Influence of Cement Gap Size, Surface Preparation, Cleaning Agent, Potting Time and Ageing on the Retention of Cemented Single Ceramic Crowns, Supported by Elos Accurate Hybrid Bases

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Abstract
Introduction: Based on experience with cemented components from various dental labs the continuous testing activities at Elos Medtech indicate that the process of cementing crowns onto dedicated abutment components is more of an art than an exact science. To gaining knowledge of the various factors affecting the stability of the cemented interface, Elos Medtech has initiated activities to support the formulation of "best practice" when it comes to cementation of dental components.

Materials and Methods: Four different parameters; cementation gap size, cleaning agents, blasting media particle size and different forms of ageing have been examined to determine their impact on the adhesive strength of the cemented hybrid base/crown interface. For the experiments, the Elos Accurate Hybrid Base Non-engaging was utilized along with custom made zirconia dental crown analogs. Cementation was performed using Panavia V5.

Results: The results show that the various tested parameters vary with respect to the overall spread of the data points. However, no significant differences between median values of the tested groups were found.

Discussion: The large spread found for some of the test groups support previous observations of varying adhesive strength resulting from components cemented at external labs. Considering that there was no significant difference between the means of the groups, focus should be on combining the parameters yielding as narrow a spread as possible, to ensure a consistent result of the cementation procedure.

Conclusion: Within the limitations of the current study, it is concluded that cleaning with either Isopropanol or Katana Cleaner are to be preferred over the use of steam cleaning. The cementation gap size should be 40 - 80 µm and care should be taken when storing the cemented components at dry conditions, over prolonged periods of time.

Introduction

The use of implant supported dental crowns, in the treatment of edentulism, is popular and well documented [1]. Cementing of crowns on dental abutments, using dental adhesive cements, is performed as a routine task at dental labs and in clinical settings, on a daily basis, across the globe. The quality of the cementation is a key parameter for the performance and long-term stability of implant supported restorations. This is becoming increasingly important as the market trend is moving towards more frequent use of the versatile, but smaller, hybrid base-type abutments [2]. Hybrid bases are well suited for ensuring aesthetically pleasing restorations for situations where the host tissues do not allow for generating an optimal emergence profile using e.g. stock or custom-made titanium abutment. This is especially important when the patient has a high smile line [3]. Since the area of the hybrid base cementing surfaces is typically reduced, compared to conventional abutment, the cementation result must be predictable and consistent, to ensure that the final restoration is capable of withstanding the masticatory forces over extended periods of time.

At Elos Medtech our resources are dedicated to the development and manufacturing of the best possible components for dental restorations. Throughout the years, our extensive testing activities have revealed that the critical cementation process is more of an art than an exact science, with cementation jobs being performed at different labs, or at different time points at the same lab, showing significantly different behavior when it comes to adhesive retention of the crown, even when the same cement systems is used. While studies are present in the scientific literature [3-7], it is difficult translate the effects of various surface pre-treatments and, thus, allow for eluting the performance of varying cement systems across different com-ponents. Based on this, the current study is intended to circle in on some of the critical aspect associated with the cementation process for the Elos Accurate Hybrid bases and to yield insights into which measures to employ for ensuring a consistent quality of the cemented interface, every time. The study utilizes the popular Panavia V5 dental cement and examines the influence of cementation gap size, different cleaning agents, blasting media size and effects resulting from ageing of the cemented components, with respect to the adhesive strength of the hybrid base/crown interface.

Materials and Methods

Sample preparation

The influence of cementation gap size, cleaning method, blasting media size and ageing on the adhesive strength of the Hybrid base/crown interface was examined via four sets of experiments. Common to all these experiments was the use of purpose-made ceramic crowns, manufactured from Zirconia (Lava™ Frame Zirconia, REF: X-69222, 3M ESPE). The external geometry of the crown was designed to allow for mounting the cemented part in a tensile testing machine, see Figure 1 for overview of the test setup.

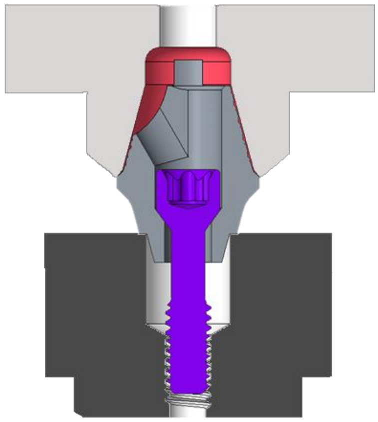

Figure 1: Overview of the component design used for the various experiments. From bottom to top, the components are as follows. (Dark gray) Implant analog, (Purple) Prosthetic screw, (Gray) Hybrid base, (Red) Cement and (light gray) ceramic crown.

All groups were comprised of 15 specimens. The first experiment was designed to test the influence of the cementation gap size on the mechanical retention of the hybrid base/crown assembly. To achieve this, the internal geometry of the crown was varied to obtain a gap distance, between the cementing surface of the crown and the cementing surface of the hybrid base, of either 20, 40 or 80 µm. Following manufacturing and sintering, the manufactured parts were measured to assess the precision of the components. Based on these measurements, the nominal dimensions of the cement gaps were 17±1, 40±2 and 79±2 µm. To prepare for the cementation process, the cementing surface of the crown was blasted using 50 µm (Edelkoround, Elstrøm Dental A/S, Denmark) at a pressure of 2 bar at a distance of 1 cm from the surface of the crown. Subsequently, excess blasting media was removed using a jet of compressed air. The crown and hybrid base were then cleaned by submerging the component in isopropanol, 99.9% (Borup Kemi, Denmark) inside an ultrasonic cleaning bath (Bransonic CPX1800-E, Emerson Automation Solutions, Denmark) for a period of 5 minutes. Subsequently, the hybrid base was cleaned in US-cleaning and mounted wearing gloves on a compatible print model analog (PMA) (Elos Medtech, Denmark) before both parts were rinsed in membrane filtered water (RO water) and dried under a stream of oil free compressed air. All handling was performed using nitril gloves. The cementing surfaces of the crown and the hybrid base were then primed using Cerafil

Ceramic Primer Plus (LOT:7L0055, Kuraray Noritake Dental Inc., Japan), in accordance with the manufacturer's specifications. When the primer was dry, freshly mixed Panavia V5 Paste (LOT:7P0137, Kuraray Noritake Dental Inc., Japan) was applied as a uniform layer, completely covering the cementing surface of the hybrid base. Immediately after, the crown was placed on the hybrid base and excess cement was removed from the margin and the screw channel. The components were then mounted in a jig, to ensure correct positioning during the curing step. Curing was performed by irradiating the cement with UV light (Bluephase G4 LED Curing Lamp, Ivoclar Vivadent, Liechtenstein) from four different positions around the interface line of the crown/hybrid base assembly. At each position irradiation was performed for 20 seconds. Following irradiation, the assembly was left in the jig for 3 minutes.

To assess the impact of different cleaning agents, hybrid bases and ceramic crowns were cleaned using either steam, isopropanol or the commercially available cleaning agent, Katana Cleaner (Kuraray Noritake Dental Inc., Japan). For these tests, the gap distance was kept constant at a width of 40 µm. The cementation protocol utilized for these tests was identical to the one used for the evaluation of the cementation gap size, however, isopropanol was exchanged for either steam or Katana Cleaner. Steam cleaning was performed using a steam cleaner (SUPER STEAMER, Feinwerktechnik GmbH, Germany) at 6 bar and at a distance of 5 cm from the surface for one minute, ensuring even contact between the steam jet and the cementing surface of the parts. Cleaning using Katana Cleaner was performed in accordance with the manufacturer's specifications.

The test to evaluate the influence of blasting media particle sizes was performed using either 50 or 100 µm particles (Edelkoround, Elstrøm Dental A/S, Denmark) for the pretreatment of the crown cementing surface. The cementing surface of the hybrid base was not subjected to the blasting step. For this round of testing the Katana Cleaner was used and the remaining steps of the cementation protocol was identical to the previous tests.

The influence of the potting time on the maximum retention force was evaluated by varying the placement of the crown on the cementation surface, from 0 to 5 minutes in steps of 1 minute. The limit of 5 minutes was chosen because the Panavia V5 Paste cured in the syringe after 5 minutes preventing discharge.

The last test series was performed to evaluate the effect of ageing of the cemented components. In this context ageing is considered subjecting the cemented components to clinically relevant external factors that could potentially affect the properties of the cemented hybrid base/crown interface. Again, preparation was performed by subjecting the cementing surface of the crown to blasting with 50 µm particles, followed by cleaning of the cementing surfaces using Katana Cleaner. The remaining cementation protocol was performed as described for the other test series. After cementation, the test groups were either stored at ambient condition for three weeks (Dry Storage) or kept hydrated inside a plastic bag, prior to being subjected to alternating temperatures under wet conditions (Thermocycling). Thermocycling was performed for 5000 cycles during which the items were alternatingly dipped into water at temperatures of 5°C and 55°C using the Thermocycler 1100/1200 (SD Mechatronik, Germany). At each temperature, the items were submerged for 20 seconds.

Mechanical testing

Prior to performing the retention test, all specimens were subjected to steam sterilization at 134°C (Lina Sterilizer, PRO13-003-17, W&H, Denmark). Subsequently, Items were mounted in a tensile testing machine (H5K-S, Tinius Olsen, Denmark) equipped with a 5 kN load cell. Tensile testing was performed at an extension speed of 0.5 mm/min, until failure. The retention force was logged throughout the experiment and the maximum retention force was determined as the highest recorded value, prior to failure.

Statistical analysis and data representation

Data from the mechanical testing is represented as boxplots with median values represented by a bold black line, the interquartile range (IQR) is represented by a gray box and the first (Q1) and fourth (Q4) quartiles are represented by dotted lines with bars at the end. Outliers are marked by circles and are defined as values that are at least separated from the mean by 1.5 x IQR. Analysis for statistical significance for differences between the median values has been performed using a two-sided Mann Whitney U Test, with a confidence level of 0.95. All statistical analysis and plots have been prepared using RStudio (RStudio, Version 1.4.1717, PBC, Boston, MA)

Results

Cementation gap size

The retention test data, obtained using the samples with varying cement gap sizes, is presented in Figure 2. As is evident, similar mean values are found between the groups (no statistically significant differences), however, the 20 µm group displays twice the spread relative to the 40 – 80 µm groups.

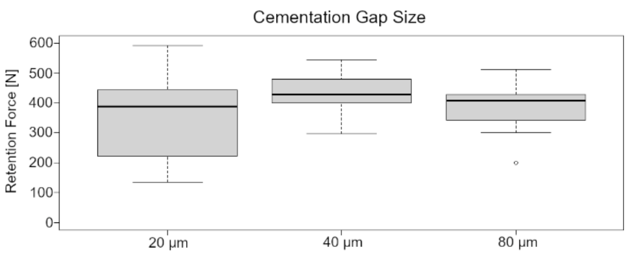

Figure 2: Boxplots showing retention force data resulting from varying the cementation gap size. For this test, all samples were cleaned using Isopropanol. No statistically significant differences were found between the median values of the groups, however, if the outlier of the 80 µm group is taken into consideration, the spread of the data for this and the 20 µm group is wider than that observed for the 40 µm group.

Cleaning method

The data obtained from the groups having been subjected to cleaning using either isopropanol, steam or Katana Cleaner is presented in Figure 3. As is evident, the steam cleaning method results in the lowest median value and the largest spread of the data set, compared to the two other groups. The highest median value, along with the lowest variance is observed for the Katana Cleaner group.

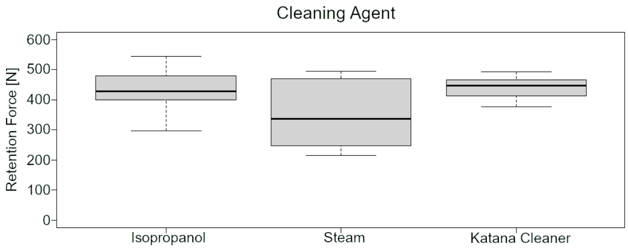

Figure 3: Boxplots showing the retention force data resulting from using either Isopropanol, Steam or Katana Cleaner as cleaning agent. No statistically significant differences were found between the median values of the groups, however, steam cleaning results in the lowest mean value and the largest spread.

Blast media particle size

Data from the blasting media particle size test is presented in Figure 4. Again, median values are comparable, however, the variance of the data resulting from the 100 µm particle size is larger compared to that seen for the 50 µm particle size.

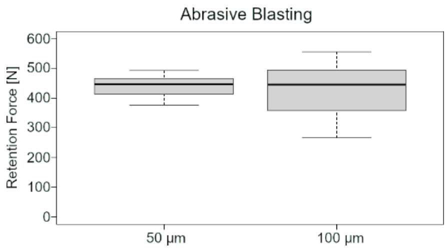

Figure 4: Boxplot of data resulting from varying the particle size of the blasting media used for the pre-treatment of the ceramic crown cementation surface. For this test, all samples had been cleaned using Katana Cleaner. No statistically significant differences were found between the median values of the groups, however, the spread for the 100 µm group is observed to be wider, compared to the 50 µm group.

Ageing

Cemented items were subjected to two different ageing parameters, namely dry storage for 3 weeks and thermocycling. The data from this test series is presented in Figure 5 and the groups are compared to parts having been tested immediately following cementation. All groups have been prepared using the Katana Cleaner and surfaces were blasted using 50 µm particles. It is evident that both dry storage and thermocycling results in a wider spread of the measured retention forces, however, no significant difference between the mean values were found.

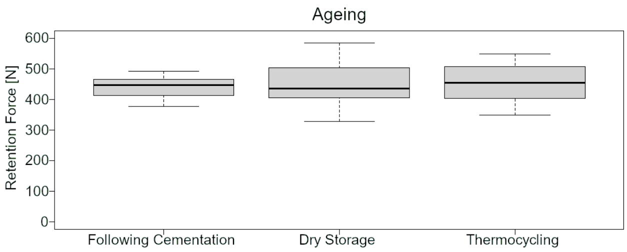

Figure 5: Boxplot of data showing the effect of ageing. While no significant differences are observed between the mean values, it is evident that both dry storage and thermocycling results in a wider spread of the data.

Potting time

As is illustrated in Figure 6 there is no effect of the potting time on the retention force of the crown on the cementation surface. However, the application of a uniform layer of the freshly mixed Panavia V5 Paste should be performed within the first 5 minutes.

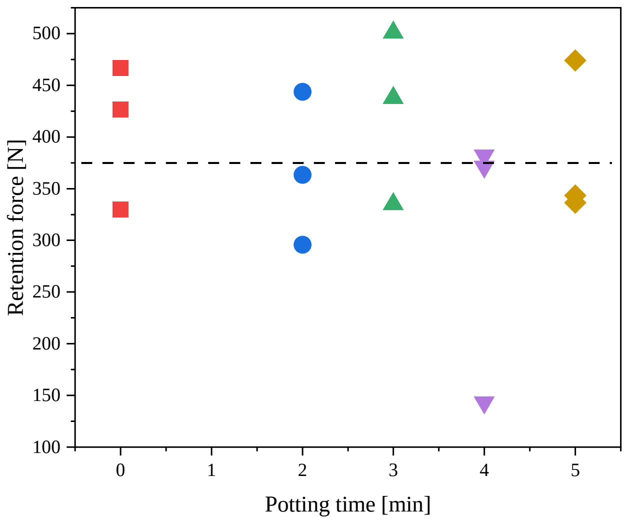

Figure 6: Scatter plot showing the retention force of the crown on the cementation surface as a function of potting time. There is no connection between potting time and retention force.

Discussion

The comparison of the groups of the four different test parameters did not show any statistically significant differences between the mean values for the retention force. However, considering the clinical use of the cemented restorations, the highest possible mean retention value is not necessarily the most desirable outcome. Instead, being able to produce restorations with adequate and consistent retention properties should be the goal for dental professional. In other words, if a specific cementation protocol yields a high median retention force but has a high spread of the data it would mean that a relatively larger proportion of the prepared restorations are at risk of failing, relative to a slightly lower median retention force showing a narrow variation. Considering the limitations of the current study, under the specified condition, the findings suggest that the optimal cementation gap is 40 µm, as this was found to yield the largest mean value and have the lowest variance, when the outlier of the 80 µm group is considered. Limited literature is available on the influence of cementation gap sizes on the retention properties of cemented interface and a direct comparison with the literature is further complicated by the use of different cement systems. The study by A. Abou-Obaid and R. Alkhudairy, 2018 examined the properties of interfaces with varying thicknesses, using a provisional cement. They found that the retention force generally decrease with increasing gap sizes (20, 35 and 50 µm) [8]. For the current study, looking at the individual data points of the 20 µm gap size group, this is found to comprise some of the highest measured values, suggesting that the lower mean and the overall larger variance of the data set could be related to difficulties in obtaining an even distribution of the cement, within the cement space. Further studies on this, e.g. based on cross-sectional analysis of the cementation gap, to assess the uniformity of the cement distribution, would be of great interest.

The test performed to evaluate the different cleaning methods indicated that the use of steam is not the best suited method for preparing the surface for cementation. If steam is used to remove remnants from e.g. a blasting process, subsequent cleaning with Isopropanol or Katana Cleaner is to be recommended. Again, the literature on this subject is limited, however, it is common to see recommendation for the use of steam cleaning in various cementation guides, provided by the manufacturers of dental components. Considering the mode of action by Isopropanol and Katana Cleaner, the findings from the current study could suggest that the reduced retention observed for the steam cleaned method could originate from surface contamination by hydrophobic species. Source of such species are diverse and omnipresent even in laboratory settings. In relation to this, it would be interesting to examine if a prolonged steaming process could enhance the adhesive retention of the crown on the hybrid base. Additionally, chemical characterization using e.g. X-ray photoelectron Spectroscopy (XPS) might be useful to further investigate the findings and shed light on the potential differences in surface chemistry.

An alternative explanation for the observed effect of steam could potentially be the presence of water at elevated temperatures. It has been found that subjecting zirconia to autoclavation over prolonged periods of time can have a negative effect on the material, as this can promote the transition from the tetragonal to the monoclinic phase and, thus, decrease the mechanical properties of the material [9]. Hence, one might speculate that the relatively short period of steam cleaning could induce slight changes in the structure of the material at the cementing surface of the zirconia. If this, however, would be a determining factor for the retention properties of the hybrid base/crown interface, one would anticipate to consistently find failures were the cement has detached from the zirconia surface. This consistency was not found for the current study, hence, this is also a subject for further investigation.

The effect of blasting media particle sizes resulted in comparable mean values for both the 50 and 100 µm groups. Looking closer at the data, it is evident that the variance of the 100 µm group is larger than for the 50 µm particles. The study by Su, N., et al., 2015 found that the use of 110 µm particles and blasting for 21 seconds at 2 bar, were to be recommended for zirconia components [10]. This contradicts the findings from the current study, as the lowest variance of the data was found for the 50 µm particles. Detailed surface characterization has not been performed in the current study, however, the 100 µm particles would be expected to yield a higher surface roughness and a larger total surface area, hence, this would be beneficial to the overall retention of the cured cement. One possible explanation for the results observed for the current study could be related to the viscosity of the dental cement. Having a material with a relatively high viscosity on a surface with a relatively larger distance between peaks and valleys of the surface structure would present a risk of not having the material contacting the total surface area. In this case, it might have bene beneficial to have applied the cement directly to the cementing surface of the crown to allow for the cement to be fully engaged with the total surface area, prior to assembling the two parts. Again, it would be interesting to perform cross-sectional analysis of the hybrid base/crown interface, to assess the degree of contact between the cement and the surface of the ceramic crown.

The final influence parameter, examined during this study, was the effect of ageing. In relation to this, manufacturers of dental cement often recommend that cemented parts are shipped under wet condition to prevent the cemented interface from dehydrating, prior to being mounted in the oral cavity. Another ageing aspect, that is not as easy to mitigate at the dry storage, is the temperature ranges that the cemented components will face during use, e.g. induced by the host eating a hot meal while having a cold drink. Collectively, the data from the ageing experiments did not show any significant differences compared to mean values of the freshly cemented components. The ageing was, however, found to increase the spread of the measured retention force values. The data might hint towards dry storage being slightly more disadvantageous, compared to thermocycling and since it is easy to prevent dehydration of the cement, based on the current data, wet storage is recommended. Generally, for the ageing test, care should be taken when drawing conclusions since we are comparing the effect of prolonged dry storage and/or thermocycling to freshly cemented components. Optimally, a group having been stored under wet conditions should have been included in the experiment and this is a point for further research. Based on the results, it appears that the ageing has an effect, however, it is not possible to elute if this effect is caused directly by the storage conditions and/or thermocycling or simply by post-curing processes within the cement.

Conclusion

Based on the finding from this study, it is concluded that

- Preparation of the ceramic crown should be performed as to produce a cementation gap size of 40 µm.
- Steam should be avoided as a method for terminally cleaning parts for cementation. The use of Isopropanol or Katana Cleaner is recommended.
- The result from the abrasive blasting process suggests that a particle size of 50 µm is to be preferred, however, more research is needed to fully understand the mechanisms involved in the observed differences, between the groups.
- Dry storage and thermocycling were found to have an effect on the spread of the data, compared to freshly prepared specimens, however, additional investigations are needed to assess to what extend the observed effects are a direct result of the external factors or merely a result of internal processes in the cement.
- There is no effect of the potting time of the Panavia V5 Paste on the cementation surface, however it needs to be applied within 5 minutes.

References

1. *Moraschini, V., et al., Evaluation of survival and success rates of dental implants reported in longitudinal studies with a follow-up period of at least 10 years: a systematic review. Int J Oral Maxillofac Surg, 2015. 44(3): p. 377-88.*
2. *Ladino, L., A. Sanabria, and M. Cruz, Titanium Bases in Implant Dentistry: A Comprehensive Narrative Review. 2020.*
3. *Ebert, A., J. Hedderich, and M. Kern, Retention of zirconia ceramic copings bonded to titanium abutments. The International journal of oral & maxillofacial implants, 2007. 22 6: p. 921-7.*
4. *Nejatidanesh, F., O. Savabi, and M. Shahtoosi, Retention of implant-supported zirconium oxide ceramic restorations using different luting agents. Clin Oral Implants Res, 2013. 24 Suppl A100: p. 20-4.*
5. *T. P. Bergamo, E., et al., Retention of zirconia crowns to Ti-base abutments: effect of luting protocol, abutment treatment and autoclave sterilization. Journal of Prosthodontic Research, 2021. advpub.*
6. *Burkhardt, F., et al., Retention Forces of Monolithic CAD/CAM Crowns Adhesively Cemented to Titanium Base Abutments-Effect of Saliva Contamination Followed by Cleaning of the Titanium Bond Surface. Materials (Basel), 2021. 14(12).*
7. *Ozyetim, E.B., et al., Effect of different surface treatments on retention of cementretained implant supported crowns. Int J Prosthodont, 2021.*
8. *Abou-Obaid, A.A. and R. Alkhudairy, Effect of Abutment Height and Cement Thickness on the Retention of Cement-Retained Implant-Supported Restorations. Advances in Dentistry & Oral Health, 2018. 9.*
9. *Pereira, G.K.R., et al., Low-temperature degradation of Y-TZP ceramics: A systematic review and meta-analysis. J Mech Behav Biomed Mater, 2015. 55: p. 151-163.*
10. *Su, N., et al., The effect of various sandblasting conditions on surface changes of dental zirconia and shear bond strength between zirconia core and indirect composite resin. The journal of advanced prosthodontics, 2015. 7(3): p. 214-223.*