibulaires, selon les critères suivants : absence de contact, contact léger ou contact fort (évalué avec le shimstock 8μ);
• des photographies intra-orales standardisées ;
• des modèles d’études supérieurs et inférieurs ;
• l’enregistrement des complications mécaniques d’après Salvi et Brägger (2009) ;
• l’analyse du temps de fabrication des couronnes définitives.

Par la suite, le taux de survie et de succès des implants a été établi d’après Buser et al. (1991).
A l’aide des photographies intra-buccales et des moulages, les paramètres esthétiques objectifs «pink esthetic score / white esthetic score» (PES / WES) ont été calculés pour les deux groupes.
De plus, un questionnaire adressant le degré de satisfaction générale et esthétique, comprenant des «visual analogue scales» (VAS), à été rempli par chaque patient, permettant de quantifier les paramètres subjectifs.
Quant au temps de fabrication lié à chacun des deux différents types de restaurations implantaires utilisés dans la présente étude, le temps total de laboratoire à partir de la conception ou de la préparation du moignon en zircone jusqu’au polissage de chaque couronne finale a été minutieusement enregistré (en minutes) par le technicien-céramiste responsable de la production de l’ensemble des couronnes.
Analyse statistique

Des méthodes d’analyse statistique standard ont été utilisées pour comparer les deux groupes. Les différents paramètres adressant les tissus mous péri-implantaires, les implants et l’apparence esthétique (PES / WES scores), ainsi que l’examen radiologique ont été analysés avec le test de Wilcoxon. Les différences entre les groupes ont été évaluées d’après les tests de Wilcoxon (signed-rank test) et de Kruskal-Wallis (rank sum test). Le niveau de signification a été fixé pour tous les tests statistiques à une valeur P ≤ 0.05. Quant à l’évaluation des différents temps de fabrication des couronnes implantaires, elle s’est faite par analyse statistique descriptive.

1.1.4 Résultats

Tous les 20 implants présentaient un bon état d’ostéointégration et correspondaient donc à un taux de survie et de succès de 100% selon des critères stricts (Buser et al. 1991).

Aucune fracture de pilier zircone n’a été enregistrée. Deux cas de léger « chipping » de la céramique cosmétique ont été observés, l’un dans le groupe test et l’autre dans le groupe contrôle. Dans le groupe test, une couronne a présenté une fracture majeure de la céramique cosmétique, ceci à cause du non-respect des critères d'inclusion. Dans ce cas particulier, le pilier préfabriqué n’offrait pas le soutien nécessaire à la céramique cosmétique avec comme conséquence une épaisseur incisale de céramique de plus de 2 mm. De plus la hauteur du pilier était inférieure au 65 % de la hauteur de la restauration complète. Une nouvelle couronne a été réalisée, et le patient a été exclu de l'étude.
Dans l'ensemble, les patients avaient une bonne hygiène buccale (mPLI moyen de 0,125), confirmé par un état sain des tissus mous péri-implantaires (mSBI moyen de 0,150) et une profondeur de sondage (PD) moyenne de 2.91 mm après un an. En comparant les groupes test et contrôle, les paramètres relatifs aux tissus mous péri-implantaires n'ont pas montré de différences statistiquement significatives pendant toute la période d'observation.

L'évaluation de la stabilité de l'os péri-implantaire a été faite sur la base des radiographies standardisées. Les valeurs DIB obtenus confirmaient un niveau de la crête osseuse mésiale et distale des implants globalement stable. En fait, les radiographies n'ont pas révélé de signes de perte osseuse péri-implantaire pendant la période d'observation. La valeur moyenne DIB pour les 20 implants était de 0,065mm.

Dans l'ensemble, aussi les résultats esthétiques étaient favorables. Les valeurs cumulatives moyennes pour PES et WES ont été de 14,7 (groupe test) et 15,0 (groupe contrôle) respectivement, ce qui n'était pas statistiquement différent. Le WES était supérieur au PES dans les deux groupes. Les paramètres de forme, volume / contour et couleur présentaient les moins bons résultats pour les deux groupes. Les paramètres de texture, surface et translucidité incisale montraient quant à eux les meilleurs résultats. Cependant, aucune différence statistiquement significative n'a été trouvée entre le groupe de test et le groupe contrôle.

Quant aux paramètres subjectifs, les réponses au questionnaire VAS n'ont montré aucune différence statistiquement significative entre les deux groupes en ce qui concerne la perception subjective du résultat esthétique.
Par contre, l'analyse du temps de fabrication a relevé des différences statistiquement significatives entre les deux groupes. Le temps moyen nécessaire à la fabrication des couronne du groupe test (pilier préformé / céramique pressée) était de 182,5 min, alors que celui du groupe contrôle (pilier CAO / FAO / céramique stratifiée) de 255 min. Plus particulièrement, le temps de modification du pilier préfabriqué dans le groupe test n’a pris que la moitié du temps de réalisation du modelage en cire et du scanning du pilier du groupe contrôle. Le temps pour la stratification dans le groupe contrôle a été nettement plus long, en comparaison avec procédures appliquées dans le groupe test (pressée de la céramique et cut back). Le temps nécessaire pour la coloration de surface, le frittage, et le polissage dans le groupe test présentait qu’un tiers de celui investi dans le groupe contrôle.

1.1.5 Discussion

Dans cette étude, aucune perte d’implant ou de pilier n’a été observée. Les 20 implants ont atteint et maintenu une bonne intégration tissulaire, comme le démontre l’analyse des paramètres cliniques et radiologiques.

Les résultats esthétiques des 20 restaurations ont été très satisfaisants comme le prouvent les scores du PES et du WES (Belser et al 2009). Aucune différence statistiquement significative n’a été observée entre le groupe test et le groupe contrôle. L’hypothèse selon laquelle aucune différence perceptible relative aux performances cliniques et esthétiques entre les deux approches ne serait observée a été donc confirmée. Toutefois, la taille de l’échantillon, relativement petite, ainsi que le temps d’observation plutôt court, doivent être évoqués parmi
les limites de cette étude. Le score moyen du WES était plus favorable que celui du PES. Cela n'est pas surprenant car l'indice WES dépend principalement de la qualité et de l'expérience du technicien dentiste, tandis que l'indice PES est lié au patient, au chirurgien, au temps et au WES (Belser et al. 2009 ; Buser et al. 2011). Toutes les 20 couronnes ont été confectionnées par un seul technicien (DV), qui a une grande expérience et qualification dans ce domaine. Cet élément a probablement contribué au fait que l'analyse des réponses par VAS quant à la perception subjective du résultat esthétique n'a montré aucune différence statistiquement significative entre les deux groupes.

1.1.6 Conclusions

L'hypothèse de départ, stipulant l'absence de différences perceptibles entre les deux approches au niveau des paramètres cliniques, ainsi que sur le plan des critères esthétiques objectifs et subjectifs a été confirmée. Il a donc été démontré que les deux modalités de fabrication de couronnes implantaires à base de moignons en zircone, permettent d'atteindre un bon niveau esthétique, tout en assurant une stabilité et un état de santé adéquat des tissus péri-implantaires durs et moux. En revanche, les deux approches étaient significativement différentes quant à leur complexité, leur temps de fabrication et en conséquence, leurs coûts. Sur le plan de l'implication clinique, les résultats de cette étude montrent que malgré une technique plus simple, plus rapide et moins chère, le résultat clinique n'en reste pas moins excellent, voir même d'un niveau comparable à celui obtenu par la technique considérée comme un «gold standard». Néanmoins, un suivi à long terme des performances cliniques des
deux modalités de fabrication de couronnes implantaires entièrement en céramique est nécessaire pour confirmer la validité des conclusions précitées.
2. ENGLISH PART

2.1 ABSTRACT

2.1.1 Objectives

To assess and compare the esthetic outcome and clinical performance of anterior maxillary all ceramic implant single crowns based either on prefabricated zirconia abutments veneered with pressed ceramics or on CAD / CAM individualized abutments veneered with hand build-up technique.

The hypothesis of this investigation was that test group (prefabricated anatomic abutment, press ceramic) and control group (individualized CAD / CAM abutment, stratified veneering ceramic) are indistinguishable when it comes to the objective / subjective comparison of esthetic integration.

2.1.2 Material and Methods

Twenty one patients who previously received a single-tooth dental implant (BLI Ø 4.1 mm, length 8,10 or 12 mm, Regular CrossFit [RC] connection, Institute Straumann, Basel, Switzerland) and a provisional directly screw-retained restoration have been recruited and randomized after final impression taking, into Group A (*IPS prefabricated anatomic abutments (PFA), color M1, straight*): one-piece screw retained single crown using a press technique (fluorapatite glass-ceramic, IPS e.max ZirPress) with cut-back technique and subsequent hand-finalizing of the veneering, or Group B (*CAD / CAM (Cares) abutments*): one-piece screw retained single crown with a hand build-up technique (fluorapatite
veneering ceramic, IPS e.max Ceram). Objective parameters were assessed one week after delivery of the final restoration (base line visit) by periodontal / peri-implant measurements, an intra-oral digital photograph (1:1 ratio), a study cast, a standardized radiograph, documentation of occlusal contacts and time-analysis of fabrication of the final implant crown. In addition, pink esthetic score (PES) and white esthetic score (WES) were calculated for both groups. For the subjective evaluation, a visual analogue scale (VAS) questionnaire was used to assess the level of patient satisfaction regarding the esthetic outcome. After 6 months and one year the previously described assessment was repeated. The patients will be followed up to 5 years after final restoration. Statistical analysis was used to compare the two groups and investigational appointments.

2.1.3 Results

Overall, no statistically significant differences were observed for the objective measurements comparing the test and control groups. Mean PES-WES values were 14.7 (test group) and 15.0 (control group), respectively. As for subjective parameters, VAS analysis of the patients’ responses regarding their perceptions of the esthetic outcome showed no statistical differences between groups and clinicians’ accuracy scores were 69.88 and 95.45 for test and control group, respectively. The time analysis revealed a significant difference concerning the mean time necessary for manufacturing the crowns. Time spent in the test group was approximately half of that used for the control group.
2.1.4 Conclusions

The postulated working hypothesis that there is no clinically discernible difference regarding the objective / subjective outcome of esthetic integration between the two approaches was accepted. Hence, this finding could be of major clinical relevance, since the two approaches are significantly different when it comes to their complexity, respective fabrication time, and so far might be more efficient regarding their resulting costs.
2.2 INTRODUCTION

For more than three decades, the validity of oral implants as a treatment option to replace missing teeth has been accumulating. The performance of oral implants has motivated manufacturers and researchers to propose more innovative and convenient treatment protocols suitable to a wider range of patients while maintaining predictable treatment outcomes. In implant dentistry, numerous designs and materials of implant-abutment systems have been available for clinical use. Titanium abutments are currently considered as the «golden standard» for implant-supported reconstructions (Andersson et al. 1995, Andersson et al. 1998) and the main reason being their excellent mechanical and biological properties. However, despite the physical advantages of titanium abutments, the esthetic outcome should also be considered as a success factor, especially in the esthetic zone. Key elements to be considered include: height of the patient’s smile line, gingival biotype, color of the neighboring teeth and the esthetic expectations of the patient (Sailer et al. 2007). Titanium abutments may lead to a grayish discoloration of the periimplant mucosa, particularly in presence of a thin gingival biotype (Jemt 1997; Yildirim et al. 2000; Henrikson & Jemt 2003; Jung et al. 2007; Park et al. 2007). In order to address these shortcomings, zirconia abutments were recently developed as an alternative.

Zirconia (zirconium oxide) was first used with medical purposes in 1969. It was introduced as a new ceramic material for orthopedic use as surgical implants, as for example as a substitute for titanium or alumina prostheses in hip replacement.
In the field of implant dentistry, the first zirconia abutment, Zirabut® (Wohlwend Innovative, Zurich, Switzerland) was produced in 1997 and many more came to the market later. In clinical studies the short- and long-term performance of zirconia abutments was evaluated. The results were encouraging for the use of ceramic abutments (Andersson et al. 1998). Zirconium oxide (ZrO2) is a ceramic material, which is not cytotoxic, not water-soluble, has low bacterial adhesion properties, is radio-opaque and has a low corrosion potential (Rimondini et al. 2002; Scotti et al. 2007; Denny & Kelly 2008; Lughi & Sergo 2010). Pure zirconia is a polymorphic crystal that can be found in three different crystalline phases dependent on the temperature: monoclinic (room temperature up to 1170°C), tetragonal (1170–2370°C) and cubic (2370°C up to the melting point) (Piconi & Maccauro 1999). The addition of «stabilizers» like yttrium and cerium oxides prevents a phase transformation and retains the zirconia crystals in their more stable tetragonal or cubic shape at room temperature (Piconi & Maccauro 1999; Zarone et al. 2011). The so-called yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) exhibits superior mechanical properties compared to other ceramics. This explains why Y-TZP is the ceramic «material of choice» today for different types of all-ceramic dental reconstructions, as frameworks, including implant abutments, in areas with high functional loading (Christel et al. 1989; Zarone et al. 2011).

A shortcoming of zirconia is its accelerated aging (Kobayashi et al. 1981). Thereby, a spontaneous slow transformation of the tetragonal phase to the monoclinic phase takes place at low temperatures (150–400°C) and in a humid environment. This leads to decrease in strength and puts the material
at risk for catastrophic failures over time (Denry & Kelly 2008; Kim et al. 2010). This aging phenomenon primarily involves un veneered zirconia frameworks and implant abutments exposed to the oral environment (Guess et al. 2010). Nonetheless, a direct relationship between aging and clinical failure of zirconia implant abutments could not be shown to date by scientific evidence (Chevalier 2006; Denry & Kelly 2008; Sailer et al. 2009). This may be explained by the lack of clinical studies on zirconia implant abutments.

Two traditional approaches are available for implant abutment construction, namely stock (standard prefabricated) abutments and the lost wax / casting approach, which have some clear restriction, i.e. they are very labor intensive and a high level of quality control is mandatory. To reduce the customization and manufacturing steps, the CAD / CAM (Computer Assisted Design and Manufacturing) protocol for abutment production was introduced. CAD / CAM production involves three consecutive steps: scanning, CAD modeling (designing), and CAM production. The scanner is the data acquisition system that records the 3D geometry of the infrastructure and converts the actual dental model into virtual dental model. The CAD component virtually designs the 3D contour of the final implant component. The CAM system produces the actual implant component according to a virtual design. In current implant dentistry, individualized implant abutments are mostly produced by milling at a central production facility. Custom CAD / CAM abutments combine most of the advantages of stock and cast custom abutments (Parpaiola et al. 2013). To date, CAD / CAM is the only way of producing implant components from high-strength ceramics such as densely sintered alumina and partially stabilized zirconia. Over the past years studies have been published.
analyzing the performance of custom CAD / CAM abutments under in vitro and in vivo conditions (Sailer et al. 2007; Sailer et al. 2009; Preis et al. 2011).

To date the existing studies on zirconia abutments have an observation period less than 5 years (Glauser et al. 2004; Canullo 2007; Sailer et al. 2009; Zembic et al. 2009; Nothdurft & Pospiech 2010; Eklundt et al. 2011). In order to confirm the same excellent clinical performance as the «gold standard» titanium abutments, more prospective clinical studies, ideally randomized controlled trials, with longer follow-up are needed to achieve an acceptable level of scientific evidence (Evans 2003).

In a randomized clinical trial, objective and subjective esthetic outcomes of two types of screw-retained single-implant crowns, i.e. all-ceramic versus metal-ceramic, were compared and no statistically significant differences were observed between the groups after two years of clinical service. The authors concluded that the material chosen for fabricating an implant crown per se does not ensure an optimal esthetic outcome if other esthetically relevant factors are not present (Gallucci et al. 2010).

However, despite improved industrial technologies, clinicians and dental technicians still face significant challenges when it comes to the implementation of zirconia abutments (adapting to a whitish ceramic material instead of a grayish metal). These include the optimal choice among the various restorative materials in order to meet both the mechanical and esthetic requirements of the patient. Furthermore, appropriate design and proper handling of the ceramic are of considerable importance. The increasing demands and expectations for accurate color matching have
become even more integral to the success of an esthetic restoration (Ishikawa-Nagai 2009).

To date, however, there is no study available that would have directly compared the performance of prefabricated versus CAD / CAM generated zirconia abutments in the esthetically relevant jaw regions. It is reasonable to assume that both procedures may provide excellent esthetics.

Hence, the aim of the present study was to test the hypothesis that no clinical discernible differences concerning both esthetics and long-term performance between the two approaches would be observed. If confirmed, this could be of practical relevance, since the two approaches are significantly different when it comes to their complexity and respective fabrication time and costs.
2.3 MATERIAL AND METHODS

2.3.1 Study Design

This study is a two-center prospective randomized trial and was designed to compare esthetic outcome and overall clinical performance of two different restorative options based on either prefabricated or CAD / CAM generated zirconia abutments. Two different veneering methods using either prefabricated zirconia abutments (PFA; available with two different cervical margin locations and in two different colors) or custom made (CAD / CAM (Cares)) abutments were used to fabricate directly screw-retained implant single crowns. For the former abutment, a press technique (fluorapatite glass-ceramic, IPS e.max ZirPress) has been employed, completed with some minor esthetic veneering (IPS e.max Ceram). For the latter, a hand build-up layering technique (fluorapatite veneering ceramic, IPS e.max Ceram) has been utilized (Table 1., Table 2.).

2.3.2 Study Objectives

The primary objective was to assess and compare the esthetic outcome and clinical performance and of anterior maxillary screw-retained one-piece all-ceramic implant single crowns based either on prefabricated zirconia abutments or on custom made (CAD / CAM (Cares)) abutments using two different veneering methods. This was assessed by means of esthetic scores (PES-WES / cast analysis) measured on study casts and via standardized photographs at baseline, 6 months and 1 year (Fig.1, Fig 2). The analysis was
performed by two independent observers in each study center (Geneva and Bern).

The secondary objectives included the following items: implant success criteria according to Buser (Buser et al. 1996) at 6 months, and after 1 year post implant restoration; implant survival rate, standard peri-implant soft tissue parameters (mod GI, mod PI, BOP, PD) at four sites of each implant restoration; mechanical / technical complications / failures; documentation of occlusal contacts (no, light or strong occlusal contact in centric occlusion) assessed with shimstock; crestal bone level change at the implant site (DIB) (mesial and distal), (Fig. 3), evaluated between implant placement and 6 months, and after 1 year; time analysis of implant crown fabrication (in minutes). Finally, patient questionnaires and associated visual analogue scales (VAS) were conducted at baseline and after 1 year (Fig 7).

2.3.3 Study Population and Randomization

Participants were recruited from two centers, the Universities of Bern and Geneva, Switzerland. In one center 10 patients, in other 11 patients were treated, resuming a total of 21 subjects, 9 women and 12 men, average age 47.3. The randomization sequence generated by two main investigators (J.G & J.W) matched 100% the patient allocation at the end of the study. All patients had previously been treated with at least one single-tooth replacement implant located in the anterior maxilla (location 14 to 24 FDI) that was subsequently restored with a directly screw-retained provisional crown. To meet the inclusion criteria, the single-tooth implant had to be a regular
diameter Bone Level Implant (BLI Ø 4.1 mm, length 8,10 or 12 mm, Regular CrossFit [RC] connection, Institute Straumann, Basel, Switzerland). After the provisional phase and final impression, patients have been randomized by the use of an envelope into Group (A = test group) (PFA, M1, straight abutments): one-piece screw retained single crown using a press technique (fluorapatite glass-ceramic, IPS e.max ZirPress) with cut-back technique and subsequent minimal hand-layered veneering (fluorapatite veneering ceramic, IPS e.max Ceram), or Group (B = control group) (CAD / CAM (Cares) abutments): one-piece screw retained single crown using a hand build-up technique (fluorapatite veneering ceramic, IPS e.max Ceram). One week after insertion of the final restoration (baseline visit) the primary and secondary outcome parameters were assessed. The study protocol stipulates a patient follow-up of 5 years after final restoration.

2.3.4 Inclusion Criteria

The subjects had been evaluated for initial study eligibility during the screening visit. Those subjects who appeared eligible according to the inclusion / exclusion criteria were asked to sign an informed consent form and were enrolled in the study. All of the following criteria have been met for inclusion in the study:

1. Subjects must have voluntarily signed the informed consent form before any study related action
2. Males and females with at least 18 years of age
3. Single-tooth gaps in the anterior maxilla in tooth positions 14-24 (FDI)
4. Successfully osseointegrated single-tooth implant (Straumann BLI 4.1 mm RC) inserted at least 16 weeks after tooth extraction and restored with a directly screw retained provisional crown

5. Full mouth plaque index according to O’Leary ≤ 25%

6. Implant axis compatible with trans-occlusal screw-retention (screw access palatal of incisal edge)

2.3.5 Exclusion Criteria

Surgical Exclusion Criteria

1. Any systemic disease that would interfere with dental implant therapy (e.g. uncontrolled diabetes, i.v. bisphosphonate intake)

2. Any contraindications for oral surgical procedures

3. History of local irradiation therapy in the head-neck area

4. Patients who smoke >10 cigarettes per day or tobacco equivalents or chew tobacco

5. Subjects who have undergone administration of any investigational device within 30 days of enrolment in the study

6. Conditions or circumstances, in the opinion of the investigator, which would prevent completion of study participation or interfere with analysis of study results, such as history of non-compliance or unreliability

7. Physical or mental conditions that would interfere with the ability to perform adequate oral hygiene

8. Pregnant or breastfeeding women

9. Existing implants in the adjacent position
**Dental Exclusion Criteria**

10. Removable dentures or un-restored tooth gaps in the opposing dentition

11. Patients with inadequate oral hygiene or unmotivated for adequate home care

12. Probing pocket depth of $\geq 4$ mm on one of the teeth immediately adjacent to the dental implant site

13. Lack of primary stability of the implant: rotational movement of the implant at a min. of 15 Ncm torque at healing cap connection, or tactile mobility at time of implant placement

14. Inappropriate implant position for the prosthetic requirements

15. Major simultaneous augmentation procedures. Mucosal dehiscence of a vertical distance of more than 3mm

16. Insufficient stability of the implant: slight rotational movement at 35Ncm during abutment connection (final loading)

**Restorative Exclusion Criteria**

17. Screw access position located too close to the planned incisal edge

18. Need of angled abutment due to prosthetic malposition of the implant e. g. placement too buccal or too palatal

19. Prefabricated abutment does not offer the needed support for the veneering ceramic; therefore, thickness of the veneering ceramic should not exceed 2mm (incisal, buccal, palatal). Exclusion if thickness of veneering ceramic is more than 2mm

20. Height of the abutment is less than 65% of the height of the complete restoration

21. Severe bruxing or clenching habits
2.3.6 Clinical Examination

Implant Success and Survival Rates

Implant success and survival were assessed at the screening-, baseline-, 6- and 12 months follow-up visits. A surviving implant was defined as an implant in place at the time of follow-up, and was considered successful if all of the following success criteria were fulfilled, which is absence of implant mobility, pain, suppuration and of peri-implant radiolucency (according to Buser et al. 1991).

Screening / Recruitment Visit Included the Following Assessments

• Verification of inclusion and exclusion criteria
• Signing of the informed consent form
• Demographic information
• Periapical radiograph
• Confirming presence of strict implant success criteria (Buser et al. 1991)

Objective Measurements

The following clinical parameters were evaluated at the BL-visit, 6-, and 12-months post-implant restoration:

• Presence / absence of plaque (mod PI): were evaluated according to criteria of the Plaque Index (PI; Silness & Löe 1964) and adapted for oral implants (Mombelli et al. 1987).
• Bleeding on probing (BOP): the presence or absence of bleeding on probing to the bottom of the sulcus / pocket was recorded according to (Lang et al. 1986).
• Pocket probing depth (PPD): measured from the gingival or peri-implant mucosal margin to the bottom of the sulcus or pocket with a probing force of 0.2-0.25 N.
Esthetic Parameters

To objectively examine the esthetic outcomes of the ICs (implant crowns), the respective casts and intraoral pictures were critically analyzed independently by two examiners (JW and JG) to assess the pink esthetic score (PES) and the white esthetic score (WES). In case of divergent scorings, two examiners revisited the documents until consensus was reached.

- **PES**: modified pink esthetic score: assessing the peri-implant soft tissue based on 5 variables (mesial and distal papilla, curvature of the facial mucosa, level of the facial mucosa, root convexity, soft tissue color and texture at the facial aspect of the implant site). Each variable is graded by the use of a score 0, 1 or 2 (Belser et al. 2009; Fürhauser et al. 2005) (Fig. 1, Fig. 5, Fig. 6).

- **WES**: white esthetic score: evaluates the visible part of the implant restoration itself with five parameters: general tooth form, outline / volume of the crown, color, surface texture, translucency and characterization of the incisal third by a score of 0, 1 or 2 (Belser et al. 2009) (Fig. 1, Fig. 5, Fig. 6).

Cast Analysis

Dental impressions were taken at the BL visit, 6-, and 12-months follow-up to record soft tissue changes, migration of neighboring teeth and changes in the length of the clinical crowns. The casts were photographed with a standardized technique using a millimeter grid as a reference (Belser et al. 2009). On these digital pictures, the mid-facial height of the implant crown (IC) and the corresponding height of the contra lateral tooth crown (TC) were measured to identify potential changes in crown height or mucosal recession (Fig. 2).
Presence / Absence of Technical / Mechanical Complications
Abutment loosening, screw loosening, implant fracture, abutment fracture, screw fracture, fracture of the veneering material, chipping of the veneering material, damage to adjacent or opposing dentition, and any other kind of technical / mechanical complication were recorded on the Adverse Event Form.

Radiographic Examination
To assess the stability of the peri-implant bone structure, the following radiographic examinations were used: a periapical intraoral radiograph was taken at screening visit. A radiographic stent was fabricated at time of final restoration in order to create a standardized film holder. Standardized radiographs and the radiographic analysis were performed at following times: baseline, 6-, and 12-month follow-up (Fig. 4). For the radiographic analysis, the radiographs were digitized using an image processing software; linear measurements were performed with the help of a cursor. One calibrated examiner (AZ) performed all radiographic measurements. The distances in tenth of millimeters between reference points on the implant and the first bone-to-implant contact, mesially and distally, were noted. The change in crestal bone height in relation to the reference points on the implant over the entire observation period was calculated. Measurements took into account distortion based on changes on the radiograph from the true dimension of the implant (i.e. length of the implant, distances between the threads) (Fig.3).

28
2.3.7 Time Analysis

The total laboratory treatment time from abutment workflow to the polishing of the final implant crown was recorded. One certified dental technician (CDT; DV) was recording the time required for CAD designing of the custom-made zirconia abutment (control group) or for modification of the prefabricated abutment (test group). In addition, the veneering process and the completion of the final restoration was measured with a stopwatch (in minutes).

2.3.8 Subjective Measurements

Questionnaire

At baseline and at the 1-year follow-up the patients were asked to answer a brief, structured questionnaire, comprising visual analogue scales (VAS) to subsequently permit statistical analysis. The questionnaire included short questions relative to patient opinion concerning the restoration, the surrounding tissues, and the overall treatment satisfaction (Fig 7).
2.3.9 Statistics

First, all data were visualized with descriptive methods using box plots. To analyze potential differences in the gingival parameters, implant mobility, esthetic parameters (PES / WES scores) and radiographic findings over the time period, the Wilcoxon signed-rank test was used. To compensate for multiple testing situations, the p-values were adjusted according to the method of Holm (1979), which allowed comparison to the usual alpha level of 0.05. Data sets of the cast analysis were first evaluated descriptively, and the differences between implant crowns (IC) and corresponding natural tooth crowns (TC) were calculated for each time point separately. To detect statistically significant differences between the $\Delta$IC-TC values, the Wilcoxon signed-rank test was used. The time-analysis initially was done utilizing descriptive methods. Differences between the groups were then evaluated using the Kruskal-Wallis rank sum test. Questionnaire data was first analyzed using descriptive statistics. Additionally, categorical variables were compared using the Fisher’s exact test and continuous variables using the Kruskal-Wallis rank sum test.

The significance level chosen for all statistical tests was $p \leq 0.05$. The statistical software package S-Plus Professional (Version 6.2, Insightful Software, Palo Alto, CA, USA) was used for all analyses.
2.4 RESULTS
All implants were osseointegrated, demonstrating ankylosis stability. None of the patients presented suppuration in the peri-implant sulcus. All 20 implants survived (100%) and fulfilled strict success criteria (according to Buser et al. 1991). Overall, the patients exhibited good to acceptable oral hygiene, documented by a mean mPLI of 0.125. The peri-implant soft tissues appeared healthy, which corresponded well to a low mean mSBI of 0.150. The mean PD was 2.91 mm at the 1-year examination (Table 3). However, none of the measured peri-implant soft tissue parameters showed a statistically significant difference between the two groups during the follow-up period.

2.4.1 Esthetic Parameters: PES/WES
Values of esthetic parameters are depicted in (Table 4). Overall, the esthetic outcomes were favorable, as documented by the clinical photographs of all 20 crowns at the BL, 6- and 12-months examinations. Within the five parameters of the PES index, the papilla height had the lowest mean values, with a value of 0.9 distally, whereas the level of the curvature of the labial mucosa performed the best, with a mean value of 1.6. Out of a maximum possible score of 20, test group scored a mean value of 14.7 and control group 15.0. These values were not statistically significantly different. WES was higher than PES in both groups. Tooth form, volume / outline, and color values scored the lowest for both groups and the highest scores were found for surface texture and incisal translucency. There was no statistically significant difference between test and control group.
2.4.2 Cast Analyses

IC and TC values performed similarly over the 1-year study period and did not show any statistically significant changes over time (Table 5). No significant differences were seen between the two groups (DIC-TC values) or within one of the groups over the period of one year.

2.4.3 Presence / Absence of Technical / Mechanical Complications

No abutment failures were recorded during the whole length of the study. Chipping of veneering ceramic was observed at 2 crowns, one in the test group and one in the control group. One crown had a major fracture of the veneering ceramic, due to a non-respect of the inclusion criteria. In this particular case the prefabricated abutment (test group) did not offer the required support for the veneering ceramic, which was more than 2mm (incisally), therefore the height of the abutment was less than 65% of the height of the complete restoration. A new crown was fabricated, and the patient excluded from the study.
2.4.4 Radiographic Findings / DIB Values

To assess the stability of the peri-implant bone structure, the following radiographic examinations were used: the obtained DIB values indicated overall stable peri-implant bone crest levels on the mesial and distal aspects of the implants. The radiographs did not reveal any signs of continuous peri-implant radiolucency during the observation period (Fig. 4). At baseline the mean DIB value was 0.065 mm for the 20 implants. The peri-implant crestal bone showed a remodeling pattern during the first 12 months of functional loading. The mean DIB values increased 0.035 mm at 6 months of loading and after one year DIB decreased 0.06 mm (Table 6).

2.4.5 Analysis of the Fabrication Time (in minutes) of the Restorations

The mean time spent for manufacturing the test group crowns (PFA, prefabricated abutment / press ceramic) was 182.5 min and 255 min for the control group crowns (CAD / CAM (Cares) abutment / hand-layered veneering) (Table 7). The fabrication time in the test group was almost half of that used for the control group. The meantime of abutment modification in the test group took only half the time than the abutment waxing and scanning in the control group. The veneering time in the control group was considerably longer, when compared to the two procedures involved in the test group (the press and cut back / veneering process). Surface staining, glazing, and polishing time in the test group were roughly one third of that of the control group.
2.4.6 Questionnaires / VAS

As for subjective parameters, the patient’s VAS responses regarding their perception of the esthetic outcome are presented in (Table 8).

Out of a maximum of 100, in the control group patients scored 71.43, whereas 69.88 were calculated for the test group. All this comparisons showed no statistically significant differences.
2.5 DISCUSSION

During the length of this study, no implant or abutment failure was observed. The 1-year data demonstrated that all 20 implants achieved and maintained successful tissue integration. This was documented by routine clinical and radiographic parameters. The mean values obtained, were all in line with previous studies using the same parameters (Bornstein et al. 2005).

The measured peri-implant soft tissue parameters showed stable and healthy conditions at the two groups during the follow-up period. The main focus of this study was the stability of the esthetic outcome of two different all ceramic prosthetic procedures based on zirconia implant abutments. The overall results for the 20 restorations were highly satisfactory for both esthetic indices, i.e. PES and WES (Belser et al 2009). No statistically significant differences were found between the test and the control group. The working hypothesis that test group (PFA, prefabricated anatomic abutment, press ceramic) and control group (individualized CAD / CAM (Cares) abutment, veneering ceramic) are indistinguishable when it comes to the objective / subjective comparison of esthetic integration was accepted. However, the relatively small sample size remains one of the limitations of this investigation.

The 1-year mean WES was more favorable than the mean PES. This was not surprising because the WES index is mainly dependent on quality and experience of the dental technician, while PES depends on patient, surgeon, time and WES (Belser et. al 2009; Buser et al. 2011). All crowns were produced by one single technician (DV), who was particularly experienced and qualified when it comes to esthetic implant restorations. It is also not
surprising that the WES did not change between the BL, 6- and 12-months examinations, because ceramics are very stable over time concerning mechanical resistance and optical properties (Belser et. al 2009; Buser et al. 2009). In general, the surface texture and translucency were highly rated by the two examiners (JW and JG), whereas color, tooth volume / outline were rated the lowest among the 5 different parameters. However, no differences were observed between test and control group. This could be explained by the fact that additionally to crown material selection also other parameters need to be considered to achieve a balanced esthetic integration, such as tooth morphology, translucency and light reflection, surface texture, level of cervical margin, presence of inter-proximal papilla, and resemblance to the contra-lateral tooth. It means that without taking in consideration the other specific esthetic parameters involved, the implant crown material alone would not be sufficient to ensure an optimal esthetic outcome (Gallucci et al. 2010).

The influence of prosthetic reconstructions on peri-implant soft tissues has been analyzed previously in different clinical situations (Jemt 1997; Chang et al. 1999; Fürhauser et al. 2005; Meijer et al. 2005; Gallucci et al. 2007; Belser et al. 2009). The results obtained in the clinical trial of Jemt (1997) showed that the soft-tissue contour adjacent to single-implant restorations changes in a systematic manner during the time period between insertion of the crowns and follow-up examinations 1–3 years later. When the PES values of the present study were compared between the two groups, no differences were observed. However, the peri-implant soft-tissue color and texture are directly related to the crown morphology as well as to the prosthetic material. Compared to the BL, 6-mo and 12-mo results, the PES values remained
relatively stable, with a mean value of 6.6 out of 10. A reduction in papilla height in general could potentially be caused by a loss of interproximal bone height at adjacent teeth because the papilla height around an implant-supported single crown primarily depends on this anatomic structure (Choquet et al. 2001). Such a change in bone height can be caused by a local infection such as periodontitis or a fractured root or by the extraction of an adjacent tooth. Of greater importance is the soft-tissue handling at the time of implant placement, where a substantial amount of keratinized mucosa should ideally be preserved at the facial aspect (Buser et al. 2004).

When the patients judged their own satisfaction with the achieved esthetic outcome, no statistically significant differences could be demonstrated between test and control group. Although the PES revealed slight differences for both groups, in most patients this did not influence their level of satisfaction with the treatment rendered. Conversely, these esthetic variables were more evident to the independent reviewers (PES / WES), which indicates that differences in assessing an esthetic outcome exist between professionals and patients. In general both types of single-implant restorations seemed to be esthetically well integrated and most of the esthetic parameters evaluated in this study reached acceptable to excellent levels for both crown types.

Two chippings (test and control group) of the veneering ceramic occurred, the failure modes were quite similar in all two crowns, i.e. all occurred in the part of the veneering ceramic. No abutment fractures were noted. Nowadays we know a lot about the mechanism of fracture, fatigue resistance or failure in dental ceramics. Although the mechanical characteristics of core materials
(zirconium oxide) have continuously been improved (i.e. increased toughness), the mechanical properties of the veneering material have largely remained unchanged (Albakry et al. 2004). Compared with the conventional powder / liquid layering technique for veneering a zirconia core material, a recent study (Aboushelib et al. 2008) showed that heat-pressed veneering porcelain produces significantly higher fracture strength and microtensile bond strength between zirconia core and veneering porcelain. Another study (Lin et al. 2011) showed similar results with the heat-pressed technique providing significantly higher flexural strength for the zirconia bilayer specimens. The possible explanation is the molten ceramic pellet, which is brought into contact with the zirconia framework during heat pressing. This procedure is under pressure and in a vacuum, resulting in improved wetting and contact between the two materials (Aboushelib et al. 2008). Since the veneering glass ceramic is the weakest part in this system, clinically observed failures are mainly restricted to the veneer layer. Additionally the veneering porcelain is the part of the reconstruction, which is directly exposed to chewing, clenching, and moisture. These fatigue, stress and corrosion mechanisms further weaken the veneer and can finally result in cracks or chippings (Kim et al. 2008; Coelho et al. 2009; Taskonak et al. 2008; Borges et al. 2009; Ortorp et al. 2009; Swain et al. 2009). Some other studies showed that not only the anatomically reduced substructure design but also the application technique and type of veneering material, quality of the veneering porcelain, firing regime and bonding to zirconia can influence the chipping behavior of zirconia supported reconstructions (Al-Dohan et al. 2004; Beuer et al. 2009; Ishibe et al. 2011; Preis et al. 2013). Other clinical trials highlighted the clinical
variables, such as an individual crown design with its occlusal variations, an individual patient’s chewing behavior, and functioning in an oral environment. These patient depending variables may have different effects on loading, force distribution, and aging and should therefore be further investigated to reduce effectively the number and dimension of failures, such as chippings and cracks (Rosentritt et al. 2009; Christensen and Ploeger 2010; Preis et al. 2013). Another variable that can influence the mechanics of implant born crowns is their connection to the abutment: screw-retained when compared to cemented restorations present several disadvantages such as an increased risk for porcelain fracture and micro-cracks (Zarone et al. 2007, Karl et al. 2012). However, there are numerous factors and co-parameters that can impact the success and survival rate of a full ceramic implant born reconstruction. The ceramic system in the present study suggests one layering ceramic (fluorapatite veneering ceramic) for highly esthetic glass-ceramics and high-strength zirconium oxide. This system promises predictable results and the same wear properties, no matter which framework material you choose. It is versatile and adaptable to all restorative options, so that we can use zirconia abutments as a basis for different all-ceramic restorations. The restoration can be fabricated through either traditional veneering / layering or modern press-on techniques and can be considered as a result of high strength, esthetics and as an ease of use into one product. Considering the two mechanical ceramic complications in the present study, the following possible explanations can be drawn: for the chipping of veneering ceramic in the test group, we can argue that on the one hand the pre-shaped abutment was eventually too small in height or not perfectly
anatomically supportive for the veneering ceramic. Such anatomical contouring is of paramount importance because it reduces the thickness of the veneering ceramics and is therefore minimizing the risk and severity of ceramic chipping (Guess et al. 2009, Guess et al. 2012, Guess et al. 2013). On the other hand the restoration–abutment adhesive interface was not strong enough, since the cosmetic ceramic was not pressed to the zirconia infrastructure. The risk of veneering ceramic fracture is expected to be minimized by methods like heat-pressing the veneering ceramic or slow cooling of the veneered zirconia-based restoration (Kim et al. 2013). In the past several years, numerous brands of zirconia-based all-ceramics have been introduced to dentistry. These materials are having a significant effect on the fixed prosthodontic laboratory industry, as well as on practitioners and their patients. However, there is currently no veneering ceramic available that can completely prevent chipping in such a situation as in the present study (test and control group chippings) and to date, there is no unique ceramic material that equally satisfies all the key properties for clinical use. The choice of a specific dental ceramic should be based on a detailed assessment of the advantages and drawbacks of the material in relation to the specific dental applications. We need always to refer to clinical data supported by scientific evidence and paying attention to the esthetic needs of the patients. The primary focus is on development of ceramics that should be parallel with material science advancement. It is therefore very important to realize more randomized controlled studies, so that different esthetic materials in the future can overcome some inherent problems of ceramics such as brittleness, risk of chipping, and difficulties with reparability.
2.5.1 Time / Effectiveness Analysis

There is recognition among dental professionals that the industry is competing a global market. Dental technicians and clinicians are creating new business strategies to stay competitive in a world market that is rapidly shaping oral healthcare services. Just as other industries before it, the dental industry is working through the growing pains of industrialized automation. Driven by the advancement of digital technology, this new global consciousness is changing the way that dental professionals are buying, fabricating, and delivering products. Laboratories have to utilize technology not only to find their niche in the market and improve productivity and efficiency but also to supply the product variety the market demands (Perry and Young Inc., Inside Dental Technology, 2010, published by AEGIS Communications).

Today’s strength of a dental technician lies in the knowledge of esthetics and to take the maximum out of that by using industrial technologies to provide the patient with good-priced restorations with flexible array of restorative options. The flexibility of restorative options is increasingly significant for any model to survive in the future. On the one hand we have technology and economy that are pushing and scripting the dental materials and their processing and on the other the design and outcome of the restoration strongly depends on the skills and preferences of the individual dental technician. Therefore, the fabrication process of the substructure and the veneering process in the different dental laboratories, especially with individualized copy milling, gains importance.

In the present study, in terms of handling, featuring, manufacturing, time and probably costs, the test group crowns presented different results than the control group crowns. In the control group, the abutment needs an
anatomically individualized correct design through waxing, followed by scanning, sending data to the milling centre for the final manufacture of the customized CAD / CAM (Cares) abutment. This path takes double the time than that of adapting the anatomically prefabricated abutment (PFA) (test group). The prefabricated abutment does not need a wax-up or scanning, there is no waiting for delivery of any parts, and it's on stock and can be prepared / adapted if necessary. The stages in the test group, which consist in: building up a crown (wax modeling / pressing; cut back / veneering; painting / glazing / polishing) can be lined up with the conventional construction of a porcelain crown, involving: layering (mixing of powder with liquid to form a paste which is layered to mimic a tooth), firing and glazing in the control group. These traditional layering technique steps are time consuming and need a long way of collection of experience and expertise in the dental technician career. A layered customized CAD / CAM (Cares) abutment (control group) with perfectly proportioned porcelain is based on old-school FM (fused to metal crown) design principles (Galucci et al. 2010). The big advantage in waxing a «pre-shaped / prefabricated abutment» (test group) is that it eliminates much of the expensive and highly skilled laboratory work associated with traditional manufacturing. The time difference in general is due to sintering time and because the expansion / contraction changes occur, contact- / occlusal-points need to be adapted after every time the ceramic was in the furnace. Another important time factor is the cooling process: after every sintering step, the cooling process standards of the furnace have to be observed and controlled. Over all it can be concluded that the traditional layering procedure costs every technician a lot of time.
Since there is a shift of paradigms, ceramic materials are the materials of the future and that means all-ceramics, with zirconia replacing metal. Traditional procedures give way to innovative CAD / CAM systems. Through that, dental laboratories can reduce time, respectively costs and increase production efficiency. The long time established layering / stratification technique is continuously disappearing. Every technician is capable to create an adequate restorative design using a novel armamentarium but following time-proven rules, i.e. the quick waxing / pressing technique to create a high-end full ceramic crown without a long life experience. A set of constant factors as function, esthetics and precision - these are and will remain the core message in prosthodontics. The working style is through the faster path ergonomic and detail-conscious, so that we can expect an excellent result regarding esthetics.

Dental technology is no longer primarily a technical craft, but has become an integral part of restorative / reconstructive dentistry, a member of the health professions. A time-effectiveness analysis in the present study is beneficial and a useful tool for decision-making in health cares. The standard cost-effectiveness analysis focuses on whether to make the switch from an old or common practice technology to an innovative technology, and in doing so, it takes a larger perspective (Willem H., et al. 2013). The purpose of the new abutment and its suitable ceramic system is not only of simplicity, convenience, elimination of several manufacturing steps and delays but also of clinical relevance, since the two approaches are significantly different when it comes to their fabrication time and according costs.
2.6 CONCLUSIONS

1. The hypothesis of this investigation that both selected zirconia-based implant-restorative procedures will provide similarly favorable esthetic outcomes was confirmed.

2. There were no clinically discernible differences between the two approaches; test and control group single-implant-born-restorations were indistinguishable from each other regarding both the objective and subjective assessment.

3. The clinical, radiographic and esthetic parameters evaluated in this study remained overall stable in both groups throughout the observation period.

4. When it comes to complexity and fabrication time, the two evaluated procedures were significantly different. In fact, the more simple and rapid fabrication process provided similar clinical outcomes as the so-called «gold standard», namely concerning esthetic appearance. Hence, this finding has major, clinically relevant implications, as the associated restorative costs are substantially inferior. This will have beneficial effects on both the technician-clinician-patient-expenses in particular and the oral health market in general.

5. Further well-controlled long-term trials are necessary to confirm these favorable preliminary results.
3. REFERENCES


4. ANNEXES