Titanium and zirconia custom implant abutments are now commonly used for esthetic implant dentistry. Custom implant abutments allow the clinician to improve an implant’s emergence profile, to customize cervical margins in accordance with the anatomy of the natural root, and to compensate for poor implant angulation. All of these are essential for optimum esthetic outcomes. Computer-aided design/computer-aided machining (CAD/CAM) technology allows the clinician to design custom implant abutment configurations and create natural-looking superstructures that are in harmony with the adjacent dentition and soft tissue. The CAD/CAM technique provides precise fit, reduces the cost of the procedure, and eliminates dimensional inaccuracies inherent in the conventional waxing and casting technique. The aim of this report is to describe a simplified technique for reconstructing emergence profiles during implant restoration using milled titanium and zirconia custom implant abutments. The results of 50 consecutive cases are reported.

Key Words: dental implant, titanium, zirconia, custom abutment

INTRODUCTION

Over the past two decades, esthetics has become an increasingly important consideration in implant dentistry. Esthetics is especially important when implant-supported restorations are placed in the anterior maxilla, where their visibility creates high patient expectations. Obtaining good esthetics at these locations is challenging because of difficult pre-existing anatomy. The ultimate goal of a dental implant is to restore missing teeth by placing implants that are anatomically correct and esthetically pleasing in functional positions that ensure long-term durability. Essential prerequisites to an esthetically successful treatment are thorough presurgical planning, appropriate site development, 3D implant positioning, soft tissue management, provisionalization, and esthetic prosthetic management. All of this must be done within the context of the patient’s expectations. Site enhancement and alveolar ridge preservation following tooth extraction have a major impact on the hard and soft tissue volume prior to placement of an implant and the definitive prosthetic implant restoration. Custom implant abutments allow the clinician to improve an implant’s emergence profile, customize cervical margins so that they are anatomically shaped in accordance to the natural tooth root, and compensate for poor implant angulation. All of these are essential for optimum esthetic outcomes.

Smile line and gingival biotype play a major role in the final esthetic outcomes. Neighboring tooth position, number of missing teeth, type of provisional prosthesis (fixed or removable), and shape and shade of adjacent dentition are positive factors that need to be considered for successful treatment planning. When the tooth is non-restorable, positive factors for favorable implant restoration include the following: gingival tissue that has a flat gingival scallop form, a thick gingival biotype, and square-shaped teeth with a high osseous crest.

Recent research has provided useful insights into soft tissue changes around implants following implant placement surgery. For example, in one clinical study, measurements were recorded at stage 2 surgery in 2-stage implant systems and at stage 1 surgery in the 1-stage system. Subsequent measurements were recorded for several interval periods up to 1 year after baseline measurements. The majority of the recession occurred within the first 3 months of healing. Eighty percent of all sites showed recession on the buccal side with average soft tissue recession amount of 0.88 mm. The investigators recommended that soft tissue be allowed to stabilize for 3 months after implant placement before selecting a final abutment or making a final impression. As a general rule, a 1-mm soft tissue recession can be expected after healing abutment connection surgery.

Soft tissue integration around dental implants has not been

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extensively studied. One study evaluated the implant-gingival junction of unloaded and loaded non-submerged titanium implants. Histological dimensions of the sulcus depth, the junctional epithelium, and the connective tissue contact were measured. Significant changes within tissue compartments occurred over healing time. Sulcus depth had a mean value of 0.49 mm and 0.50 mm after 3 and 6 months of healing, respectively. The difference became statistically significant after 15 months, with a mean value of 0.16 mm. Similarly, the mean length of the junctional epithelium after 3 and 6 months of healing was 1.16 mm and 1.44 mm, respectively. After 15 months, the mean values became significantly different at 1.88 mm. A different pattern of changes was reported for the length of connective tissue contact: after 3 months of healing, the mean value was 1.36 mm. This was significantly different from the same area after 6 and 15 months, which were 1.01 mm and 1.05 mm, respectively. These results will inform treatment decisions, since preservation or reconstruction of soft tissue integration around the implant restorations is as important as preservation of the hard tissue integration around functioning implants.11

Computer-aided design/computer-aided machining (CAD/CAM) technology allows the clinician to design custom implant abutment configurations and create an anatomically natural-looking superstructure that is in harmony with the surrounding dentition and adjacent soft tissue.12 The CAD/CAM technique provides precise fit of the intended prosthetic design, reduces the cost of the procedure, and eliminates dimensional inaccuracies due to conventional waxing and casting techniques.1,13 The precisely fitting implant custom abutment improves implant longevity and prosthetic success and simplifies the restoration.1,12,13

During the past three decades, there has been considerable research on implant prostheses. The highlights of the research results for titanium and zirconia abutments will be compared for each of the following topics: in vitro properties, survival, marginal adaptation, bone loss, soft tissue response, esthetic outcomes, and technical complications.

Yttria-stabilized zirconia ceramics is a biocompatible biomaterial for restoration that has excellent esthetic and mechanical properties. Recently, zirconia custom abutments have been proposed as an excellent alternative to titanium custom abutments for esthetic implant restorations in the maxillary anterior region. The strength of the zirconia abutment is comparable to that of titanium (281 N versus 305 N); both are strong enough to withstand static and dynamic loads that occur in vivo. The flexure strength of the zirconia abutments is similar to that of titanium abutments: both are strong enough to be used in a cantilever structures. The material is susceptible to undergoing the stress-induced transformation toughening mechanism because of the very fine grain size. The bacterial adhesion was registered by a percentage of bacterial biofilm of 12.1% on the zirconia abutment, compared to 19.3% on the titanium abutment. This is very important in the maintaining of zirconia restorations around dental implant.14–16

The fracture resistance of zirconia implant abutments exceeds the maximal reported incisal forces (90–370 N). The maximum load capacity was 484.6 ± 56.6 N for NobelProcera (NobelProcera Abutment Zirconia, Nobel Biocare, Yorba Linda, Calif), 503.9 ± 46.3 N for Aadva (Aadva CAD/CAM Zirconia Abutment, GC Advanced Technologies Inc, Alsip, Ill), and 729.2 ± 35.9 N for Lava abutments (Lava Zirconia abutment, 3M ESPE, St Paul, Minn). With standard diameter internal tri-lobe connection implants, the maximum load capacity of the Lava abutment was significantly higher than that of the Aadva or NobelProcera abutment. No significant difference in maximum load capacity was noted between Aadva and NobelProcera abutments. The mode of failure among the Aadva, NobelProcera, and Lava abutments was different.17

Scanning electron microscopy revealed that titanium implants exhibited more wear after cyclic loading when connected to zirconia abutments (maximum wear, 10.2 μm) than when connected to titanium abutments (maximum wear, 0.7 μm).18

Sailer et al reviewed the performance of ceramic and metal implant abutments supporting implant restorations and estimated a 95% 5-year survival rate for the implants in function. For example, in one study, the 5-year rate for soft tissue recession around ceramic abutments was clinically more pronounced than around metal abutments (8.9% and 3.8%, respectively). In another study, the estimated 5-year rate for the soft tissue recession was 2.1% for ceramic abutments and 4.1% for metal abutments. The rate for bone loss was higher for implants supporting metal abutments (3.9%) than for those supporting ceramic abutments (1.7%). The total estimated 5-year rate for esthetic complications for ceramic and metal abutments supporting fixed restorations was 5.4%. Problems with the esthetic outcome were more frequently reported for metal abutments.19 Several articles imply that peri-implant soft tissue esthetics can be enhanced by controlling the contour of provisional restorations. Clinical and histological studies show that gold, titanium, and zirconia ceramic abutment materials all exhibit excellent biological responses around dental implant restorations.2,1

The marginal bone loss at one-year follow up after prosthetic loading was not significantly different between all-ceramic and metal-ceramic restorations (−0.08 mm ± 0.25 mm and −0.10 mm ± 0.17 mm, respectively). The marginal adaptation of the all-ceramic crowns was significantly poorer than for the metal-ceramic crowns. The professional-reported color match of all-ceramic crowns was significantly better than metal-ceramic crowns, but other esthetic parameters showed no statistically significant difference between all-ceramic and metal-ceramic restorations.20 After three years, 100% of zirconia implant abutments and 97% of crowns survived. Marginal bone loss was significantly higher around gold-alloy (0.41 mm ± 0.58 mm) when compared to zirconia abutments (0.15 mm ± 0.25 mm). The professional-reported esthetic outcome showed superiority in esthetic and color match of all-ceramic over metal-ceramic crowns.21

Based on the meta-analysis of 46 studies, survival of implants supporting single crowns was to 97.2% after five years and 95.2% at 10 years. For example, in one study of implant-supported single crown restorations, 96.3% survived 5 years and 89.4% survived 10 years. At the 5-year follow up, the cumulative percentage of restorations that exhibited soft tissue complications (eg, mucositis, bleeding, suppuration, and soft tissue dehiscences) was reported to be 7.1%. The subset of
restorations with bone loss >2 mm was reported to be 5.2%. After five years, 8.8% of the restoration exhibited screw-loosening, 4.1% exhibited loss of retention, and 3.5% exhibited fracture of the veneering material. The cumulative 5-year esthetic complication rate due to soft tissue recessions, an unfavorable color, and visible crown margins was reported to be 7.1%.22

The zirconia custom abutments performed well over the 5-year follow up period.23 The rates of both technical and biological complications were low (1%), and the patients were extremely satisfied with the restorations in general. There were no significant differences for changes in any of the soft tissue measurements. The peri-implant bone level changes from placement to the clinical examination 3–5 years later were small (0.29 mm ± 0.87 mm).23

The bone resorption around transmucosal implants loaded for 12 months was reported as 0.86 mm ± 0.99 mm. When prefabricated solid abutments were used, the connective tissue and junctional epithelium migrated on the transmucosal machined surface of the implants’ necks following the resorption of the bone, regardless of the length of the implant’s neck.24

The preceding review demonstrates that laboratory research and clinical trials support the use of customized implant abutments. The aim of this report is to describe a simplified technique for reconstruction of the emergence profile at the time of implant restoration, especially in the anterior esthetic zenith, using milled titanium or zirconia custom implant abutments. We describe the outcomes of such treatment based on our experiences with a series of 50 consecutive cases.

**MATERIALS AND METHODS**

Fifty implants were restored using computer-milled titanium or zirconia custom implant abutments25 followed by definitive ceramo-metal (for posterior implants) or full ceramic crowns (for anterior implants). Step-by-step procedures:

- (Clinical) Patients presented with straight healing abutments (Figure 1) and treatment removable partial dentures (Figure 2). All implants were restored by the first author (AK). All prosthetic restorations utilized recommended manufacturers’ components and protocols.
- (Clinical) After approximately 3 months of healing postsurgery, the healing abutment was removed and an impression coping was screwed into the internal connection of the implant and secured with a guide screw (Figure 3a).
- (Clinical) A periapical radiograph was made to confirm the appropriate fit of the impression coping to the implant platform (Figure 3b).
- (Clinical) Subsequently, an implant level impression was made using a polyvinyl siloxane material (PVS, 3M ESPE, St Paul, Minn) with the closed tray-impression technique. Facebow and interocclusal relationship were recorded at this time.
- (Clinical) After removing the impression coping and replacing the healing abutment, an implant replica was connected to the impression coping and inserted back into the PVS impression (Figure 3c).
- (Laboratory) Sufficient gingival mask silicon (Gingifast Elastic, Zhermack Inc, River Edge, NJ) was added around the impression coping and the implant replica to cover the coping-replica junction (Figure 4a).
- (Laboratory) A stone model was made from the impression using type IV stone (Resin Rock, Whip Mix Corp, Louisville, Ky).
- (Laboratory) After the stone had set, the impression was retrieved and the working cast trimmed and mounted on an articulator in maximum intercuspation (MI).
- (Laboratory) On the stone model, the gingival mask was modified using a round diamond bur to create the emergence profile of the missing tooth (Figure 4b).
- (Laboratory) A temporary abutment (plastic or titanium) was screwed into the implant replica and secured with the lab screw. A full contour tooth wax-up was made after any necessary modifications had been made to the temporary abutment (Figure 5).
- (Laboratory) A silicone index to the full-contour tooth wax-up and adjacent teeth was made at this stage. This silicone index will later be used in the fabrication of polymethyl methacrylate (PMMA) provisional crowns and subsequently will aid in fabrication of the definitive restorations (Figure 6).
- (Laboratory) A wax-up cut-back was made to create the finish line and final contour of the definitive custom abutment (Figure 7).
- (Laboratory) The abutment wax-up was then retrieved from the model and scanned with a digital scanner (Procera Piccolo Scanner, Nobel Biocare). Computer-assisted milling machine was used to fabricate either a milled titanium or milled zirconia custom implant abutment (Figure 8a and b).
- (Laboratory) The definitive custom implant abutment received from the manufacturer was carefully disinfected and checked for the appropriate emergence profile (Figure 8c). If a minor modification was required to the fitting surface of the abutment, the titanium custom abutment was subsequently highly polished with a metal polishing kit.
- (Laboratory) The definitive custom abutment was then screwed into the implant replica on the model and a provisional crown was made using PMMA (Figure 9).
- (Clinical) Approximately 2 weeks after the implant level impression was made, the patient returned for delivery of the definitive custom abutment and provisional crown. If necessary, local anesthesia was administered. Then, the straight healing abutment was removed and the disinfected custom abutment was screwed into the implant’s internal connection and torqued to 35 Ncm (Figure 10).
- (Clinical) The custom abutment’s screw access was filled with a cotton pellet soaked with chlorhexidine mouth rinse and blocked with a light-curing temporary resin composite (Fermit, Ivoclar Vivadent, Amherst, NY) (Figure 10).
- (Clinical) The PMMA provisional crown was then cemented with a zinc oxide-eugenol cement (TempBond, Kerr Corporation, Orange, Calif) (Figure 11). Excess cement was carefully removed from around the peri-implant mucosa. All the provisional crowns were placed in function with full contact in centric occlusion.
Approximately 2 weeks after the provisionalization stage, the patient returned for the abutment level impression. During the healing period, the peri-implant mucosa, guided by the emergence profile of the abutment, adapted to the custom abutment.

Next, the provisional crown was removed and remaining cement was cleaned off the definitive custom abutment. To retract the peri-implant mucosa, a single retraction cord (00") was packed around the custom abutment. The cord was left in place for five minutes and then removed immediately prior to making an abutment level impression using PVS impression material (PVS, 3M ESPE).

At this stage, standard crown and bridge laboratory procedures were followed to fabricate the definitive ceramo-metal or full ceramic crown (Figure 12).

Two weeks later, a definitive full ceramic or ceramo-metal crown restoration was cemented onto the abutment (Figures 13 and 14).

The occlusion was checked using 8 μm foil (Shimstock Occlusion Foil, Patterson Dental, St Paul, Minn) and the occlusion was adjusted so the foil could be withdrawn unless the patient closed under maximum intercuspation.
RESULTS

Clinical results

The criteria for implant success included stability, absence of a radiolucency around the implants, absence of peri-implant mucositis or inflammation, and absence of pain. No patients complained of pain, and there was no evidence of infection associated with any implants.

At the 12-month follow-up, all the implants had survived. No pain or final prosthesis mobility was recorded. The mucosa around the custom abutments was healed within normal limits and finely adapted to the definitive crowns (Figure 15). No mucositis or irritation was reported.

Radiographic results

Radiographic evaluation was performed at the provisional stage (Figure 16a) and 12 months after placement of the definitive restoration (Figure 16b). A radiograph showing the emergence profile as transferred to the implant by the custom abutment was recorded (Figure 16c). Vertical bone resorption was not clinically significantly different between the stages of the treatment.
FIGURES 11–15. **Figure 11.** Polymethyl methacrylate provisional crown reported after cementation. **Figure 12.** Standard crown and bridge laboratory procedure were followed to fabricate the definitive crown restoration. **Figure 13.** Peri-implant mucosa adapted to the custom abutment guided by its emergence profile. **Figure 14.** The final crowns after cementation. **Figure 15.** The fully healed mucosa around the definitive crown reported after 1 year in function.

**FIGURES 16–18.** **Figure 16.** Radiographs. (a) Titanium custom abutment at the provisionalization stage. (b) At 12 months at placement of the definitive restoration. (c) Showing the emergence profile that has been transferred to the implant via the custom abutment. **Figure 17.** The patient was satisfied with the esthetic outcome. **Figure 18.** Custom abutment can correct implant misalignment.
**Esthetic results**

An important esthetic outcome was whether or not papillae had reformed around the custom abutment and the definitive crown. Two other outcomes were whether papillae had changed position and whether papillae had reformed around the emergence profile of the custom abutment. All 3 of the esthetic outcomes were achieved in all patients. Clinically, all soft tissues appeared pink and healthy (Figures 14 through 16). All patients were satisfied with the final esthetic outcomes (Figure 17).

**DISCUSSION**

Many patients, especially those who need implant prosthesis in the maxillary anterior area, choose implant treatment in hope of better esthetics. This report describes a simplified technique to create an emergence profile that will improve the esthetic outcome of the implant restoration. Esthetic success requires an adequate volume of bone, and a sufficient quality and appropriate volume of soft tissue. Natural appearing adaptation of peri-implant mucosa to and around the restoration is critical to achieving an aesthetic result. Because of the larger exposure of teeth and gingival tissue, restoration of high-smile line patients is more challenging due to the high esthetic demand. The location of the implant, the relationship of the implant/abutment interface, and the crestal bone around the implant determine whether there will be enough support for the gingival tissue surrounding the implant crown. To achieve an acceptable esthetic result, the mesiodistal and buccolingual implant position and angulation in the residual alveolar ridge, the minimal interocclusal distance, and the maximal interproximal contact point to crestal bone distance each must approximate 6 mm.

To achieve an optimum esthetic result with implant restorations, the peri-implant soft tissue should be modified to create an appropriate emergence profile and natural contour at the provisional stage. The implant’s apico-coronal position should be 3–4 mm below the gingival line to make room for an emergence profile that aligns well with the adjacent gingival level. Also, the implant’s mesiodistal position should be at least 1 mm from a natural tooth and at least 3 mm from another implant.

Soft tissue management can be performed before implant placement, during stage 1 surgery, during stage 2 surgery, or after the restoration is placed to increase the amount of keratinized tissue and preserve the papilla. The bone around adjacent teeth promotes papilla development, demonstrating why papillae are more likely to be associated with single-implant restorations than multiple-implant restorations. Several investigations have reported that if the distance from the bone level on the adjacent tooth to the contact point is less than 5 mm, papillae are more likely to reform. In one study, there was an average of 30% increase of the volume of the papillae 1 year after prosthesis insertion. In most cases, papilla spontaneously regenerated after a few years in function. Despite improved surgical techniques that have been recently developed, the factors that encourage regeneration of papillae adjacent to dental implants are still a matter of debate.

Custom abutments can be used to correct implant angulation (Figure 18), and along with provisional crowns, can improve the implant restoration’s emergence profile. Peri-implant soft tissue manipulation is possible if the implant is deep enough and the proper gingival biotype is present. A gradual transfer from the profile of the implant platform to a natural emergence profile can be easily created using a customized implant abutment and implants that are placed 3–4 mm subgingivally in a thick soft tissue biotype. Shallow implants that are associated with a thin peri-implant soft tissue biotype will make it difficult to create a satisfactory emergence profile, and consequently, successful esthetic outcomes will be more difficult to achieve.

There are several CAD/CAM technology systems that can be used to develop esthetically natural-looking implant restorations. To minimize undesirable stress concentrations, computer-milled custom abutments must fit accurately. There have been several investigations of the fit at the interface between implants with different internal connections and titanium or zirconia CAD/CAM computer-milled custom abutments. Microscopic evaluation of internal systems connected to titanium or zirconia abutments show that the implant-abutment interfaces are well sealed under no-loading conditions. A tight interfacial contact is desirable to maximize mechanical stability of abutments and prosthesis. In any case, because poor adaptation at the implant-abutment interface might produce biological and mechanical complications, it seems desirable to have as close a marginal fit as possible. The customization possible with CAD/CAM abutments allows for more refined prosthetic designs and enhanced soft tissue contour. It is expected that refined designs will make possible implant-supported restorations that are more esthetic, biologically compatible, and durable.

**CONCLUSION**

Optimal esthetic implant restorations depend on thorough presurgical planning, accurate three-dimensional implant placement, careful soft tissue management, and proper provisional restorations. When titanium and zirconia custom abutments are used at the provisional crown stage of implant construction to modify the emergence profile and natural contour, implant restorations exhibit excellent esthetics and healthy gingival tissues. Since the probability of successful restoration depends on several anatomy-dependent factors, each patient should be counseled about the likelihood of success in his or her particular case.