

EDITOR'S NOTE: As of the printing date of this publication, the Ankylos SynCone and Cercon abutments were not yet approved for use in the United States. Ankylos implants are approved for single stage surgical placement and immediate loading in the United States, but immediate loading is restricted to the anterior mandible, based on 4 intraforaminal placed implants, and is not indicated for single, unsplinted implants.

## NEW PROSTHETIC RESTORATIVE FEATURES OF THE ANKYLOS IMPLANT SYSTEM

Paul Weigl, DMD

### KEY WORDS

Clinical studies  
Dental implants  
Endosseous  
Implant design  
Implant abutment joint  
Abutment design  
Biologic width  
Soft-tissue management  
Implant-borne removable  
dentures

**Problem:** All oral implant systems rely on the abutment part of the implant to provide stability for the dental prosthetic. The Ankylos implant offers precisely machined, tapered-cone abutment (Morse taper) connection. This tapered abutment connection provides high resistance to bending and rotational torque during clinical function, which significantly reduces the possibilities of screw fracture or loosening. **Purpose:** This report describes the design and mechanical construction characteristics of the Ankylos implant system that make it possible for the system to provide final restorations that are natural looking, esthetically acceptable, durable, and cost effective. **Methods:** Review of the clinical literature. **Results:** The clinical results of single-tooth crowns borne on Ankylos implants in the lateral tooth region are excellent after a minimum of 5 years in function (mean = 6.3 years) compared with the high prosthetic complication rate with other systems. Abutment loosening occurred in only 1.3% of the 233 innovative implants restored with crowns that were designed with a physiologically shaped occlusal surface. **Conclusion:** This implant system is exceptionally well suited for use in the restoration of missing natural teeth.

### INTRODUCTION

Implants are widely used to support and retain both fixed and removable dental prostheses. Rapid technological advances along with the wide use of implants in dentistry have resulted in a variety of different implant systems. All systems are based on the principle that a part of the implant (the abutment) rises into the oral cavity to support or retain the prosthodontic restoration. The construction and design of these prostheses and the procedures

used to fabricate them depend on the design features that are characteristic to each implant system. In addition to the basic function of providing anchorage for a prosthetic restoration, there are other requirements of an implant design that are also essential to the production of clinical restorations of excellent quality. The implant design should facilitate (1) the development of physiological contours with implant-supported fixed dentures identical to those obtained with natural-tooth anchored crowns and bridges; (2) the

Paul Weigl, DMD, is an assistant professor in the Department of Prosthetic Dentistry at J. W. Goethe-University Frankfurt am Main, Theodor-Stern-Kai 7, Building #29, 60590 Frankfurt am Main, Germany.

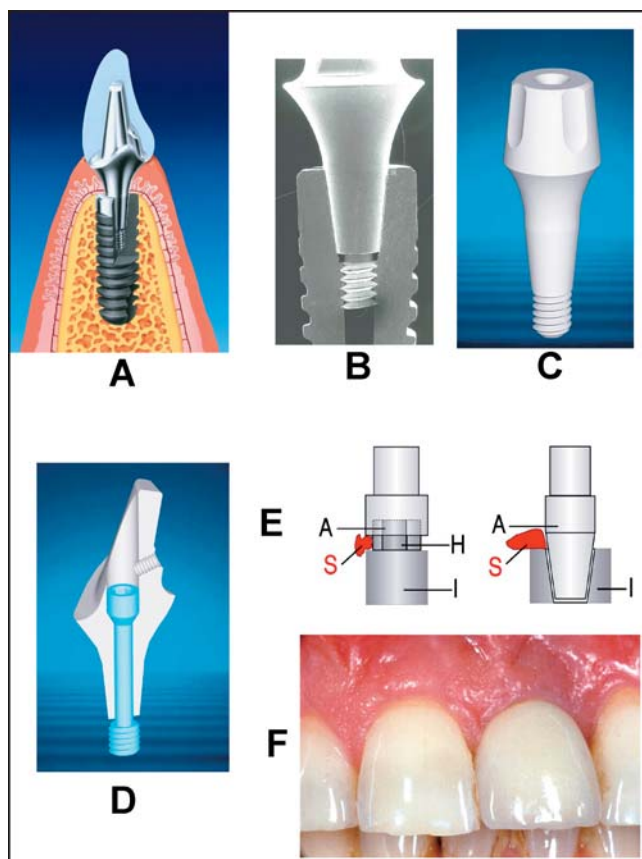


FIGURE 1. (A) The innovative implant-abutment connection encourages the development of a thick layer of soft tissue around the small diameter of the implant abutment and the flat top of the implant fixture. The formation of the horizontal biological width is graphically illustrated. (B) The cone shape of the implant-abutment connection transfers horizontal forces over a wide area of the implant. The connecting abutment screw is loaded in a vertical direction only. The flat shoulder of the implant fixture supports the thick mucosal layer. (C) The 1-piece standard abutment of the Ankylos implant system. (D) The 2-piece balance abutment with a center tightening screw (zirconium oxide shown; titanium is also available). Abutment can be rotated to the desired position and fixed to that position by tightening the central screw (Note: screw rotates within a sleeve inside of the abutment and cannot be dislodged from the abutment). (E) The tapered-implant abutment connection prevents the trapping of soft tissue between the abutment and the implant, which can occur in many 2-piece flat hex implant-abutment connections (A = abutment, I = implant, H = hexagon, S = soft tissue). (F) Actual clinical case showing the interdental papillae that has formed.

fabrication of final restorations with esthetics that are highly acceptable; (3) restorations of high-strength and long-term durability; and (4) the fabrication of highly cost-effective and highly functional restorations for missing natural teeth. The new and innovative Ankylos implant design (Friadent GmbH, Mannheim, Germany) makes all of these easy to produce. This paper will focus on the special characteristics (de-

sign and mechanical construction) of the Ankylos implant system that make it possible to meet these requirements in the fabrication of high-quality dental prostheses.

#### IMPLANT-ABUTMENT INTERFACE DESIGN

The Ankylos implant system has a unique transition from the implant body to the prosthetic

abutment. The cross section of the abutment is smaller than the width of the top of the implant because of the tapered implant-abutment connection (Figure 1A). The conical male component is attached to the female (internal cone matrix) by a central screw, thus achieving a "key-to keyhole" fit within the tapered connection. The precise  $4^\circ$  taper of the cone produces a considerable amount of frictional retention between the tapered abutment and the implant. This friction is more than adequate to provide antirotation properties for the abutment during clinical use.

The abutment fixation screw, which is generally the weakest component of other implant systems, is completely protected against overloading. If horizontal forces are transferred over absolutely form-fitting joint surfaces of this precision-tapered conical abutment connection (Figure 1B), any strain on the central running fixation screw is eliminated. In engineering, the conical connection is among the most preferred connections for applications requiring the transfer of high transverse forces. The Ankylos implant capitalizes on conical technology to maximize the advantages of this new implant design over the more conventional implantabutment designs. These advantages include (1) the precision-machined conical taper connection of the implantabutment joint produces a high level of mechanical stability under all clinical loading conditions that involve nonaxial loads applied to the abutment; (2) horizontal bending forces are evenly distributed over the entire abutment connection; and (3) the strain on the central fixation screw is significantly reduced when the implant-abutment is loaded.

The cone angle is precisely machined so that twisting the

components together by hand eliminates the space between the implant and the abutment. This joint generates enough frictional retention to make removal of the abutment from the implant extremely difficult. In the Ankylos tapered abutment connection, the abutment screw provides retention only during abutment placement. The frictional retention within the tapered connection retains the abutment once it has been seated. Some implants use steeper cone angles than that of the Ankylos implant and the abutment is hammered into the implant,<sup>1</sup> which makes it extremely difficult or impossible to change the abutment or transfer the orientation of original abutment in the mouth to the master laboratory cast.

#### ABUTMENT DESIGNS

There are 2 types of abutment designs manufactured for this new implant design: the 1-piece standard abutment (Figure 1C) and the 2-piece balance abutment (Figure 1D). Each abutment is available in titanium or zirconium oxide and is designed for specific prosthetic applications.

##### *Standard abutment*

The 1-piece standard abutment consists of (1) a threaded end section to tighten the abutment into the implant; (2) the tapered conical male section to stress distribution; and (3) the actual prosthetic functional part (eg, snap attachments, post for a crown, etc). The abutment is mounted onto the implant with a torque wrench. For cases involving a few missing natural teeth, the clinical and laboratory procedures are similar to those used for conventional crowns and bridges on natural teeth. In the case of full-denture replacements, specialized

abutments are available for snap attachments as well as magnet attachments for retention.

The standard abutment is mainly designed for use in the lateral tooth region where it is rarely necessary to alter the shape of an abutment in order to optimize the esthetic outcome. To transfer the relationship of the abutment in the mouth to the working laboratory cast, exact-fitting impression caps are placed on the abutments and an impression taken. Abutment analogs are carefully positioned in the impression caps within the impression, and a stone cast is poured. In some cases it may be necessary to reduce the top facial part of the abutment to provide room for the veneering layer of a porcelain-fused-to-metal restoration to improve esthetics. This can be done intraorally, or the dental technician can reduce the abutment replica on the working cast and fabricate a transfer index, which indicates the volume and location of the material that must be removed from the abutment by intraoral grinding.

The standard abutment is fabricated in 1 piece and can withstand the enormous loads that are common for single premolar and molar crowns of patients, even when there is evidence of excessive bruxism. The fatigue resistance of this abutment-implant interface is high. After cyclical loading at 100 N, a force applied perpendicular to the long axis of the implant failed to produce any evidence of loosening or fracture of the abutment. This abutment is considerably less expensive than a 2-piece balance abutment because fewer steps in manufacturing are required.

##### *Balance abutment*

The balance abutment is a 2-piece abutment that replaces the inte-

grated thread of the 1-piece abutment with a fixation screw that runs through its center (Figure 1D). The fixation screw can be rotated to tighten that abutment without moving it. This unique feature permits the angulated 2-piece abutment to be positioned in any clinically appropriate position. Once positioned, the abutment is secured in that position by tightening the screw to prevent any movement. Therefore, an asymmetrical abutment line is possible, too, closely simulating the size and shape of the natural tooth after tooth preparation (Figure 1D).

The 2-piece abutment can be optimally aligned on the working laboratory cast for the planned restoration (Figure 2A). Its shape (asymmetrical abutment line) reduces the time required by the dental technician to orient and shape the abutment compared with the 1-piece standard abutment shown in Figure 1C. This is a major advantage, especially if the abutment is made of dense, hard zirconium-oxide ceramic. In large clinical cases involving multiple abutments with splinted castings (superstructures), the angled abutments can be rapidly aligned parallel to each other without extensive mechanical shaping. During manufacturing, the thread of the fixation screw for the 2-piece abutment implant system is not cut into the screw shank, which would tend to reduce the mechanical strength of the screw; instead, a screw shank is placed through a central hole in the angle abutment, a sleeve is placed on the end of the screw shank, and they are laser welded together. The thread is incorporated within this sleeve (Figure 1D). Unlike many other abutment retaining screws, this unique manufacturing process makes it impossible

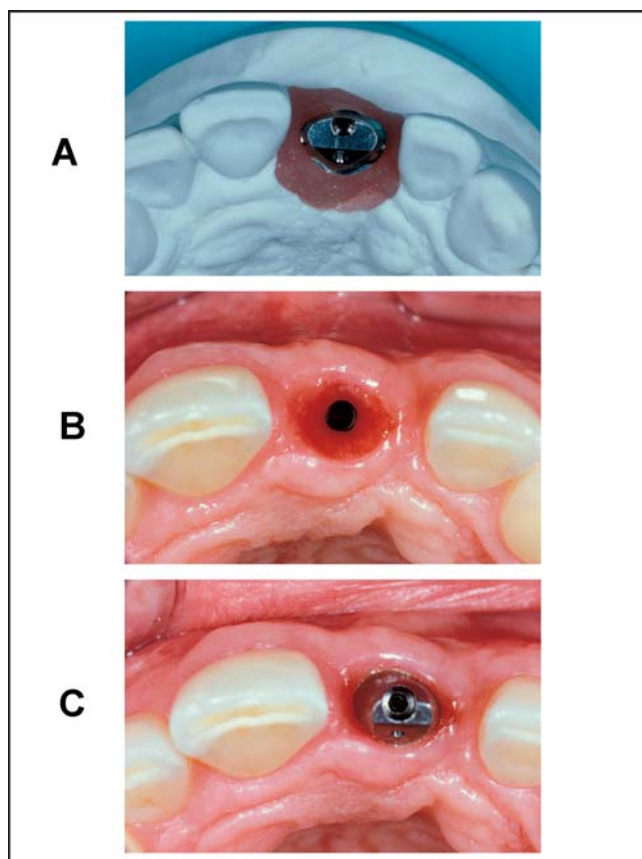


FIGURE 2. (A) Master laboratory cast with 2-piece balance abutment that has been modified to fit the dental arch and provide space for the development of an esthetic restoration. (B) Same clinical case as shown in (A). Note the emergence (biological width) profile evident in soft tissue and that the top of the implant is not visible because the soft tissue covers the top of the implant fixture. (C) Same clinical case from occlusal view, with abutment in place.

for the screw to be separated from the abutment and lost.

The 2-piece abutment is specifically designed for crowns or bridges on implants that may require modification of the size or shape of the abutment for esthetic reasons (Figures 2A through C and 3A through C). The intraoral position of the implant must be accurately transferred to a master working cast with impression abutments mounted on the implants and their relationship recorded with an accurate impression. Implant analogs are positioned in the impression, and a working cast is poured. The required modification process

can then be easily completed in the dental laboratory on the master working cast. The dental technician selects the appropriate abutments and positions them in the implant analogs on the master cast. He or she then completes the final restoration and verifies the accuracy of fit and esthetics on the working master cast.

The restorations are then ready to be returned to the treating dentists to verify their fit, form, and esthetics in the mouth. To transfer the exact position of the 2-piece abutments from the master cast to the patient's mouth, a transfer key is made of resin (Figure 4A). When the res-

toration is initially positioned in the mouth to verify the acceptability of the restoration, it is not necessary to tighten the fixation screw because the precision fit of the tapered abutment connection provides all the initial retention needed. If the restoration is determined to be satisfactory, the fixation screw can be fully tightened without movement of the 2-piece abutment. In the case of bridges or splinted crowns, their metal frame can be used instead of the transfer key as a means of transferring the relationship of the abutments from the laboratory working cast to the mouth.

#### CLINICAL IMPACT OF THE NEW ABUTMENT-IMPLANT INTERFACE DESIGN

The design of the Ankylos abutment (Figure 1A and B) offers several clinically important advantages over conventional 2-stage screw-retained abutment systems: (1) physiologically shaped occlusal surfaces; (2) unsplinted single-tooth crowns; (3) wide variety of options used to attach the prosthesis to the abutment; and (4) improved esthetics.

#### *Physiologically shaped occlusal surfaces*

The function of the occlusal surfaces of implant-supported dentures is similar to those of the natural teeth (ie, the achievement of maximum chewing efficiency with minimum force and the protection of the periodontics of the antagonists and the jaw joint from misapplied loads). The major difference is that the implant is retained in the bone ankylotically whereas the natural tooth is retained by the periodontal ligament. Animal studies by various groups<sup>2,3</sup> have demonstrated that horizontal-force com-



ponents on superstructures do not cause any histological changes in the bone-implant interface when compared with a control group. Clinical studies<sup>4</sup> confirm that there is no statistically significant difference between angled and straight abutments in long-term success prognosis of implants.

The mechanical load capacity of implant systems is direction dependent. Most 2-component, screw-retained abutment systems are sensitive to forces acting horizontally on the abutment if the mechanical load-bearing capacity of the implant-abutment connection point is low. The study by Mollersten et al<sup>5</sup> showed that implant systems with their short external hexagon (3i, Brånemark, London, UK) performed particularly poorly. This low mechanical load capacity at the abutment connection has led to the establishment of specific concepts in occlusion for implant prosthetics with the goal of protecting the implant from mechanical overloading that would contribute to subsequent component failure.

Clinically, the highest mechanical loads on an implant occur with unsplinted molar crown restorations. Currently, the mechanical strength of the many types of screw-retained implant-abutment connections is too low<sup>5-9</sup> and screws frequently loosen or break. In addition, this can lead to fracturing of the implant. To reduce the horizontal load, the occlusal surface shape that is recommended today<sup>10</sup> has a reduced orovestibular (buccal lingual) extension, a flat cusp angle, and a dynamic occlusion on the laterotrusion side. The conical implantabutment connection of this new implant has particularly high strength in the horizontal direc-

tion, which permits the development of a physiologically dimensioned occlusal surface (Figure 4). The cusp angle of an implant-supported crown is defined exclusively by anatomic determinants, and in some circumstances it can be very steep. Cuspid guidance can also be developed with implant-supported cuspid crowns.

#### *Unsplinted single-tooth crowns*

Crown and bridge prostheses, with their intermediate connections, are difficult to clean and are subject to trapping food under the connectors. Unsplinted single-tooth crowns simulate missing teeth far better than do crown and bridge restorations. If there is

adequate bone volume, every missing tooth should be considered for replacement by an implant restored with a single-tooth crown (Figure 4A through D). If augmentation measures are required to increase the bone volume, a risk-benefit analysis should be completed to compare other possible treatment options, such as an implant-borne or tooth- or implant-supported connecting bridge.<sup>11</sup>

The splinting of implant-supported single-tooth crowns makes it difficult to maintain an acceptable level of hygiene; however, the splinting does help prevent the horizontally directed load peaks on the individual implants. This insight<sup>8</sup> is confirmed by the clinical behavior of implants with low

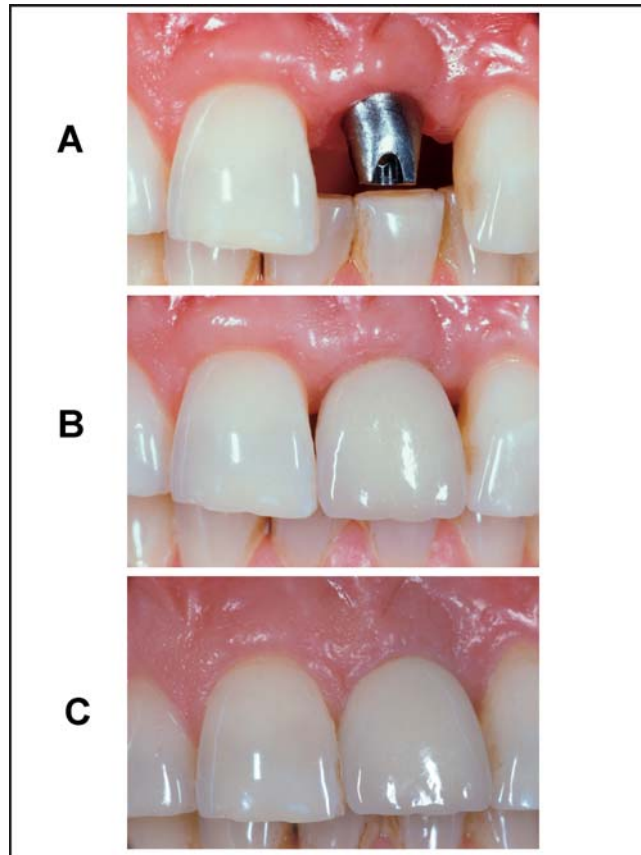


FIGURE 3. (A) Same clinical case (shown in Figure 2) from facial view. (B) Same clinical case after insertion of the final crown. (C) Same clinical case showing the interdental papillae that has formed and still remains after more than 5 years of clinical function.

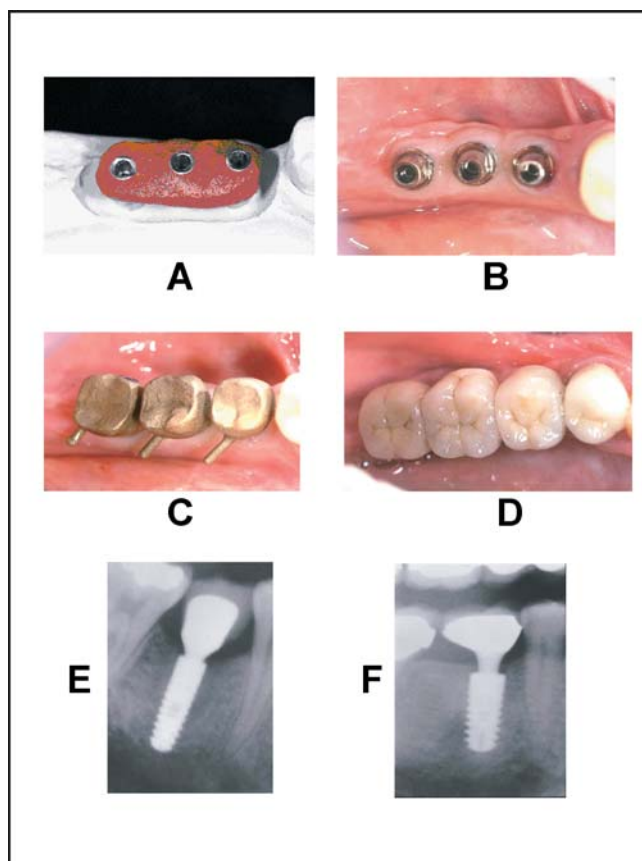


FIGURE 4. (A) Balance posterior abutments on master laboratory cast positioned within resin index. (B) Assembled balance abutments in mouth after their relationship has been transferred from the master cast by using the resin index. The central screw has been tightened to retain the abutments in a clinically acceptable position in the mouth. (C) Completed castings in the mouth to verify accuracy-of-fit and relationship within the dental arch. (D) Completed porcelain-metal restorations. (E) Tissue response to single crown replacing natural molar tooth. (F) Another clinical case with implant restoration replacing molar after 5 years of clinical function. Note the excellent bone and soft-tissue response in both (E) and (F).

mechanical strength.<sup>9</sup> In cases with missing single molars, prosthetic complications (screws loosening and breaking) have been reduced from 48% to 8% with the insertion of 2 Brånemark implants.<sup>12</sup> This type of molar restoration, however, is difficult to clean (simulation of a furcation), complex, expensive, and, above all, unnecessary if a high-strength implant is used instead of low mechanical-strength implants.<sup>13</sup>

Prosthetic applications that have the potential of producing high horizontal loading of the implant, such as single-tooth

crowns in the lateral dental region in patients with bruxism, require the use of an implant system with very high mechanical strength if splinted superstructures are to be avoided. High mechanical strength is primarily derived from an implant-abutment connection that can withstand a high nonaxial load, such as the strong and precise connection of this innovative implant system. At the J. W. Goethe University in Frankfurt/Main, Germany, all implant-borne prosthodontics are followed up every 6 months and the clinical perfor-

mance parameters are recorded in a database. The clinical results of single-tooth crowns borne on Ankylos implants in the lateral tooth region are excellent after a minimum of 5 years in function (mean = 6.3 years) compared with the high prosthetic complication rate with other systems.<sup>6,7,9,12</sup> Abutment loosening occurred in only 1.3% of the 233 innovative implants restored with crowns that were designed with a physiologically shaped occlusal surface. This very small complications rate is extremely important to note because 10.2% of the implants belonged to patients with pronounced bruxism. Bruxism does not represent a contraindication for the use of implant prostheses when implant systems with high mechanical stability are used. Even when a patient has a malocclusion, the implants have withstood extra-axial loads for years.

#### *Retention method of prosthesis*

The problem of the abutment loosening with the tapered abutment connection used in this new implant system is very rare. Compared with retaining the prosthesis with screws, cementation has the distinct advantage of not involving gaps between the abutment and the prosthesis, which are almost impossible to clean. Cemented prostheses are (1) technically simpler; (2) can be fabricated more economically; and (3) require less clinical expertise than do restorations retained with screws. Functional or esthetic problems with implant-abutments retained by an axial central screw can be eliminated with cementation (Figures 3B and C and 4D). The use of a transverse retaining screw to retain a crown requires an additional amount of alloy in the region of the screw

head. This produces overcontouring of the restoration and creates the possibility of future periodontal problems. The disadvantages of cementation include (1) losing access to the abutment screw if it becomes loose (this is not a major problem with the conical implant-abutment connection used in this implant system); (2) having limited access to the peri-implant soft tissue; and (3) having difficulty in the expansion of the prosthesis, if it becomes necessary, in the future. These can be countered by the use of a temporary cement, in which case retention is generally sufficient for several years. Permanent cementation is necessary only for tooth- or implant-supported connecting bridges.

### *Esthetics*

Because of the design of the tapered abutment connection of this new implant system, an enhanced volume of connective tissue forms around the submucosal neck of an abutment (Figure 2B). Because of the small cross section of the abutment, this thick layer of soft tissue covers the dark gray titanium of the neck of the abutment. The thickness of the vestibular part of the mucosa collar can be preserved by using a tilted 2-piece abutment or by milling the facial margin of the standard abutment to gain additional vestibular space. As a result, the mucosa apical to the margin of the restoration will have a healthy pink, normal appearance. The esthetics of conventional 2-stage implants are sometimes less than satisfactory as a result of the thin layer of soft tissue covering the apical part of the implant-abutment. To resolve this problem, an expensive all-ceramic abutment must be used if available.

The emergence profile of a crown that develops during healing depends not on the diameter of the implant shoulder but on the shape of the abutment (Figures 2B and C and 3A through C). The crown margin on the abutment can be extended apically to a distance of about 1 mm from the implant shoulder to provide additional space for the soft tissue. Even with a small thickness of soft tissue covering the crestal bone, it is possible to achieve a natural emergence profile with this implant. The implant must be inserted slightly below or even with the crestal-bone level to allow development of a mucosal layer that is as thick and wide as possible.

The vertical height of bone around an implant depends largely on the formation of the biologic width at the abutment-implant interface<sup>14,15</sup> to provide space for the connective tissue. Animal experiments<sup>14,16</sup> have shown that with conventional platform-sized abutments the marginal (crestal) bone loss is between 1.5 and 2.0 mm. There are two potential reasons for this crestal bone loss: (1) Anaerobic pathogenic organisms tend to become established in gaps or in the open spaces of some 2-stage implant system. This is especially true if these spaces are exposed to the oral environment and act as an exit for the developing bacterial toxins or corrosion products; (2) cyclical forces developed during chewing cause micromovement between the implant and the abutment as a result of these gaps in the implant-abutment joint designs. This movement also tends to prevent bone formation in the area.<sup>17</sup> Chou et al<sup>18</sup> have documented no major crestal bone loss (0.2 mm/y from the time of implant placement to 36 months) for this new implant system.

The unique abutment design of the Ankylos system contributes further to the formation of the healthy biological width because the area between implant shoulder and abutment is not exposed on the peripheral contour next to the bone (Figure 1A and B). The biological width, which represents the distance between the bone and the exposed implant-abutment margins, is switched from the vertical to a horizontal level. This horizontal placement of the biologic width can preserve the initial vertical bone height at the top of the implant shoulder (Figure 4E and F). Consequently, the possibility of a prolonged establishment of the papilla is increased because the vertical distance between the bone and the proximal contacts of the suprastructures can mostly be maintained below 5 mm.<sup>19</sup>

The horizontal area of bone can be increased with smaller-diameter implants. This new implant system makes this easy because (1) the natural emergence profile of an Ankylos-supported anterior crown does not depend on the implant diameter but is formed by the abutment (Figures 1A-F, 2B and C, and 3A); and (2) the mechanical strength and durability of its universal dimensioned taper connection does not depend on the implant diameter. A small-diameter Ankylos implant does not compromise either the esthetics or the mechanical strength but does increase the width of the crestal bone, which supports the overlaying peri-implant mucosal layer, thereby providing a very stable situation for this tissue. Bone thickness of 1.5 mm surrounding the implant is usually possible without the use of augmentation procedures. This avoids thin areas of crestal bone, which tend to resorb until uni-

form bone thickness is present around the implant.

A further advantage of small-diameter implants is that the shoulder meets the ridge anatomy at the esthetic zone. The crestal bone is generally lower on the facial and lingual areas compared with the interproximal areas. If a wide-diameter implant is used, the dentist must make a decision concerning the coronal-apical implant depth at the time of implant surgery. If the implant shoulder is placed beneath the bone in the interproximal area, the alveolar contours will be responsible for establishing the shoulder at a point that is level with the facial bone margin. This will cause a considerable amount of bone resorption interproximally due to the formation of the biological width. If, on the other hand, the implant shoulder is placed level with the interproximal crestal bone, the facial shoulder will be left commensurately exposed, which after healing would leave a darkened gingival margin due to its translucent nature. This problem can be avoided by using either a scalloped-designed implant shoulder<sup>20</sup> or a smaller-diameter implant. By establishing the biologic width in the interproximal areas, it is possible to maintain the soft-tissue contours and papillae that are desired between adjacent implants (Figure 3B and C).

When all-ceramic crowns or bridges are planned, it is advisable to use a white-colored ceramic abutment; however, the choice of ceramic materials for abutments is limited. Because superior bending strengths and fracture-resistance values characterize zirconia ceramics, the Ankylos system selected the zirconium-oxide ceramic (Figure 1C and D) as the best material for its all-ceramic abutment line. If

this ceramic abutment needs to be customized, it involves considerable time and the use of specialized instruments by the dental technician. The prefabricated 2-piece abutment (Figure 1D) simulates a prepared anterior tooth and requires considerably less effort to customize. The taper abutment connection enables this kind of abutment to be freely rotated to achieve a harmonic integration in the dental arch. On contrast implant-abutment joints rotary-secured by a hexagon or an octagon, the rotary position of the abutments is limited to 6 or 8 defined positions.

#### *Mounting of abutments at a submucosal implant shoulder*

The abutment shoulder should be covered by the soft tissue to mask the gray color of the titanium and to position the crown margin into a submucosal region. Conventional implant-abutment joints that extend around the diameter of the implant may trap soft tissue between the horizontal surfaces of the top of the implant and the abutment (Figure 1E). Some implant companies recommend that an X ray be taken after abutment connection to rule out this possible complication. The innovative tapered abutment connection of this system allows the soft tissue to be positioned around the tapered abutment connection and over the horizontal platform at the implant shoulder (Figure 1A). The small diameter of the abutment at the level emerging out of the taper connection of the implant prevents tissue from becoming trapped between the abutment and the implant (Figure 1E); therefore, an X ray is not necessary. Figures 2B and C and 3A show the collar of soft tissue after 2 weeks of abutment connection. After re-

moving the healing abutment, a clean and open access to the internal cone of the implant body exists, and a collar of firm soft tissue covers the residual peripheral part of the implant shoulder (Figure 2B).

#### *Unlimited versatility in combining implants and abutments of different sizes*

The dimension of the Ankylos-implant tapered connection is totally independent of the implant length and diameter. This universal abutment-implant connection provides an unlimited number of combinations of implant and abutment sizes. This significantly reduces the supply inventory of different abutments required in the dental office. It also eliminates the possibility of assembling a small abutment and with an implant of a different diameter.

#### *Prefabricated cone tapered (telescopic) retainer for removable dentures*

A primary goal of implant-prosthetic therapy is to avoid (1) any unnecessary grinding of natural teeth for fixed prostheses; or (2) the use of conventional removable dentures. If a jaw has a small number of residual teeth, is completely edentulous, if it has anterior alveolar ridge defects, fixed rehabilitations may require multiple implant insertions. In the esthetic region, surgical tissue reconstructions are frequently required (transplants, soft-tissue plastic surgery) to provide adequate bone for implant placement. These procedures, however, are generally reserved for specially trained and experienced surgeons. Many patients are not prepared to accept a few risks. They may have limited financial resources, or they are old enough



that therapy with removable superstructures is definitely preferred, but they want treatment that provides predictable results as far as stability, esthetics, and function.

The removable prosthesis provides a couple of options for providing stability and function: (1) the number of implants required can be as few as 2; and (2) surgical tissue reconstruction is generally not required, which keeps the cost of treatment considerably less. These options can be modified depending on the patient's budget and age. Most older patients are physically and mentally capable of maintaining a removable denture without assistance, but this may not be the case with fixed prostheses. Compared with a fixed prosthesis, cleaning unsplinted retaining elements (magnet, ball-and-socket anchor, telescopic abutment) is easy. The high long-term success rate prognoses of endosseous implants (15 to 20 years) makes it necessary to plan superstructures that are appropriate to the patient's age (simplified hygiene and handling) at the time of planning before starting treatment.

There are different approaches to retaining removable dentures: (1) bar-retained superstructures, which have proven successful in clinical use (assuming good oral hygiene and regular check-ups); and (2) telescopic superstructures, which offer improved comfort and denture stability. The simplified hygiene and the integration of abutment teeth in the removable prosthesis is a clinically relevant advantage.<sup>21</sup> However, conventional methods of the fabrication of telescopic superstructures are very difficult, time consuming, and expensive to fabricate and are therefore not extremely popular.

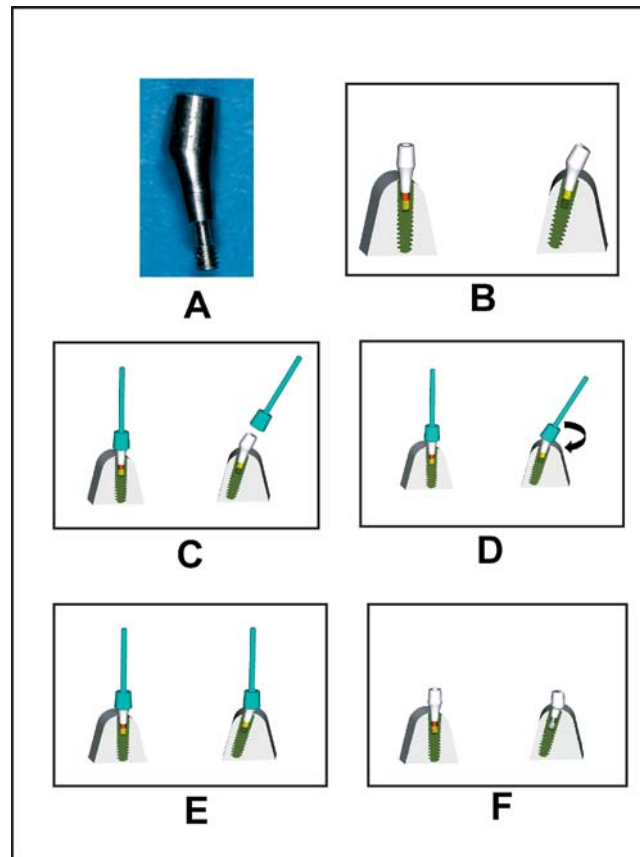


FIGURE 5. (A) The prefabricated SynCone abutment, which is composed of 2 cones. The bottom cone is for the tapered implant abutment connection, and the top cone is for accepting the superstructure of the prosthesis. The central screw positions the orientation of the 2 cones into a secure position. (B) Surgical placement of implants did not provide for a parallel relationship of the abutments of 2 or more implants. The angled SynCone abutment is shown on the right. (C) The alignment tools with extensions are placed on the abutments. (D) The extensions provide a visual method of assessing a common orientation. (E) The abutments are rotated until a common orientation is observed that will allow the fabrication of the final prosthesis (ie, the extensions are aligned and parallel), and the central screws are then tightened. (F) This relationship is transferred to the mouth by using resin keys as described above.

To address the problem of costs associated with this type of implant prostheses, this new implant system offers precisely machined prefabricated male and female components for telescoping applications, which can be easily integrated into a removable denture. The innovative SynCone abutments are in the form of cone-shaped patrices (Figure 5A) that can be easily rotated to the desired position on the master working cast by the laboratory technician. Any differences in the alignment of the axis (which

establishes the path of insertion or removal of the prosthesis) of the implants can be easily corrected by rotating the angled abutment of the implant (Figure 5B through F). Extensions on the caps that fit over the abutments provide a visual indication as to the extent of parallelism of the abutments (Figure 5C through E). Once the appropriate orientation of the implant-abutment connection of the SynCone abutment has been determined, it can be firmly secured in this position by tightening a central retaining screw

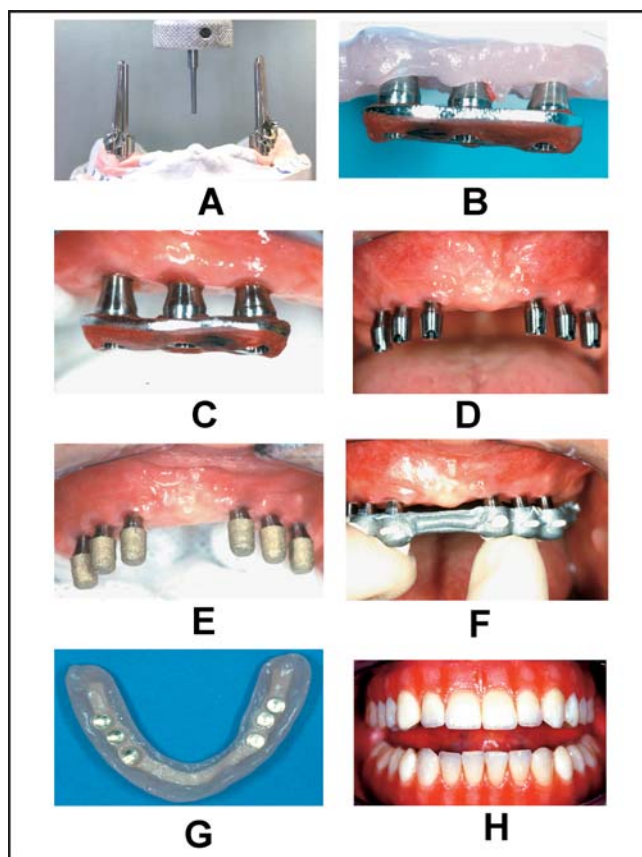


FIGURE 6. (A) The alignment tools attached to orient the prefabricated SynCone abutments with a parallelometer in the laboratory. (B) The resin key is used to record the desired abutment relationships before transferring this relationship into the mouth. (C) The resin key and abutments are transferred into the mouth (this shows a fixed partial-denture resin key). (D) Clinical view of SynCone abutments after being transferred into the mouth. (E) The precision prefabricated matrices (telescopic matrices) are positioned over the abutments (they are not attached to the abutments; frictional retention retains them in their place). (F) The custom-cast splinting frame for the overdenture is cemented over the matrices. (G) Final impression with splinting frame. (H) Final clinical view of completed telescope overdenture.

with a wrench. Once the screw is secured, rotation from this position is prevented. The time required for the dental technician to orient that SynCone abutments and fabricate a telescopic prosthesis is significantly reduced. The alignment of the abutments to a common path of insertion is verified with the parallelometer (Figure 6A). The final alignment of the abutments is securely fixed on the working cast with a wrench (Figure 6B). This relationship is then transferred into the mouth (Figure 6C and D) with a custom-formed resin positioning key. The

prefabricated cone matrices are then placed over the abutments (Figure 6E). The tertiary scaffold that will hold the matrices in place is then cast, finished, and cemented over the matrices in the mouth (Figure 6F).

This innovative treatment regime is based on the need to optimize the precision of the scaffold with telescopic cones when long distances<sup>21</sup> (Figure 6G) are involved. The intraoral cementation of the prefabricated matrices to the customized prosthesis scaffold (Figure 6F) ensures an accurate fit. The use of the tertiary

scaffold as the template for determining jaw relations and as the basis for the impression of mucous membrane areas covered by the prosthesis reduces the need for corrections of the occlusion and the prosthesis base at the time of prosthesis insertion.<sup>22</sup> The fabrication process greatly simplifies and accelerates the technical dental and clinical procedures. This eliminates a major reason for criticism of implant-supported conical prostheses—the comparatively complex dental technical fabrication that requires extreme accuracy and the associated high costs for the patient. The clinical degree of difficulty also is reduced to the level of a ball-and-socket prosthesis<sup>22,23</sup> by using the SynCone prefabricated parts. The patient clearly benefits because the high-precision fit eliminates detectable prosthesis kinetics, so the prosthesis is perceived as a fixed bridge or the patient's own dentition.<sup>21</sup> Therefore, this type of denture (Figure 6H) achieves a high degree of quality in a simple, reproducible, and cost-effective manner.

#### SUMMARY AND CONCLUSION

The examples discussed in this paper demonstrate the basic features of the Ankylos endosseous dental implant and the versatility of the new prosthetic features, which provide treatment options that are scientifically sound and provide cost-effective esthetic prosthetic replacements. This implant system is exceptionally well suited for use in the restoration of missing natural teeth.

#### REFERENCES

1. Muftu A, Chapman RJ. Replacing posterior teeth with freestanding implants: four-year

- prosthodontic results of a prospective study. *J Am Dent Assoc.* 1998;129(8):1097–102.
2. Asikainen P, Klemetti E, Vuillemin T, Sutter F, Rainio V, Kotilainen R. Titanium implants and lateral forces. An experimental study with sheep. *Clin Oral Implants Res.* 1997;8:465.
3. Celletti R, Pameijer CH, Bracchetti G, Donath K, Persichetti G, Visani I. Histologic evaluation of osseointegrated implants restored in nonaxial functional occlusion with preangled abutments. *Int J Periodont Restor Dent.* 1995;15:562.
4. Balshi TJ, Ekfeldt A, Stenberg T, Vrielinck L. Three-year evaluation of Brånemark implants connected to angulated abutments. *Int J Oral Maxillofac Implants.* 1997;12:52.
5. Mollersten L, Lockowandt P, Linden LA. Comparison of strength and failure mode of seven implant systems: an in vitro test. *J Prosthet Dent.* 1997;78:582–591.
6. Ekfeldt A, Carlsson G, Borjesson G. Clinical evaluation of single-tooth restorations supported by osseointegrated implants: a retrospective study. *Int J Oral Maxillofac Implants.* 1994;9:179.
7. Henry PJ, Laney WR, Jemt T, et al. Osseointegrated implants for single-tooth replacement: a prospective 5-year multicenter study. *Int J Oral Maxillofac Implants.* 1996;11:450.
8. Rangert B. Mechanical and biomechanical guidelines for the use of Branemark System—general principles. *Aust Prosthodont J.* 1993;7:39.
9. Rangert B, Mech E, Krogh P, Langer B, Van Roekel N. Bending overload and implant fracture: a retrospective clinical analysis. *Int J Oral Maxillofac Implants.* 1995;10:326.
10. Weinberg LA. Reduction of implant loading using a modified centric occlusal anatomy. *Int J Prosthodont.* 1998;11:55.
11. Block MS, Lirette D, Gardiner D, et al. Prospective evaluation of implants connected to teeth. *Int J Oral Maxillofac Implants.* 2002;17:473–487.
12. Balshi T, Hernandez R, Pryszyk M, Rangert B. A comparative study of one implant versus two replacing a single molar. *Int J Oral Maxillofac Implants.* 1996;11:372.
13. Romanos GE, Nentwig GH. Single molar replacement with a progressive thread design—implant system: a retrospective clinical report. *Int J Oral Maxillofac Implants.* 2000;15:831–836.
14. Hermann JS, Buser D, Schenk RK, Schoolfield JD, Cochran DL. Biologic width around one- and two-piece titanium implants. *Clin Oral Implants Res.* 2001;12:559–571.
15. Cochran DL, Hermann JS, Schenk RK, Higginbottom FL, Buser D. Biologic width around titanium implants. A histometric analysis of the implanto-gingival junction around unloaded and loaded nonsubmerged implants in the canine mandible. *J Periodontol.* 1997;68:186–198.
16. Brogini N, McManus LM, Hermann JS, et al. Persistent acute inflammation at the implant-abutment interface. *J Dent Res.* 2003;82:232–237.
17. King GN, Hermann JS, Schoolfield JD, Buser D, Cochran DL. Influence of the size of the microgap on crestal bone levels in non-submerged dental implants: a radiographic study in the canine mandible. *J Periodontol.* 2002;73:1111–1117.
18. Chou C-T, Morris HF, Ochi S, Walker L, DesRosiers D. AICRG: part II: crestal bone loss associated with the Ankylos Implant: loading to 36 months. *J Oral Implantol.* 2004;3:134–143.
19. Tarnow DP, Cho SC, Wallace SS. The effect of inter-implant distance on the height of inter-implant bone crest. *J Periodontol.* 2000;71:546–549.
20. Wöhrle PS. Nobel Perfect esthetic scalloped implant: rationale for a new design. *Clin Implant Dent Relat Res.* 2003;5(suppl 1):64–73.
21. Weigl P, Lauer H-Ch. Advanced biomaterials used for a new telescopic retainer for removable dentures: ceramic vs. electroplated gold copings, Part II: clinical effects. *J Biomed Mater Res.* 2000;53(4):337–347.
22. Trimpou G, Weigl P, Arnold R, Lee JH, König A, Lauer HC. Effiziente Herstellung von implantatgestützten Konusprothesen auf präfabrizierten Matrizen und Patrizen des Ankylos®-Systems. *Interdisziplinäre Zahnheilkd.* 2003;6:126–137.
23. May D, Romanos GE. Immediate implant-supported mandibular overdentures retained by conical crowns: a new treatment concept. *Quintessence Int.* 2002;1:5–12.

## NOTE

The results and opinions presented are those of the author and do not necessarily reflect the opinions of the American Academy of Implant Dentistry. This manuscript does not represent an endorsement of the evaluated implant by the American Academy of Implant Dentistry.