

# CAD/CAM Conic Crowns for Predictable Retention in Implant-Supported Prostheses

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**Purpose:** To evaluate CAD/CAM conic crowns to obtain a reversible and predictable retention in implant-supported prostheses. **Materials and Methods:** Five 1- to 8-degree CAD/CAM abutments and their respective copings (n = 40) were designed and manufactured to measure the retention strength (in N) on a Zwick/Roell testing frame. **Results:** The mean retention strength values found, in descending order of cone angle, were as follows: 8 degrees, 21.02 N; 7 degrees, 23.16 N, 28 N, and 36.40 N; 6 degrees, 40.46 N; 5 degrees, 66.36 N; 4 degrees, 61.23 and 76.12 N; 3 degrees, 93.44 N, 103.21 N, and 112.04 N; 2 degrees, 154.20 N; and 1 degree, 204.74 N, 261 N, and 293.40 N. These data describe a high-intensity ratio with a curvilinear trend that can be used to develop predictive models. **Conclusion:** With the limits of this study, it can be concluded that retention strength increased as the cone angle decreased. The data described a curve from which two predictive models were developed to find retention strength from the cone angle used and the cone angle that would be needed to deliver a given retention strength. This study is the first step in searching for an alternative to cemented and screw-retained implant-supported prostheses and new retaining elements in implant-retained prostheses. *Int J Prosthodont* 2016;29:230–232. doi: 10.11607/ijp.4303

Fixed implant-supported prostheses are currently categorized as one of two types: cement-retained or screw-retained. Each has advantages and drawbacks, and the two types consequently are recommended for different purposes. Conic crowns provide an interesting alternative with advantages over both. Prostheses can be made that can be retained without cement or screws but are reversible and predictable.

Since their introduction, the efficacy and advantages of conic crowns and their good long-term prognosis in prosthodontics have been shown.<sup>1</sup> Retention depends on physical-mechanical factors such as friction between the retaining surfaces, metallic surface adherence, negative pressure, and technical characteristics of the primary and secondary structure design, such as cone angle, height, materials, and surface polishing.<sup>1–4</sup> Conic crowns may be electroformed, using gold essentially, which affords very precise internal fitting,

or conventionally sprued with nonprecious metals. Computer-aided design/computer-assisted manufacture (CAD/CAM) procedures allow for the use of homogenous and cheaper materials, control of many of these parameters, and the tolerance to ensure a reversible retention force.<sup>5</sup>

The aim of the present study was to explore and evaluate in vitro CAD/CAM conic crowns to obtain a reversible retention strength, possibly generate a predictive model to find the retention form cone angle and vice versa, and open a new line of research.

## Materials and Methods

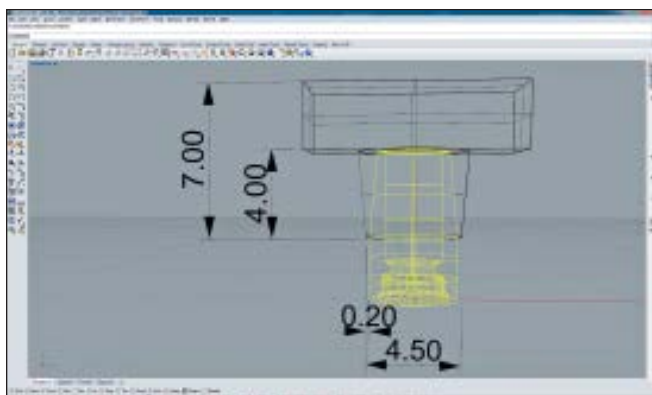
Eight specimens were subsequently designed with cone angles of 1 to 8 degrees using Rhinoceros 5.0 design software (McNeel & Associates). All the specimens were identical except for the cone angle, the sole variable studied. All the abutments were 7 mm high: 4 mm in the cone itself plus 3 mm at the base to attach the element to the milling unit. The interface between the occlusal surface and the lateral walls was rounded with a 0.05-mm radius, generating a knife-edge finish line. The copings were 0.2 mm thick and 7 mm high: 4 mm to fit over the conic part of the abutment plus 3 mm for the T (3 × 10 × 4 mm) for the clinical pull-out trials. Both elements were designed to ensure close contact along the entire interface, disregarding milling tolerances except as related to abutment rounding (Fig 1).

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**Fig 1** Specimen design example: 1-degree to 8-degree CAD/CAM conic abutments.



**Fig 2** Pulling test.

With Sum3D Dental 2011 CAM software (CIM System) running on the computer and after selecting a type V  $9.8 \times 10$ -mm titanium milling block (Zenotec Ti Disc, Wieland Dental), the CAD-generated STL file was imported and applied to the block. The position of the sprues, the burring machine (C20U, Hermle), the burs, and the strategy for milling copings and abutments were then defined. The above data were used to engineer the piece and develop a burring program that, after computer simulation, was exported to the burring machine driver for milling (Fig 1).

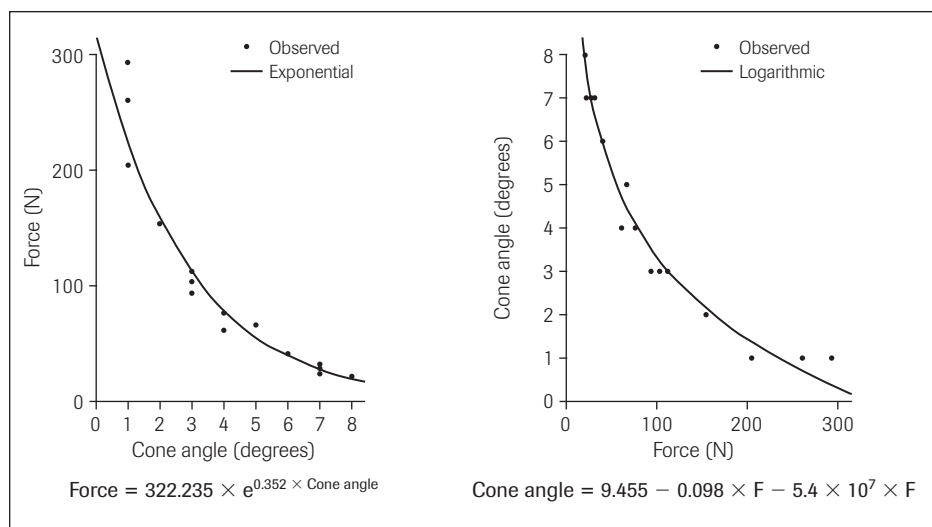
Retention strength was measured on a Zwick/Roell BT1-FR2.5TS.D14 testing frame connected to a computer running manufacturer software. The parameter measured was failure strength, the force needed to separate the coping from the abutment and reduce the adherence between the two surfaces to naught. Before the trials proceeded, a self-centering stainless steel tool was made that could be attached to the hook on the strength sensor and the T on the copings. The support was positioned on the test frame and secured to the clamp with a long steel screw. The pull-out test software was configured to a preload of 0.5 N and a speed of 1 mm/min. The same start position was defined for all measurements. The abutments were bolted one by one to the support with a 1.20-mm hexagonal titanium screw (GT Medical) at a torque of 20 N. A separate screw was used for each subset of cone angles. The coping was then fitted tightly onto the abutment and loaded to 30 N. The pulling tool was positioned on the sensor, which was set to zero, and the trial began (Fig 2). The failure strength, recorded in N, was defined as the force required to pull the two elements apart. The test was run five times on each specimen.

The findings were statistically analyzed with classical exploratory and descriptive tests of the quantitative variables, including goodness of fit to the Gauss curve (Kolmogorov-Smirnov when  $n > 50$  and Shapiro-Wilk when  $n < 50$ ), as well as with analysis of variance (ANOVA) tests: ANOVA followed by Tukey multiple contrasting and estimates of linear, quadratic, cubic and logarithmic regression models, calculating  $R^2$  parameters and goodness of fit.

## Results

The mean retention strength values found, in descending order of cone angle, were as follows: 8 degrees, 21.02 N; 7 degrees, 23.16 N, 28 N, and 36.40 N; 6 degrees, 40.46 N; 5 degrees, 66.36 N; 4 degrees, 61.23 and 76.12 N; 3 degrees, 93.44 N, 103.21 N, and 112.04 N; 2 degrees, 154.20 N; and 1 degree, 204.74 N, 261 N, and 293.40 N.

The model for predicting retention strength from the cone angle showed that although the linear fit was reasonably acceptable ( $R^2 = 0.796$ ), the value was lower than obtained for the nonlinear models, confirming the aforementioned visual impression. While the degree of fit was very good ( $R^2 > 0.900$ ) for all the nonlinear models, the best fit was found for the exponential regression model, which yielded a value of 97.2%. The model to predict the cone angle from retention strength was built as the reverse of the model described above. Given that both described the same relationship, the linear model showed the same degree of fit, which was likewise lower than the values found for the nonlinear models ( $R^2 > 0.900$ ). The best fit was afforded by the cubic model, which explained 98% of the variability (Fig 3).



**Fig 3** Predictive parametric models.

## Discussion

Within the limitations of this *in vitro* study, these findings were regarded as highly promising, particularly in light of the paucity of papers on the design and performance of double system crowns. Such differences notwithstanding, other authors consistently observed that smaller cone angles yield higher retention strength.<sup>1,4,5</sup> Cone angle, then, is one of the parameters affecting such strength, along with abutment height, existence of occlusal space, surface roughness, coping thickness, material used, initial load, and insertion/removal cycle.<sup>3</sup> Regardless of the methodology used, all authors showed that cone angle was inversely related to retention strength, although the actual relationships were hardly predictable.<sup>1,4</sup>

Consequently, two models or formulas were developed from the empirical data, without rejecting any, to create a powerful predictive model. The findings showed that if a 6-degree cone angle is used, the design strength that can be expected is 39 N, and if the strength required is 76 N, a 4-degree cone angle is needed. These models will contribute to standardization of and protocol for CAD/CAM restoration fabrication and will aid in determining the cone angle needed to attain a given strength target. They will also make it possible to propose an angle with which to obtain predictable retention strength and optional reversibility based on retention study findings for removable dentures and fixed cement-retained implant-supported prostheses.

However, the results of this study must be considered with caution because a convenience sample of five identical specimens was used and analysis of

sample size was not performed. Because of this and other limitations, this preliminary study should be continued with further studies using a larger number of samples and analyzing other possible variables within the same line of research. This led to a more stable conclusion.

## Conclusions

On the basis of these findings and with the limitations of the *in vitro* study, the following conclusions were drawn: in CAD/CAM conic crowns, retention strength increased as the cone angle decreased; predictive models can be developed for both cone angle and retention strength; and this line of research opens the door to a wide field of future studies.

## Acknowledgments

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

## References

1. Bayer S, Stark H, Gözl L, et al. Clinical retention force development of double crowns. *Clin Oral Invest* 2012;16:407–411.
2. Schunke S. Principales métodos de funcionamiento del sistema de coronas dobles. *Quintessence Técnica* 2008;19:557–568.
3. Beuer F, Edelhoff D, Gernet W, Naumann M. Parameters affecting retentive force of electroformed double-crown system. *Clin Oral Invest* 2010;14:129–135.
4. Bayer S, Stark H, Mues S, Keilig L, Schrader A, Enkling N. Retention force measurement of telescopic crowns. *Clin Oral Invest* 2010;14:607–611.
5. Shimakura M, Nagata T, Takeuchi M, Nemoto T. Retentive force of pure titanium konus telescope crowns fabricated using CAD/CAM system. *Dent Mater J* 2008;27:211–215.