Virtual Abutment Design: A Concept for Delivery of CAD/CAM Customized Abutments—Report of a Retrospective Cohort

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This report presents early clinical experiences with the treatment of a consecutive cohort of 89 patients who received 125 prostheses supported by 205 milled abutments. Abutments were fabricated using unique computer-aided design software to deliver both titanium and zirconia abutments based on idealized values for tooth dimensions and emergence profiles as well as on a scan of the proposed definitive prosthesis. (Int J Periodontics Restorative Dent 2013;33:51–58. doi: 10.11607/prd.1272)
milling techniques, which do not rely on the CAD principle. Numerous articles have been published on the precision of fit of CAD/CAM abutments as well as their fatigue resistance. The majority of these have focused on the zirconia abutment, while a few have focused on titanium and alumina abutments. Most of these studies have identified notable or significant issues with tolerance of fit between the implant and abutment, as measured by microgap and rotational misfit. Alumina was shown to be less accurate than titanium and zirconia, although titanium was not as precise when accuracy of fit was measured after dynamic loading. Nonetheless, almost all of these studies concluded that both tolerance of fit and fatigue resistance were within clinically acceptable limits.

One of the more recent systems to be introduced into the market is the Atlantis system, which offers a multiplatform range of CAD/CAM-milled abutments for a variety of different implant systems. To date, other than a few case reports, little has been published on this system, and no information is present within the literature regarding the CAD technology (Virtual Abutment Design [VAD], Astra Tech) used to create the optimal abutment morphology, which can then be milled in either titanium, TiN-coated titanium (Gold Hue), or zirconia. The purpose of this article is to present this technology and report on the early clinical experiences with its use at five different centers.

Method and materials

VAD technology

VAD technology centers on a philosophic belief that the morphology of an abutment should be determined by the morphology of the restoration it is intended to support. The CAD process achieves this by requiring articulated master casts incorporating a silicone soft tissue mask, implant analogs, and a removable diagnostic wax-up of the proposed definitive restoration, which is an absolute requirement when there are four or more adjacent implants.

Scans of the diagnostic wax-up allow transfer to the digital environment. The software has many built-in parameters based on generic information of tooth dimensions and form, which are used to help in the design of an optimal tooth/site-specific abutment.

The scanned diagnostic wax-up is converted into a lattice scaffold, within which the abutment design is developed by the CAD operator (Fig 1). Manual alteration of the abutment can be affected by a variety of parameters dictated by the clinician or CAD operator. These include emergence profile, margin placement, retentive properties, abutment form and length relative to the planned restoration, and occlusion. The restorative space between the proposed abutment and occlusal surface is generically set within the software according to standard recommendations for porcelain-fused-to-metal restorations; however, this measurement is subject to a prescriptive override if necessary. In addition, there is a minimum abutment height set as a default within the software to ensure adequate retention. If lim-
ited occlusal clearance results in a reduction of abutment height below this critical limit, authorization from the clinician/laboratory technician to override this default is required. With regard to buccal-lingual and mesiodistal dimensions, the horizontal space is highly regulated by the minimum dimensions and thickness required for the abutment material. The core wall must have a certain thickness to ensure strength, and this will also influence the shoulder width for narrower situations. The size of the blank is the principal determinant for the maximum size of an abutment.

**Emergence profile**

The emergence profile is often determined by the size and form of the healing abutment and is typically cylindric (Figs 2a and 2b), unless an anatomical healing abutment is used or, more typically, a provisional crown is used to develop the soft tissue profile (Figs 3a and 3b). The need to transfer this soft tissue profile within the impression has been stated previously and typically requires customization of the impression coping using pattern resin to capture the contour and form of the mucosal sulcus space, which can be achieved extraorally prior to taking the intraoral impression (Figs 4a and 4b).

It is also possible to develop the emergence profile by anatomically contouring the definitive abutment itself. Either way, the need to contour the submucosal portion of an abutment is critical not only to the emergence profile and soft tissue health but also to establish a good cervical anatomy that enhances esthetics and reduces the risk of trapping food. To this end, the software uses three classic anatomical shapes (triangular, ovoid, and square) that are determined by tooth position (ie, square for
molars, ovoid for premolars, and triangular for incisors), and four options are available to allow for increased soft tissue support (Fig 5). The choice of emergence profile is made by the clinician. The four options are:

1. No tissue displacement. The CAD abutment will have a form that matches the sulcus space captured in the impression, with a diameter that falls 0.05- to 0.2-mm shy of the scanned diameter. This ensures that there is no pressure on the soft tissues.
2. Support soft tissue. This mediates a moderate anatomical shape to the abutment up to 0.2 mm wider than the scanned tissue aperture.
3. Contour soft tissue. This is the default option and provides an anatomical geometry with up to 1.0 mm of pressure against the mucosal cuff.
4. Full anatomical dimensions. This option is considered to offer the best emergence profile since the geometric form and diameter are dictated by the specific tooth being replaced.

Margin location
The location of the margin is of significant concern due to the risk of cement-induced peri-implantitis, which may occur with deeper margins and excess cement when using stock cylindric abutments in which the interproximal and palatal margins are typically 1 to 2 mm

Figs 4a and 4b  The submucosal form can be captured in an impression flask and used to customize implant-level impression copings using pattern resin. These can then be used during the master impression without risk of losing support to the tissues or the emergence profile.

Fig 5  Submucosal form is determined by the degree of soft tissue support.
deeper than the labial margin. This can result in bone loss and a compromised clinical outcome. A recent study demonstrated that a number of cements typically used with implants are not even evident on radiographs, thereby compounding the problem. To address this issue, the CAD software recognizes the digital soft tissue margin from the gingival mask on the master model and by default places the buccal restorative margin 1.0 mm subgingivally, the interproximal margins 0.75 mm subgingivally, and the palatal/lingual margins 0.5 mm subgingivally. This default setting can be altered by the clinician/laboratory technician to prescribe the desired position.

All of the information is processed as JPEG images and sent to the laboratory technician for final approval prior to milling of the abutments. These images offer a variety of views with and without masking of the diagnostic wax-up so that details regarding the abutments, their profile and margin locations, as well as how they relate to the overlying diagnostics can be appreciated (Fig 6). The final abutments are then milled to these exact specifications (Fig 7). The impact of the submucosal profile, tissue contouring, and margin location can be immediately appreciated in the definitive abutments (Figs 8 to 10).

In consideration of the definitive restorations, the use of CAD/CAM copings adds further poten-
tial accuracy to the overall restorative result.\textsuperscript{26–28} Currently, copings are not offered with their respective abutments, and this remains a weakness in the system. Nonetheless, the fact that a suprastructure can be fabricated directly on the abutments ensures that the fit of the restorations is excellent and can be readily appreciated both clinically (Fig 11) and radiographically (Fig 12).

Milled grooves can also be added upon request to optimize retention of the precisely fitting suprastructures.

Data acquisition

Five centers took part in gathering data for this pilot study. A total of 89 consecutively treated patients (36 men, 53 women; mean age, 52.3 years) received a total of 125 prostheses supported by 205 Atlantis abutments, all on Astra Tech implants. Thirty patients were reported to have a predisposing periodontal condition, and 25 patients were smokers. The only inclusion/exclusion criteria were that the patients presented with successfully osseointegrated implants and were planned for cement-retained restorations. There were no restrictions in choice of abutment material or selection of any of the values for the emergence profile or margin placement. These matters were determined by the individual clinician according to the specific demands for each individual implant. In this way, it was felt that the clinical efficacy of the system was being tested in its “as used” rather than experimental state. To this end, no calibration of the examiners was indicated or appropriate.

All tooth positions were included in this pilot group, with 49 mandibular implants (15 incisors, 2 canines, 13 premolars, and 19 molars) and 156 maxillary implants (45 incisors, 16 canines, 58 premolars, and 37 molars). Implant diameters restored were 3.0 (n = 11), 3.5 (n = 68), 4.0 (n = 58), 4.5 (n = 55), and 5.0 mm (n = 13), and lengths ranged from 6 to 17 mm, with the majority being 9 (n = 42), 11 (n = 59), or 13 mm (n = 60).

With respect to material of the Atlantis abutments, 149 were milled in titanium, 32 in zirconia, and 24 in titanium Gold Hue. These abutments were used to support 54 porcelain-fused-to-metal single crowns, 31 all-ceramic single crowns, 5 all-ceramic fixed partial dentures (FPDs), 34 porcelain-used-to-metal FPDs, and 1 metal-acrylic FPD.

The span length for porcelain-fused-to-metal FPDs varied from 2 to 12 units supported by 2 to 7 abutments. The span length for all-ceramic FPDs varied from 3 to 5 units supported by 2 to 3 abutments. The single three-unit metal-acrylic FPD was supported by 3 abutments.

All 125 restorations were in function for 6 to 28 months, with a mean of 15.5 months.

All abutment types were used in all regions of the mouth (ie, incisor,
canine, premolar, and molar regions), including the use of zirconia abutments for molar restorations.

Data were collected on any adverse events that occurred during the provision, application, or clinical function of these abutments.

Results

To date, there have been no recorded abutment or screw fractures, with only one episode of abutment screw loosening at a mandibular first molar site where a 3.5-mm-diameter implant was restored using a titanium Gold Hue abutment. In addition, loss of cement retention was noted for only two crowns supported by zirconia abutments and one FPD cemented to titanium Gold Hue abutments. The only other adverse event was one case of discrepancy between the clinical position of an abutment and the premilled abutment design. It was unclear how this discrepancy occurred, but it is likely that either the impression coping or abutment replica had been seated incorrectly.

Discussion

The use of CAD/CAM technology is defined by the computer design process, and as such is more sophisticated than the copy milling technique. The VAD software used in the fabrication of the 205 abutments appears to meet this definition. The significant advantage of only having to take an implant-level impression without needing any knowledge of abutment options or designs means that such technology brings the restoration of implants within the remit of most general practitioners and ensures that the restorative work is completed to the highest of standards.

In the authors’ experience, this abutment system has proven to be consistently reliable and predictable based on an initial pilot study of 205 abutments used to restore implants for both single crowns and FPDs. The software can be used with eight other systems (BioHorizons, Biomet 3i, Camlog, Friadent Xive, Keystone Dental, Nobel Biocare, Straumann, and Zimmer). However, it is not within the confines of this study to confirm the reliability of the abutments for use with these systems, and this certainly warrants separate and further studies.

While this system can be recommended for clinical use, longer-term data and an ongoing audit of specific soft tissue responses as measured by pocket depth, bleeding on probing, and other well-recognized indices along with the reporting of any adverse events (in particular, rates of peri-implant mucositis or peri-implantitis) would be a valuable addition to the literature.

Acknowledgment

The authors reported no conflicts of interest related to this study.

Fig 12  Radiograph demonstrating excellent crown/abutment marginal fit and a propitious marginal bone response.
References