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.*

THE ANKYLOS IMPLANT SYSTEM: CONCEPT AND CLINICAL APPLICATION

Georg-H. Nentwig, DMD

KEY WORDS

Ankylos implant system
Progressive thread design
Tapered abutment connection

Problem: The Ankylos system was developed in 1985 and has been in clinical use since 1987. Some of its significant design features include (1) a progressive thread structure of the endosseous implant body for targeted load distribution to the apically positioned spongy bone; and (2) the gap-free subgingival tapered connection to the abutments. **Purpose:** The purpose of this report is to demonstrate that the Ankylos Implant System meets both the patients' and the dentists' standards of success and is suitable for use as single tooth replacements, bridge abutments, and retention elements for all regions and prosthetic indications. **Method:** The data from 5439 implants were evaluated between October 1991 and October 2002. The implants were considered successful if the following criteria were met: (1) clinical stability and function; (2) no inflammation of the peri-implant hard and soft tissue; (3) no progressive loss of the peri-implant bone; (4) no progressive loss of the peri-implant mucosa; and (5) satisfaction of the patient. All implants placed during this period were included in the evaluation as a prospective study. The average loading period was 56.8 months. Postoperative follow-ups were made once a year by a standardized protocol. The results were classified by prosthetic application in Table 1. A total of 943 implants were placed as single tooth restoration and were followed for the duration of the study. **Results:** The success rate for this type of restoration was 98.7%. For free-end implant restorations, there were 1679 implants placed with a 97.9% success rate. When the edentulous area involved a large gap, a total of 805 implants were placed with a 97.3% success rate. For cases involving reduced dentition, 606 implants were used with a 95.8% success rate. Another significant finding was that the success rates classified by maxilla and mandible showed no differences.

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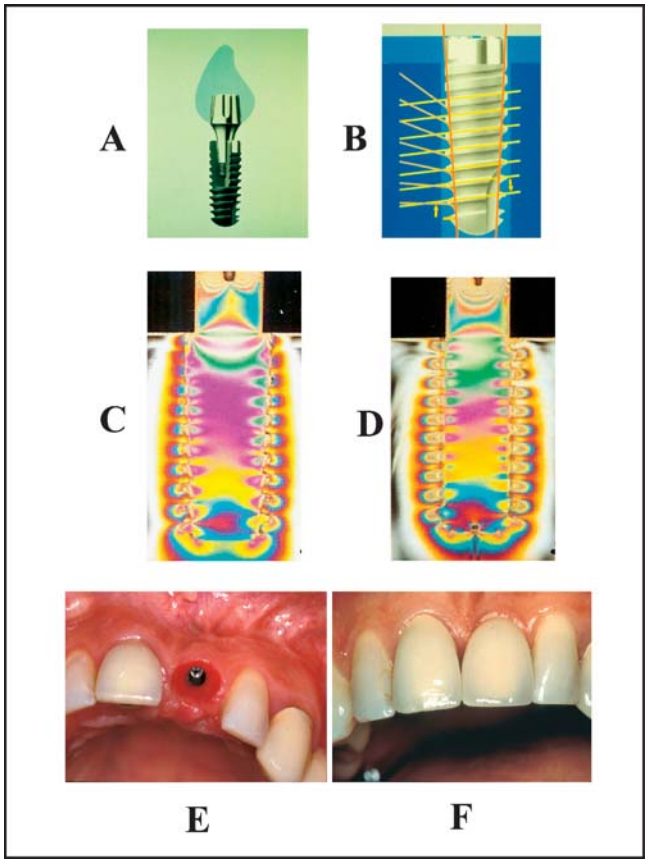

FIGURE 1. (A) Technical drawing of Anklyos implant. (B) Varying thread design on apical portion of implant. To reduce the stresses on the crestal bone during clinical function, no threads are machined on the cervial collar of the implant. (C) Photoelastic model of Anklyos implant showing only minimal stress concentrations in the area of crestal bone, with maximal stress concentrations shifted to the area of flexible trabecular bone. (D) Photoelastic model of convential screw implant design with similar stress for the entire length of the implant and at crestal bone. (E) Clinical case showing uncovered implant after removal of the sulcus former. Note the access to submerged implant fixture and the healthy emergence profile in the soft tissue. The top of the implant fixture is not visible but is covered by a dense layer of soft tissue. (F) Clinical case after insertion of the final crown. Note the excellent soft-tissue response in the cervical area.

INTRODUCTION

The definition of success for a dental restoration retained or supported with implants from the patient's view is very simple: The patient is concerned about function and esthetics. As dentists, however, we must establish different criteria to define successful implant treatment. In simple terms, success can be described as the following: (1) biological stability (ie, no loss of hard and soft tissue because of infections or overloading); (2) mechanical stability (ie, no fracture, loosening, or damaging of the prosthetic components, including implants and implant-abutment joints); and (3) hygienic ability (ie, the implant borne reconstruction must be designed so that it can be easily cleaned by the patient).

The question that implant dentistry must address is how the implant system can best contribute to successful replacements for missing natural teeth and, at the same time, maximize the satisfaction of both the patient and the dentist. This can be answered by the basic principles on which the Ankylos implant system was designed.

Moser and Nentwig[1] developed the Ankylos implant (Figure 1A) in 1985. It was designed with the following objectives in mind: (1) it should be universally applicable as either a delayed or an immediate implant prosthesis; (2) it should exhibit maximum primary stability even in poorly structured bone; (3) it should allow for optimum load distribution for permanent bone stability during functional loading; (4) it should facilitate soft-tissue stability because of the "gap-free," bacteria-proof tapered abutment connection with maximum mechanical stability; (5) it should provide for simple prosthetic restoration options, including a combination of implants with remaining natural teeth; and (6) it should be an economical restorative treatment option for the replacement of all missing natural teeth.

PROSTHETIC INDICATIONS

The Ankylos system (Friadent GmbH, Mannheim, Germany) is available in different diameters (3.5, 4.5, 5.5, and 7 mm) and 5 different lengths (8, 9.5, 11, 14, and 17 mm), making it suitable for all indications of implant treatment, including both immediate and delayed implant placement. There are 2 lines of prosthetics: standard abutments, which are connected to the implant at chairside before the impression is made, and "balance abutments," which are selected in the laboratory by the dental technician and are customized as required. This requires an accurate clinical im-

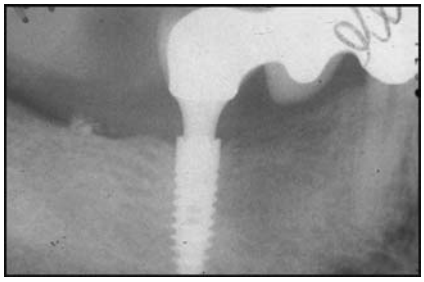

FIGURE 2. Ankylos implant that has been in clinical function for 56.8 months. Note the lack of (saucer shaped) bone loss around the implant in the area of the crestal bone. Note also that in this case the Ankylos implant is replacing a molar tooth and the bridge is attached to a natural tooth, without evidence of negative clinical complications. In response to clinical loading, a dense layer of bone is forming around the implant.

pression to transfer the correct position of the implant to a "working laboratory cast." With the working cast, the technician modifies the abutment and fabricates the final restoration. An orientating stent (positioning index) is then fabricated on the laboratory cast, which provides the treating dentist with a means of duplicating the relationship of the balance abutment and restoration with the remaining teeth. The stent and the final restoration are returned to the dentist for final insertion in the patient.

ENDOSSEOUS PART

The endosseous part features a special thread design with the thread depth increasing toward the apex. Therefore, an internal tapered body is combined with an outer screw (Figure 1B). The varying thread design distributes the chewing forces toward the flexible spongy bone while providing simultaneous load relief at the cervical (crestal bone) region.[1,2] The reason for this design is that the relatively elastic spongy bone, which contacts about 90% of the implant body, decreases in volume in the cervical direction and becomes less elastic because of the cortical supporting shell, whose rigidity is approximately 10 times higher than the spongy bone. After being osseointegrated and clinically loaded, the implant causes an increase in tension peaks in the very tiny cortical layer, which can lead to subsequent cervical bone loss.[3]

Both photoelastic studies and finite-element stress analyses have confirmed that the Ankylos special thread design reduces the functional stresses at the cervical section (crestal bone) (Figure 1C) compared with other implant systems (Figure 1D). In actual clinical cases, load-induced cervical bone loss occurred in fewer than 20% of cases. Even in these few cases, the amount of crestal bone loss was minimal, and there was no detectable evidence of the progression of this bone loss in either single tooth restorations or implant-tooth supported bridges (Figures 2 and 7A through C).[4]

The thread portion of the implant is grit blasted to produce a sharp edge and rough surface, both of which are important prerequisites for fast cellular adhesion and osseointegration (Figure

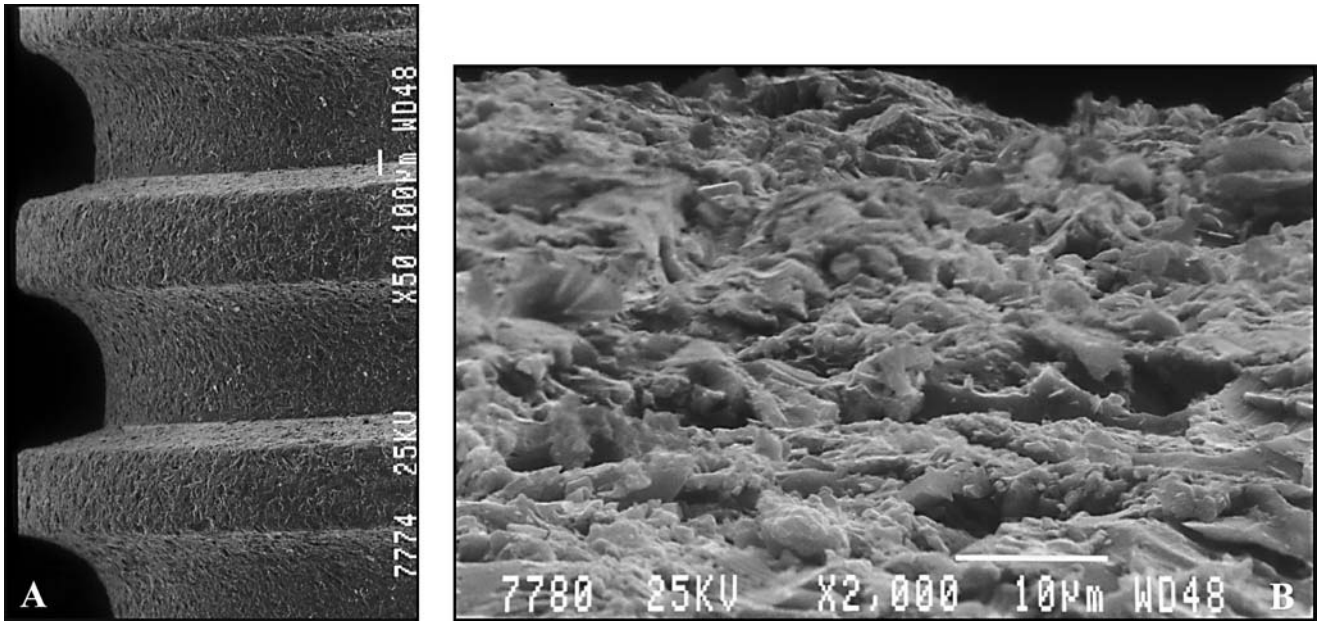

FIGURE 3. (A) Photomicrograph showing the variations in the thread design and surface roughness (×50). FIGURE 3. (B) Photomicrograph of surface roughness of the Anklyos implant (×2000).

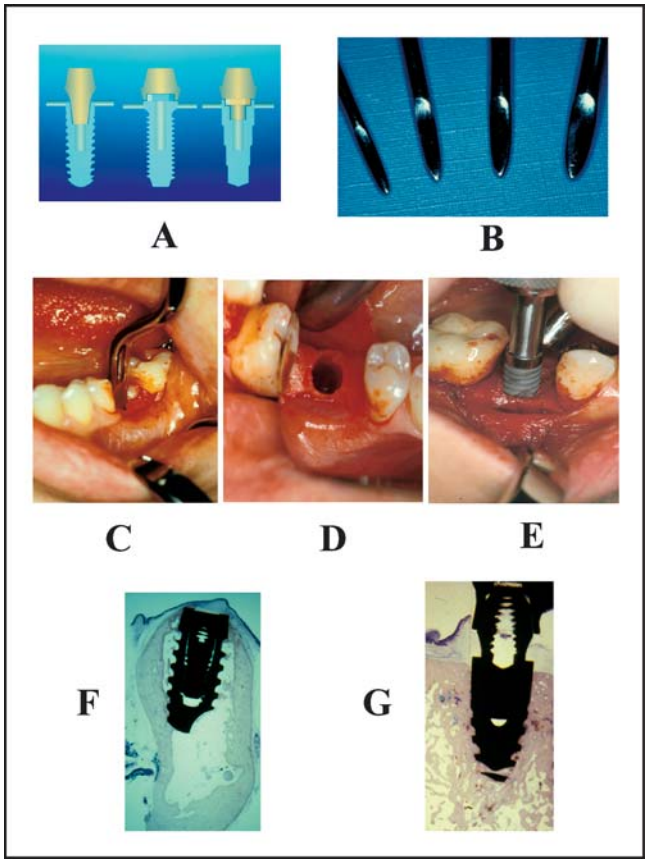

FIGURE 4. (A) Three different types of abutment connections for implants (from left to right): tapered connection, external hex, and internal hex. (B) Bone-spreading and -condensing instruments for preparing the implant site. (C) Clinical case showing the use of the instruments after the use of the pilot drill. (D) Clinical case after bone condensation with bone-spreading instruments. (E) Clinical case; placement of Ankylos implant. (F) Ankylos implant placed in poor-quality bone density in a monkey (healing stage). (G) Anklyos implant after progressive loading (bone training) and final loading of restoration in a monkey. Note the dense bone formation around the Anklyos implant.

3A and B). This irregular surface of a small (3.5 × 11 mm) Ankylos implant provides the same surface area as that of a natural molar tooth. This implant dimension can thus perform the same function as a bridge abutment. The increasing thread of the implant body also can function as a self-tapping device and does not require any thread preparation when placed in poor-quality bone. The result is excellent primary stability, even in a class 4 bone.

CONNECTION DESIGN

At the level of the connection between the endosseous implant and the abutment components, the dimension of the abutment should be smaller than the diameter of the implant body ("platform switching") to get the optimal effect of the barrier and protection function of the peri-implant soft tissue (Figures 1A, 2, and 7C). Moreover, this allows the establishment of a tissue collar overlapping the bone-implant interface. This requirement cannot be met with conventional, external, or internal connections (Figure 4A) because diameters of both the implant body and the abutment are identical.[5] A microgap between the implant and the abutment is an unavoidable feature of these implant designs. Micromovements further enlarge this gap during clinical function. This is particularly true with the short overlaps found in external hex connections. The microgap provides a space for bacterial contamination with subsequent irritation of the adjacent tissue, which ultimately results in cervical bone loss to below the connection joint.

FIGURE 5. Precision fit of the tapered implant–abutment connection in the Anklyos implant. Note the lack of a gap between the implant fixture and the abutment, which is often found in other implant-abutment connections.

The tapered implant–abutment connection (Figures 1A, 4A, and 5) was used in the design of the Ankylos implant because it offers the following technical advantages: (1) in contrast to hexagonal or tube-in-tube connections, the tapered connection technology ensures the best possible load transfer; (2) a precisely manufactured tapered connection can be gap free and therefore bacteria-proof (Figure 4A); and (3) the Ankylos tapered

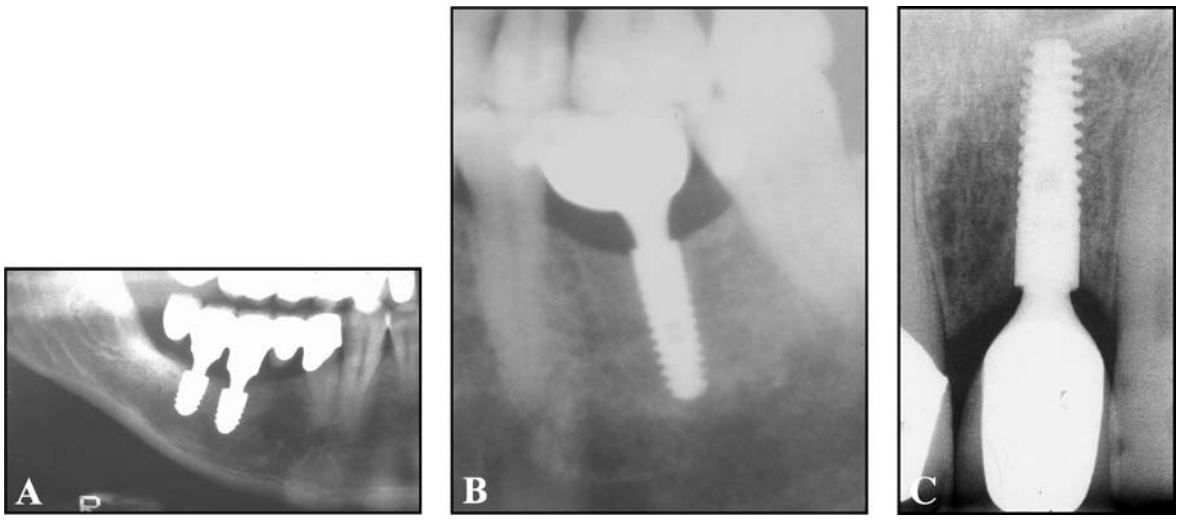

FIGURE 6. (A) Clinical case; free-end saddle, 2 Anklyos implants replacing mandibular molars, prosthesis is attached at anterior end to natural teeth as abutments. Period of clinical function is 56.8 months, and bone is healthy. (B) Clinical case; single Ankylos implant replacing a mandibular molar. Period of clinical function is 56.8 months. Note excellent bone response around implant and lack of evidence of crestal bone loss. (C) Clinical case; 1 Anklyos implant is replacing a missing maxillary central incisor. Period of clinical function is 56.8 months. Note excellent bone response around implant and lack of crestal bone loss.

connection is rotationally stable, requires a comparatively low torque (15 N/cm), and offers the greatest possible security against screws loosening and breaking.[6]

The following advantages have also been demonstrated in clinical use: (1) in the Ankylos system the dimensions of the connection are always the same, so that any endosseous component can be combined with any abutment as required; (2) the angled abutments can be aligned in any direction and can be placed parallel to one another; (3) the second-stage surgery is minimally invasive because it is not necessary to expose the periphery of the submerged endosseous implant (Figure 1E); and (4) the tapered connection can always be assembled precisely. The trapping of soft tissue between the abutment and the implant body that may occur with the other abutment-implant connection designs is not a problem with the tapered abutment present in the Ankylos implant.

The bacteria-proof seal, the lack of micromovements because of the friction grip, and the minimally invasive second-stage surgery without any major trauma for the periosteal tissue are also important factors in preventing cervical bone loss.[5]

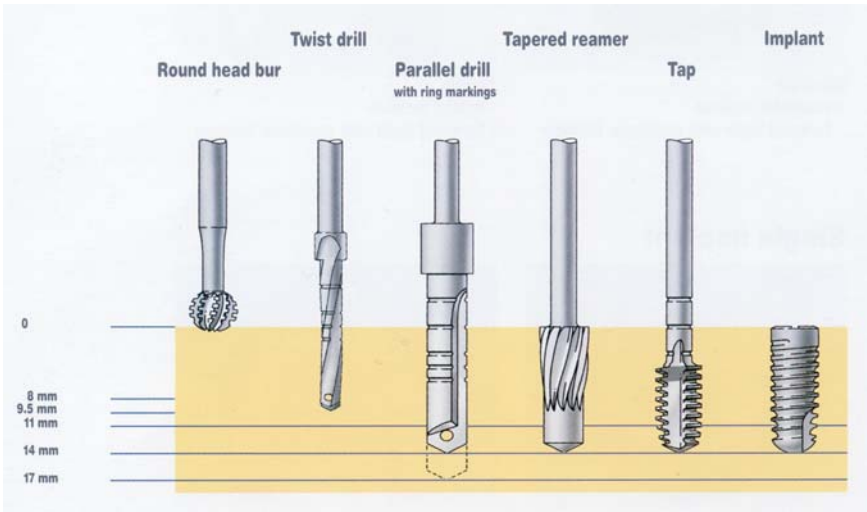

FIGURE 7. Instruments used in the placement of the Anklyos implant (from left to right): round bur to prepare for the pilot drill, the pilot drill, enlarging the implant site to the depth and width required, reaming the bone to provide tapered-implant site, tapping the implant site, and the final insertion of the implant.

SURGICAL PROCEDURE DEPENDING ON THE BONE QUALITY

Preparation of the bone site before implant placement is divided into the following steps with the instruments shown in Figures 4B, C, E, and Figure 6. These include (1) pilot drilling; (2) drilling to the diameter and length planned; (3) conical reaming; and (4) final thread tapping. This procedure

TABLE

Success rates for Ankylos implants used in 4 different prosthetic applications*

Prosthetic Application	Total No. of Implants	No. of Failures	Success Rate (%)
Single tooth	943	13	98.7
Free-end	1679	36	97.9
Large gap	805	22	97.3
Reduced dentition	606	26	95.8

*Rates varied slightly between 96% and 99%, depending on the application. The overall success rate was between 97% and 98%, which is excellent.

can be modified depending on the bone quality. In the case of particularly poorly structured bone (D3/D4), which becomes clinically obvious with low resistance during the pilot drilling, the bone should be condensed with a condensing instrument, which expands the bone to the corresponding diameter of the planned implant. Manual instruments are best suited for this purpose, such as the Bone Spreading System with 4 different sizes by Nentwig (Figures 4B through E). The condensing procedure is followed by parallel drilling to create a cylindrical hole of the desired diameter and length. The implant site is then shaped congruently to the internal tapered configuration of the implant body with the conical reamer.

A conical reamer, which corresponds to every available implant size, can also be used as a tool to check for the correct implant position and orientation. The reamer functions as a cutting instrument when rotated clockwise and as a condensing instrument when rotated counterclockwise. This provides for another condensation procedure in poorly structured bone. The last step in the preparation of the implant site involves tapping the threads, but this is done only in the presence of normal- or hard-quality bone. In poor-quality bone, the implant can be placed directly into a compromised soft bone and will function as a self-tapping screw to provide high primary stability.

PROSTHETIC PROCEDURE DEPENDING ON THE BONE QUALITY

Because structurally weak, poor-quality bone is not expected to improve its quality during the unloaded healing period, a subliminal (progressive) loading phase should be used for 6 to 8 weeks after second-stage surgery with temporary dentures or soft diet. During this ''training phase,'' the peri-implant spongious bone will be significantly restructured and will result in increased bone density. This has been demonstrated by animal experiments (Figures 4F and G) and also by clinical studies (Figures 2 and 7A through C). This restructuring corresponds with the idea of ''progressive bone loading'' developed by C. Misch.[7] The normal chewing load will then be restored with the final denture. The main advantage of this procedure is that it can reliably prevent implant losses in the early functional phase. In addition, implants that are particularly heavily loaded as bridge abutments or molar replacements can be safely adapted to their normal function (Figures 2 and 7A through C).

RESULTS TO DATE AT THE CLINIC FOR DENTAL SURGERY AND IMPLANT DENTISTRY AT THE UNIVERSITY OF FRANKFURT

The data from 5439 implants were evaluated between October 1991 and October 2002. The implants were considered successful if the following criteria were met: (1) clinical stability and function; (2) no inflammation of the peri-implant hard and soft tissue; (3) no progressive loss of the peri-implant bone; (4) no progressive loss of the peri-implant mucosa; and (5) satisfaction of the patient.

All implants placed during this period were included in the evaluation as a prospective study. An example of the quality of the final clinical case obtained with this implant is shown in Figure 1E. The average loading period was 56.8 months. Postoperative follow-ups were made once a year by a standardized protocol. The results were classified by prosthetic application in the Table. A total of 943 implants were placed as single tooth restoration and were followed for the duration of the study. The success rate for this type of restoration was 98.7%. For ''free-end saddle'' implant restorations, there were 1679 implants placed with a 97.9% success rate. When the edentulous area involved a large gap, a total of 805 implants were placed with a 97.3% success rate. For cases involving reduced dentition, 606 implants were used with a 95.8% success rate. Another significant finding was that the success rates classified by maxilla and mandible showed no differences.

CONCLUSION

The clinical experience with the Ankylos system has demonstrated that the objectives formulated at the beginning of the study could

be met. The significant difference compared with other systems is certainly the tapered connection, which provides excellent biological and mechanical stability and an unusual prosthetic versatility. In the meantime, many implant manufacturers have adopted the concept of the implant design in the form of a tapered screw. When combined with condensing bone preparation and bone training, the implants can achieve a high degree of osseointegration even in structurally weak bone and can serve as reliable prosthetic pilars. This also allows particularly economical solutions with a small number of implants as retention elements for fixed or removable dentures.

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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.