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Retentive Characteristics of Ankylos® SynCone Conical Crown System Over Long-term Use *in vitro*

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Abstract - *18 Ankylos® SynCone conical crowns with 4-degree angle and 18 SynCone conical crowns with 6-degree angle were tested in vitro for a total of 5 000 insertion-separation cycles to investigate their retentive characteristics. Under 20 N insertion force, the retentive force of Ankylos® SynCone conical crown system was between 5 and 10 N. The rentenive force kept almost constant during the entire testing cycles. It was thus shown that the SynCone conical crown system could potentially provide adequate and constant retentive force to retain implant-supported overdentures. It may be considered to retain implant-supported mandibular overdentures as an alternative to bar attachments.*

KEY WORDS: Conical crown, Retentive characteristic, Overdenture, Dental implant

INTRODUCTION

The treatment of edentulous or partially edentulous patients with osseointegrated implants has become a routine part of daily dental practice. Although premature loading has been discussed as one of the causes for early implant losses[1], immediately loading implants has gained popularity among clinicians to overcome the discomfort, inconvenience and anxiety associated with waiting period of the two-stage surgical protocol[2]. The main factor influencing the success of immediate loading is the primary stability of implants[2,3].

Primary stability can be enhanced when cross-arch implant splinting is performed and this prosthetic approach is recommended in immediate implant loading[2]. In edentulous patients treated with implant-supported overdentures, the usual way to splint implants is with a bar and this type of restoration has a high success rate[4-14]. However, this type of rigid connection requires considerable amounts of material and lengthy laboratory procedures and the 12-24 hours delay of the prostheses delivery may also be a negative feature for the patient.

A prefabricated SynCone conical crown system (Ankylos®) is thus introduced to overcome the disadvantages of the above technique. It combines the capability of Ankylos® implants to withstand immediate loading with an innovative telescopic crown technique (an implant abutment and a prefabricated SynCone cap, see Fig. 1). After the Ankylos® implant has been placed into the site slightly subcrestally and the SynCone abutment with adequate sulcus height has been screwed to the implant, the prefabricated SynCone cap is placed on the abutment securely; then the old denture is trimmed out to prevent it interfering with the caps and relined with cold-curing acrylic. The denture is then supported by the implants and retained by the SynCone conical crown system. This technique can reduce total treatment time and simplify the technical procedures through prefabricated components for the chairside procedures.

An innovative feature of Ankylos® implant system is the conical connector of the abument (Fig. 1), which enables a pre-angled SynCone abument (15°) to be aligned wherever required through 360 degrees to compensate for non-parallelism of the implants and ensure high rotational stability through a thermodynamic expansion of the conical connector in the patient mouth. Hence, this system can also be used in situations where clinically unparallel implants exist.

May & Romanos[15] reported a single center study, in which prefabricated SynCone conical crowns were used to retain and stabilize the immediately loaded, implant-supported mandibular overdentures. They concluded that this type of secondary splinting via conical crowns had a similar effect to the primary splinting with a bar; it also simplified laboratory procedures and might improve oral hygiene[15].

Under normal occlusal force, the adequacy for retaining and stabilizing an overdenture over long-term use with the prefabricated SynCone conical crown has not yet been studied. The effect on the osseointegration of implants associated with use of this system and repeated dislodgement has also not been examined. This *in vitro* study was designed to generate data on its retentive characteristics and consequences of repeated dislodgement on its retentive force. It was assumed that under suitable occlusal force the retentive force of SynCone conical crowns is favourably about 5-10 N and stays almost constant over long-term use.

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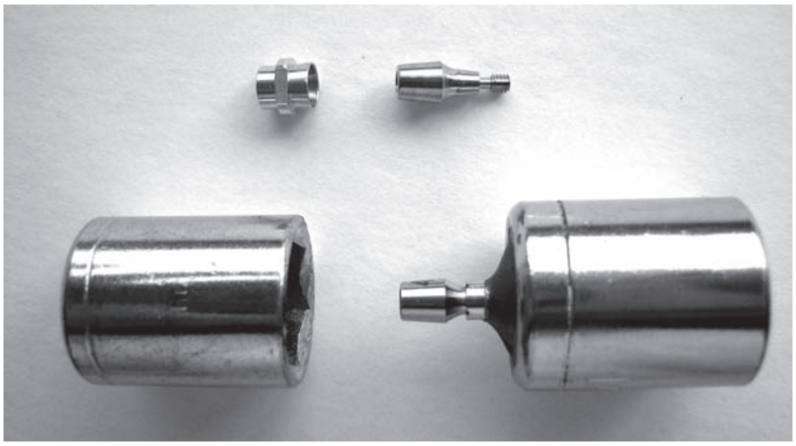

Figure 1. *The composition of a SynCone conical crown (an implant abutment and a taper cap) and the two test components used to attach the two parts of the conical crown.*

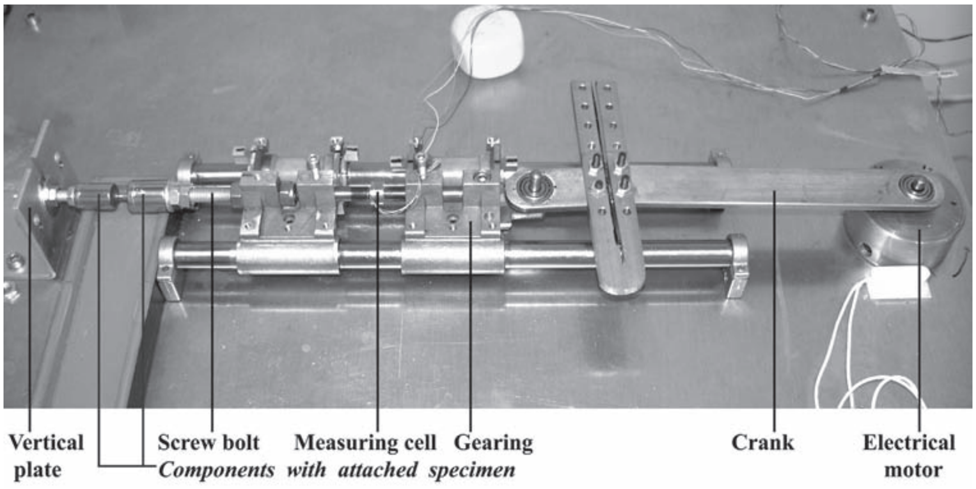

Figure 2. *The measuring device with the attached specimen*

MATERIALS AND METHODS

1. Study specimen

The SynCone conical crown system consists of an implant abutment and a taper cap (Fig. 1). In our investigation the straight SynCone abutments were selected. A total of 36 SynCone conical crowns were selected. According to the taper of the SynCone conical crown and the test conditions, the study specimen were divided into 6 groups, each group consisted of 6 SynCone conical crowns (for group assignments and test conditions also see Table 1): 4-degree / 10 N insertion force group; 4-degree / 20 N insertion force group; 4-degree / 30 N insertion force group; 6-degree / 10 N insertion force group; 6-degree / 20 N insertion force group; 6-degree / 30 N insertion force group.

2. Measuring device

Repeatedly measuring the retentive force of the SynCone conical crown was carried out with the Life-test device (Labview) (Fig. 2), which consists of an electrical motor, a crank, a pair of gearings with the measuring cell between them, a screw bolt and a vertical plate with a slot which were used to fix the two test components (Fig. 1). The motor runs continuously with a speed of 1 cycle per second. With the help of the crank, it moves the gearings forward and backward. The measuring cell detects the force changes for each cycle between the two gearings and transmits the signals to the amplifier. The amplified signals are then captured by the software (Labview, Version 3.1) and converted to the specific data (tensile force and compressive force) (Fig. 3).

3. Preparation of the study specimen

Before the measurement, a corresponding laboratory implant analog (Ankylos®) was aligned along the long axis of one test component and embedded with Pattern Resin (GC) in it, which was later screwed to the screw bolt of the measuring device. Then, a SynCone implant abutment was attached tightly to the implant analog (Fig. 1). Following that, a corresponding SynCone taper cap was placed securely on the abutment. This component was then attached to the screw bolt of the measuring device and the other test component was fixed on the vertical plate of the measuring device (Fig. 2). The electrical motor was

Table 1. *Mean actual insertion force (N) for each group*

Nominal insertion force	*Angle of the conical crown*	*Mean of actual insertion force*	*Standard deviation*	*P-value*
10 N	4-degree	9.86	1.14	0.760
	6-degree	10.01	0.29	
20 N	4-degree	19.88	1.06	0.948
	6-degree	19.91	0.53	
30 N	4-degree	30.09	0.67	0.197
	6-degree	29.69	0.22	

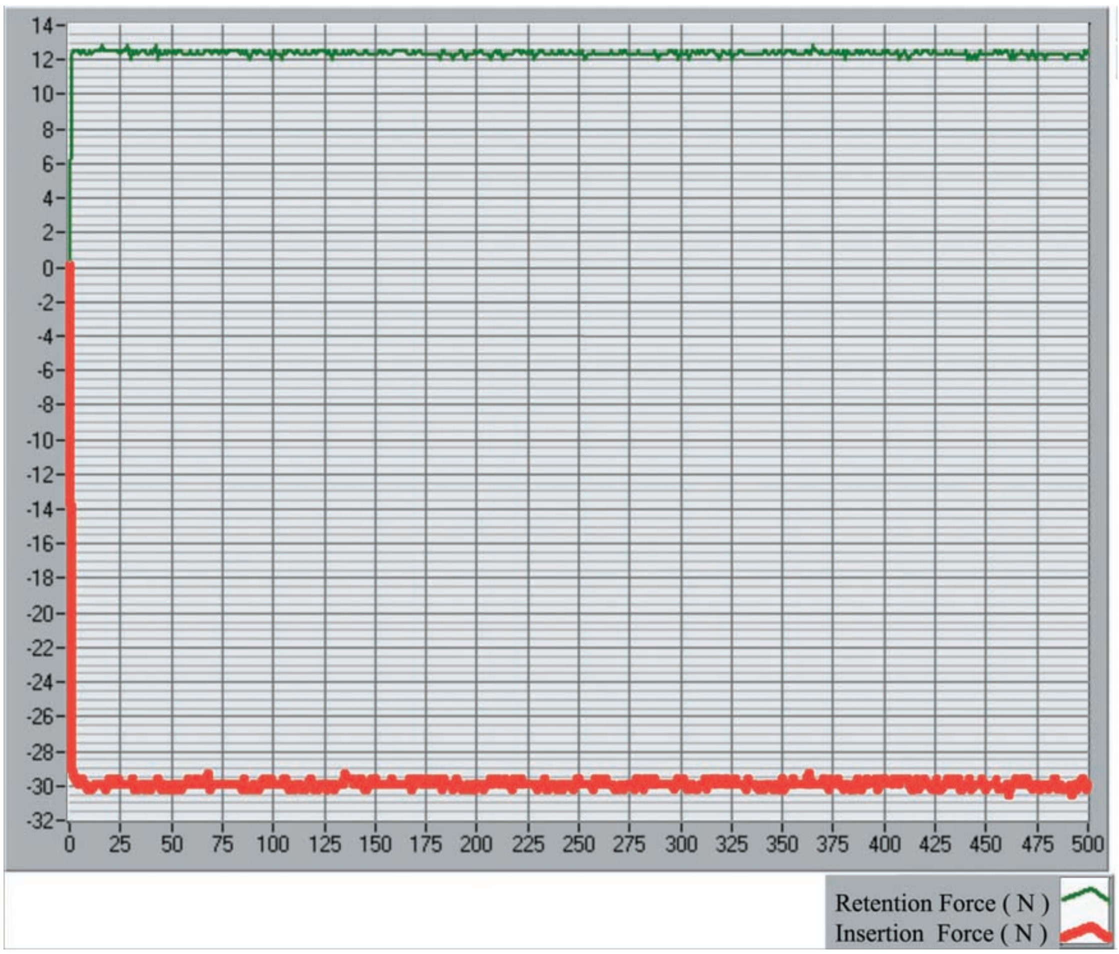

Figure 3. *An example of recorded graph for a cycle-unit (X-axis represents cycle, Y-axis represents force (N)).*

rotated manually to a position, in which a nominal insertion force of 10 N, 20 N or 30 N was generated. Afterwards, the SynCone taper cap, which had been placed securely on the SynCone abutment, was embedded with the Pattern Resin into the other test component. After the pattern resin had polymerized, the electrical motor was rotated manually to its initial position, in which the SynCone abutment and the cap were detached to the greatest distance (Fig. 2). The sample was then ready for testing.

4. Measuring process

During the entire measuring process, running room temperature water was directed to flow through the SynCone abutment and the edge of the taper cap with a flow rate of 40ml/min. The device was then calibrated for the initial force between the two gearings to approximate 0 N (range -0.03 to +0.03 N) and then the electrical motor was run for 500 cycles. The insertion and retentive forces were recorded after each interval of 25 cycles. Thus, after 500 cycles, 20 measurements were available, of which the mean values were calculated as the data of this cycle unit for the tested conical crown. The measuring process was repeated 10 times as described above, until 5 000 insertion-separation cycles (10 cycle units) were completed.

STATISTICAL ANALYSIS

The SPSS software (Release 8.0.0, SPSS Inc.) was used. With the General Linear Model (GLM) Repeated Measures procedure, the actual insertion forces for the 10 N, 20 N and 30 N groups were compared within the 10 cycle units (within-subjects factor) and between the 4-degree and 6-degree groups (between-subjects factor). The mean insertion force for each group was tested using a One-Sample T test to see whether it was different from the nominal value. One-way ANOVA was used to analyze the effect of the insertion-separation cycle on the retentive force of the conical crown; the GLM Repeated Measures procedure was applied to evaluate the effects of the insertion force and the conical crown angle on the retentive force of the conical crown.

RESULTS

1. Mean actual insertion force for each group

For the SynCone 4-degree conical crowns, the mean actual insertion forces for the 10 N, 20 N, 30 N insertion force groups were 9.86 N, 19.88 N, 30.09 N respectively; for the SynCone 6-degree conical crowns, the mean actual insertion forces for the 10 N, 20 N, 30 N insertion force groups were 10.01 N, 19.91 N, 29.69 N respectively (Table 1).

For the 10 N, 20 N and 30 N insertion force groups respectively, the actual insertion forces within the 10 cycle units and between the 4-degree and 6-degree groups had no significant difference ($P>0.05$) (Table 1). An instance of the live change of the actual insertion forces in a cycle-unit recorded by the measuring device was showed in Figure 3. These results demonstrated that the actual insertion forces stayed almost constant during the insertion-separation cycles and were similar between the 4-degree and 6-degree groups.

The results of One-Sample T test also showed that there was no significant difference ($P>0.05$) between the mean actual insertion force and the nominal insertion force for each group.

2. Retentive force of the SynCone conical crown for each group

For the SynCone 4-degree conical crowns, the mean retentive forces of the 10 cycle-units for the 10 N, 20 N and 30 N insertion force groups were 4.43 N, 8.01 N, 13.47 N respectively; The range of the difference in retentive force among the cycle units was below 0.5 N (Table 2).

For the SynCone 6-degree conical crowns, the mean retentive forces of the 10 cycle-units for the 10 N, 20 N and 30 N insertion force groups were 3.53 N, 7.23 N, 10.88 N respectively; The range of the difference in retentive force among the cycle units was about 0.5 N (Table 2).

3. Comparison of the retentive force among the cycle units

The retentive force gradually decreased as the number of insertion-separation cycles rose (Fig. 3). According to the statistical analysis (one-way ANOVA), however, for each group there was no statistical significant difference ($P>0.05$) in retentive force among the cycle units, which was only about 0.5 N.

4. Comparison of the retentive force among 10 N, 20 N and 30 N groups

According to the results of GLM Repeated Measures procedure analysis, the differences of the conical crown retentive forces among the 10 N, 20 N, 30 N groups, both for the 4- and 6-degree conical crown, were statistically significant ($P<0.01$). Variance analysis manifested further that significant differences ($P<0.01$) existed between all the two groups of 10 N, 20 N, and 30 N groups. The interaction between the insertion force and the angle had a significant effect, too ($P<0.05$). These results showed that the retentive force of the conical crown rose obviously with higher insertion force; and the smaller the angle of the conical crown was, the more the retentive force increased.

5. Comparison of the retentive force between the 4- and 6-degree groups

When the retentive forces were compared between the 4- and 6-degree groups, the data (Table 2) showed that, as the angle of the conical crown increased, its retentive force decreased. However, the GLM Repeated Measures procedure analysis indicated that significant differences existed only for the 10 N group ($P<0.05$) and for the 30 N group ($P<0.01$); as for the 20 N group, there was no statistical significance in retentive force between the 4- and 6-degree groups ($P>0.05$).

Table 2. *Mean, standard deviation, minimum, maximum and range of the retentive force (N) of the 10 cycle-units for each group*

Groups	*Mean*	*Standard deviation*	*Minimum*	*Maximum*	*Range*	*P-value*
10 N groups						
4 degree	4.43	0.11	4.21	4.59	0.37	0.027
6 degree	3.53	0.19	3.24	3.84	0.60	
20 N groups						
4 degree	8.01	0.16	7.83	8.24	0.41	0.081
6 degree	7.23	0.13	7.01	7.39	0.38	
30 N groups						
4 degree	13.47	0.10	13.36	13.64	0.27	0.009
6 degree	10.88	0.16	10.61	11.06	0.45	

DISCUSSION

The retaining, supporting and stabilizing of an overdenture can be achieved at the same time with the conical crown technique[16]. The denture constructed with conical crowns transfers occlusal force to a great extent along with the long axis of the tooth[17]. It is also convenient for keeping oral hygiene and can be easily repaired or reconstructed[17,18]. Because of the above-mentioned advantages, the conical crown technique is increasingly used in dental implantology for retaining delay-loaded overdentures. It can further be used to retain immediately loaded implant-supported mandibular overdentures as an alternative to the conventional bar splinting technique[15]. When used in immediate loading situations, however, the conical crown technique needs to be further investigated to ensure its availability and long-term prognosis. In the present study, the retentive characteristics of Ankylos® SynCone conical crown system, a system used in dental implant immediate loading situations, have been investigated.

Unlike the devices used in other similar studies[19-23], the device in this study can provide both the retentive force and the actual insertion force of each cycle, by which the actual insertion force can be monitored during the experiment course (Fig. 3). According to the calibration procedure, the measuring device in this study provided a high accurate measurement with ±0.03 N. On the other hand, the monitored insertion forces kept constant during the cycle courses; they were close to the nominal force values and similar between the 4-degree and 6-degree comparison groups (no statistically significant difference). This ensured the accuracy and the comparability of the recorded data.

As the results of this study showed, the retentive force of the SynCone conical crown kept almost constant during the 5,000 insertion-separation cycles, which correspond to nearly 5-year use when 3 times a day is counted for inserting and removing the denture for cleaning.

The range of the differences in retentive force during the 5,000 insertion-separation cycles (10 cycle units) was lower than 0.5 N (except for the 6-degree/10 N group, of which the value is 0.60 N). Because of the difference in the materials and the fabricating methods used in the conical crown, the results of this study have no comparability with those of most other authors' studies[19,20,22,23]. A comparison can only be conducted with the results of Besimo *et al.*[21], who studied the retentive force losses in 5.5^o and 6.5^o conical crowns made of pure titanium, gold and cobalt-chromium alloys. In their study, the retentive values between the primary titanium and secondary gold crowns had no statistically significant difference within the 10,000 cycles. The results of present study conform to this conclusion.

Under 10 N insertion force, the retentive forces of the 4- and 6-degree SynCone conical crowns were below 5 N; under 20 N insertion force, the values were between 5 N and 10 N; while under 30 N insertion force, the values rose above 10 N. As the insertion force increased, the retentive force increased significantly, which conforms to the previous studies[24]. However, the retentive force, according to the results of present study, did not increase always significantly with the decrease of the conical crown angle: under the 20 N insertion force situation, the retentive forces between the 4- and 6-degree conical crowns did not differ from each other significantly. This phenomenon can be explained as follows: The Ankylos® SynCone conical crown system is so designed to achieve suitable 5-10 N retentive force under the suitable 20 N biting force, that under this biting situation the difference in retentive force between the 4- and 6-degree conical crowns is little; Just as this study showed, however, the smaller the angle of the conical crown was, the more the retentive force changed with the change of insertion force, so the difference in retentive force between the 4- and 6-degree conical crowns for 10 N or 30 N insertion force situations should become larger and more significant.

Körber[24] has recommended that the retentive force of a conical crown should be controlled between 5 N and 10 N. Within this force range, the conical crown can completely retain a denture against adhesive force of food without any damage to the supporting tissues.

Nevertheless, if the conical crown system is to be employed successfully, the abutments must be parallel or have the common path of insertion/dislodgement. The conical connector of the SynCone abutment is the basis for the success of the SynCone implant system. Its conical geometry complies with the important demand that an angled abutment can be aligned wherever required through 360 degrees to compensate for non-parallelism and ensure high rotational stability. Many authors have studied the biting forces of patients wearing implant-retained mandibular dentures[25-32]. According to these studies, the average maximal biting force is about 130 N, while normal chewing force is below 100 N. From these three aspects, it can be concluded that under normal chewing force of the patient, four interforaminal SynCone implants with SynCone conical crowns, each of which bears about 20 N occlusal force, are capable of retaining implant-supported overdentures without damage to the supporting structures by the removal of dentures. Both of the 4- and 6-degree SynCone conical crowns could be used, since under this load situation, the retentive forces between them have no significant difference.

For the patients with a high biting force, however, we would recommend the 6-degree conical crown because the retentive force of the SynCone conical crown with smaller angle increases more rapidly as insertion force (biting force) increases. Furthermore, when the overdenture constructed with SynCone conical crowns is completely seated, all the taper caps will bind tightly to the implant abutments due to the retentive characteristics of the conical crown. Consequently, a secondary splinting effect could be acquired to prevent or minimize the micromovement of immediately loaded implants, which would benefit the osseointegration of immediately loaded implants.

CONCLUSION

Based on the limitations of the current investigation, the following conclusions can be drawn:

1. The SynCone conical crown may provide constant retentive force over long-term use. The anticipated use is at least 5 years when 3 times a day for removing and cleaning the denture is counted.

2. The SynCone conical crown is capable of providing adequate retentive force of about 5-10 N for the implant-supported overdentures, when four interforaminal SynCone conical crowns are loaded under normal chewing force.
3. The authors recommend use of the 6-degree SynCone conical crown for patients with high biting forces based upon the laboratory results in this study.

MANUFACTURES' DETAILS

- Ankylos® Syncone conical crown system, Friadent Gmbh, Germany
- Labview®, National Instruments Corporation, Austin, USA
- Ankylos® implant analog, Friadent Gmbh, Germany
- Pattern Resin, GC Corporation, Tokyo, Japan

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