ROTATIONAL ACCURACY OF ALL-CERAMIC RESTORATIONS ON CERAONE COMPONENTS

LIBERDADE ROTACIONAL DE RESTAURAÇÕES TOTALMENTE CERÂMICAS SOBRE COMPONENTES CERAONE

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RESUMO

Objetivo: Este estudo avaliou a desadaptação interna de sistemas cerâmicos em prótese sobre implantes em relação à liberdade rotacional das restaurações após várias cocções da porcelana. **Materiais e métodos:** Foram analisados três sistemas cerâmicos: Procera AllCeram, In-Ceram e CeraOne sobre análogo e intermediário CeraOne. A liberdade rotacional foi medida com um dispositivo acoplado a um relógio comparador em quatro tempos: fase de coifa, após aplicação do corpo da porcelana e glaze, e após duas queimas adicionais. Os dados foram analisados por testes de Friedman, de Kruskal-Wallis e de Wilcoxon, α = 0,01. **Resultados:** As médias de liberdade rotacional em graus foram: 0,08 para In-Ceram/Análogo; 1,64 para Procera/Intermediário; 1,72 para CeraOne/Intermediário; 1,88 para CeraOne/Análogo e 1,97 para Procera/Análogo. O sistema In-Ceram sobre o análogo apresentou níveis de liberdade rotacional dez a vinte vezes menores que CeraOne e Procera. Não houve diferença entre as fases de confecção da restauração para In-Ceram. O comportamento de CeraOne e Procera foi similar, com aumento da liberdade rotacional sobre intermediário e análogo com a progressão da confecção da restauração. A liberdade rotacional sobre intermediário foi menor que sobre análogo. **Conclusão:** A liberdade rotacional variou em função da etapa do processo de fabricação dependendo do sistema totalmente cerâmico.

UNITERMOS: adaptação; cerâmica; implante dentário.

SUMMARY

Aim: *This study evaluated the rotational accuracy between single-tooth all-ceramic restoration and laboratory analog/abutment.* ***Materials and methods:*** *Three all-ceramic systems were tested: Procera AllCeram, In-Ceram, and CeraOne. Rotation freedom was measured with a customized device at four phases of the restoration manufacturing process: coping, after application of ceramic and glaze, and after two additional firings. Data were analyzed using Friedman, Kruskal-Wallis, and Wilcoxon tests at* α *= 0.05.* ***Results:*** *The mean values of rotational freedom for each set of ceramic system/support element were (in degrees): 0.08 for In-Ceram/Analog; 1.64 for Procera/Abutment; 1.72 for CeraOne/Abutment; 1.88 degrees for CeraOne/Analog; and 1.97 for Procera/Analog. In-Ceram on analog had rotational freedom values tento twenty-fold lower than the systems CeraOne and Procera. In-Ceram had no significant difference of rotational misfit for any of the four stages of fabrication. CeraOne and Procera systems showed similar patterns with increasing rotational freedom along the manufacturing phases, considering both abutment and analog measurements. The values of rotational freedom for the Abutment group were significantly lower than for the Analog group.* ***Conclusion:*** *Rotational freedom varied as a function of the stage of the manufacturing process depending on the all-ceramic system.*

UNITERMS: *adaptation; ceramics; dental implantation.*

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INTRODUCTION

One major indication of implant-supported prosthesis is the replacement of single anterior tooth when the adjacent teeth do not need dental treatment. As the rehabilitation of the anterior segment requires excellence in esthetics, all-ceramic crowns are often used because offer greater light transmission through the restoration compared to metalloceramic crowns. Many manufactured and customized all-ceramic systems for implant-supported prostheses are available. In 1991, Nobel Biocare introduced the CeraOne components, which present anti-rotational features between the manufactured abutment and the alumina coping[1,8]. Procera AllCeram is another all-ceramic system developed by Nobel Biocare and uses a computer-assisted process (CAD/CAM) to fabricate customized copings[17]. Also, In-Ceram system (Vita, Germany) has been widely used in copings applied over refractory dies[13].

Besides esthetics, other requirement for implant-supported prostheses is passive fit and adaptation of components. Internal and marginal misfit may cause biofilm accumulation, ceramic fracture at cervical margins, and alteration of positioning and occlusion due to rotation of the restoration during cementation[4,7,10]. The evaluation of internal adaptation is more complex than the assessment of marginal adaptation, and several methods have been proposed: measurement of the luting agent thickness with optical microscopy[18], weighing of a silicon film representing the gap between components[9], and measurement of rotational freedom[5,6,7,14].

Up to date, studies on internal misfit of all-ceramic implant-supported prostheses are scarce. Information of rotational freedom after successive ceramic firings also is lacking. This study aimed to evaluate the internal adaptation of all-ceramic single restorations by measuring the rotational freedom between the internal hexagonal of the restoration and the external hexagonal of the implant prosthetic component. Comparisons were made as a function of three ceramic systems (CeraOne, Procera AllCeram, and In-Ceram); four phases of fabrication of the ceramic restoration: ceramic coping and after three ceramic firings (body + glaze, first additional firing, and second additional firing); and the support element (CeraOne analog and CeraOne abutment).

MATERIALS AND METHODS

Ceramic restoration fabrication

Each experimental group had five specimens. Test specimens were made with Vitadur Alpha ceramic (Vita, Germany) applied over three all-ceramic systems: prosthetic components of the manufactured system CeraOne DCA 127 (Nobel Biocare, Gothemborg, Sweden), customized copings of the system Procera AllCeram (Procera production AllCeram system for CeraOne abutment, Nobel Biocare AB, Gothemborg, Sweden), and customized copings of the system In-Ceram (Vita, Germany).

In-Ceram copings were fabricated by a specialized dental laboratory (Laboratório Luiz Arthur Schneider Ltda, Porto Alegre, RS). The analog was duplicated into five refractory dies, which were coated with a thin layer of a sealer and two layers of Vita In-Ceram Interspace Varnish (Vita, Germany) on the axial and occlusal walls. Alumina was prepared in the proportion of 38 g of Vita In-Ceram Alumina Powder to 5 mL of Vita In-Ceram Alumina Mixing Liquid and one drop of Vita In-Ceram Additiv. A silicon index with the CeraOne DCA 127 dimensions was adapted over the refractory dies to standardize the coping shape. Sintering was performed using the program 1 of the Inceramat II oven. After this cycle, the alumina copings were allowed to cool inside the oven until room temperature. The sintered alumina copings were then removed from their dies, and the surface was coated with a mixture of AL 4 In-Ceram Alumina Glass Powder and distilled water, except for the margins. After glass application, all copings were taken to the Inceramat II oven for the glass infiltration process (program 2).

Vitadur Alpha ceramic (Vita, Germany) was prepared and applied over all copings according to the manufacturer's instructions. Standardization of shape was obtained with a metallic index (6 mm diameter, 6 mm height). Ceramic firings were performed according to the program: First firing (drying for 3min, pre-heating for 3min, rise of temperature from 575°C at a rate of 55 °C/min, final temperature of 920°C – with no vacuum for 1min); Glaze (drying for 2min, pre-heating for 3min, rise of temperature from 575°C at a rate of 55°C/min, final temperature of 920°C – with no vacuum for 1min). Two additional firings simulated corrections in the ceramic application.

Measurement of maximum rotational freedom

For the measurement of rotational freedom on the abutment, all-ceramic copings and restorations were attached to one abutment CeraOne (SDCA 334 – Nobel Biocare, Gothemborg, Sweden). The same procedure was done for the measurement of rotational freedom on the analog CeraOne (DCD 129 – Nobel Biocare, Gothemborg, Sweden). Rotational freedom between the internal hexagonal of the ceramic copings and the external hexagonal of the abutment (or analog) was evaluated using a device developed by Meyer (2000). This device is composed by a dial indicator with 0.01 mm precision (Mitutoyo, model 2046-08, 0.01-10 mm, Brazil), one metallic base and one attachable metallic bar (Figure 1).

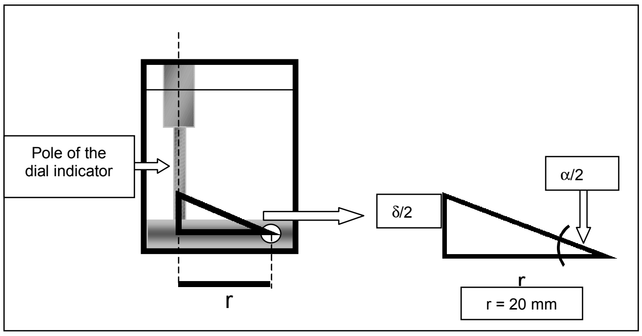

Figure 1 – Graphic representation of the device used to measure rotational freedom, where [r] = bar radius, [α] = angle formed during the bar displacement, and [δ] = displacement of the bar, which moves the pole of the dial indicator. The circle indicates the place of fixation of the implant/abutment or implant/analog.

The dial indicator was attached to a lateral hole of the metallic base and fixed with a screw so that its pole was parallel to the surface of the metallic base. The ceramic restoration was then fixed in a hole of the metallic bar with a screw. Rotational freedom was measured in four occasions: coping phase and after each ceramic firing (body + glaze, first additional firing, and second additional firing). Before measurement, the ceramic restoration was completely seated over the abutment (or analog) and fixed to the metallic bar with one screw so that the bar was perpendicular to the dial indicator pole. The bar was then digitally pressed against the pole to promote rotation of the restoration over the abutment (or analog). The concurrent movement of the bar intruded the pole of the dial indicator, which measured this displacement in millimeter. Before the real data collection, one operator (J.W.) performed a calibration session to standardize positioning and measurement procedures.

Data were collected according to the following operational steps: 1) Execution of 20 movements of the metallic bar with progressive digital pressure to verify maximum displacement; 2) Return of the dial indicator to zero after each bar movement; and 3) Reading of the maximum value of displacement before the metallic bar become loose. The limit of rotational freedom was measured in millimeter and transformed in degrees using the formula: *Sen* $(\alpha/2) = (\delta/2)/20 = (0.005)/20 = 0.014°$. Therefore, 0.028° was equal to 0.01mm of displacement of the dial indicator.

Data were statistically analyzed by Friedman, Kruskal-Wallis, and Wilcoxon tests, at 0.01 level of significance.

RESULTS

Measurement of rotational freedom for In-Ceram system on abutment could not be performed because all restorations did not fit. All-ceramic systems showed statistically different rotational freedom means when combining all phases of restoration fabrication (Table 1). For Ceram system, values were approximately twenty-fold smaller than CeraOne's and Procera's.

TABLE 1 – Rotational freedom (in degrees) as a function of Ceramic system – support element and phases of restoration fabrication.

Ceramic system	Mean*	SD	Rank Order	p
Support element (n = 5)				
In-Ceram – Analog	0.08 A	0.07	3.0	< 0.001**
Procera – Abutment	1.64 B	0.09	9.0	
Ceraone – Abutment	1.72 C	0.07	12.0	
Ceraone – Analog	1.88 D	0.05	18.5	
Procera – Analog	1.97 E	0.05	22.5	
Phases of fabrication (n = 25)				
Coping	1.09 A	0.52	1.5	< 0.001***
Coping + *Glaze*	1.29 B	0.64	2.1	
1 additional firing	1.58 C	0.80	2.8	
2 additional firing	1.87 D	0.93	3.6	

* Means followed by different letters are statistically different.
** Kruskal-Wallis test.
*** Friedman's test. Post-hoc comparisons by Wilcoxon's test.

All combinations but InCeram's presented significant increase of rotational movement for all phases of restoration fabrication (Figure 2). Considering Procera AllCeram and CeraOne systems, the mean values of rotational freedom on

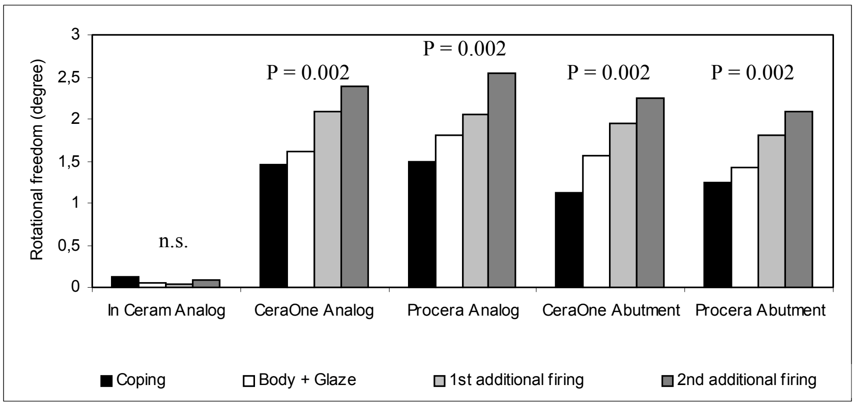

Figure 2 – Rotational freedom as a function of the four phases of restoration fabrication for each ceramic system/support element combination (n = 5).

the analog were statistically higher than the mean values on the abutment for all phases of restoration fabrication except for the second firing (Table 2).

TABLE 2 – Rotational freedom means as a function of the support element (analog *versus* abutment) within each phase of restoration fabrication for Procera AllCeram and CeraOne ceramic systems (n = 10; Wilcoxon's test).

Support element	Mean	Standard deviation	p
Coping			
Analog	1.4756	0.062	0.005
Abutment	1.1872	0.079	
Body + Glaze			
Analog	1.708	0.1048	0.005
Abutment	1.496	0.1392	
1st Additional Firing			
Analog	2.072	0.1128	0.007
Abutment	1.868	0.1885	
2nd Additional Firing			
Analog	2.464	0.1885	0.012
Abutment	2.167	0.1354	

DISCUSSION

Many methods have been proposed to assess the fit accuracy of indirect restorations at margins and interfaces of restoration and abutment. Microscopic measurements of the thickness of luting agents in cemented restorations[12,18] provide information of internal adaptation only in selected points. Rotational freedom measurements reflect internal adaptation in a global view and also allow serial observation of the same specimen along its fabrication process. The distance between two points when the walls of the internal hexagonal of the restoration contact the external hexagonal of the abutment or analog establishes the limit of maximum rotational freedom. With this method, our results show that a progressive increase of rotational freedom occurs along the fabrication phases of all-ceramic implant-supported restorations. Mean values of rotational freedom increased from 1.09 to 1.87 degrees. Binon[5] (1995) and Meyer[14] (2000) consider that five degrees of rotational freedom between metallic implant components would be the clinical acceptable threshold. However, the importance of this value may be different for all-ceramic restorations.

A problem derived from the increase of rotation of ceramic restorations is the possibility of horizontal movement in relation to their support elements. This generates stress concentration at the restoration margins, which can lead to ceramic fracture. Rotational freedom could be visually detected after the second additional firing of the ceramic systems. However, this magnitude of rotational movement would limit the clinical use of these ceramics as internal space between restoration and support element always is needed for the luting agent.

Individual analyses for each group showed that the rotational patterns of CeraOne and Procera were homogeneous in all phases of restoration fabrication. Significant increase in rotation was disclosed along the ceramic firings. The rotational freedom almost duplicated between the coping phase and the second additional firing. In clinical terms, this relationship becomes important, as several additional firings may be necessary to correct minor defects and achieve optimal esthetic results.

The behavior of In-Ceram system was completely different from the others. When the specimens were fabricated following the manufacturer's recommendations and using two spacer layers applied over the analog die, all copings did not adapt over the abutment. Therefore, rotation measurements only could be performed on the analog. This fact suggests that the dimensions of analogs and abutments are different, which is critical for In-Ceram restorations. Others also have found that In-Ceram system requires up to three layers of spacer to provide sufficient internal room for complete seating on abutments[18]. On the other hand, In-Ceram copings on the analog did not have any difference in rotational freedom with addition of ceramic or firings. This dimensional stability may be explained by its physical structure, which presents diffusion of glass through the alumina porosities reinforcing the coping[16].

CeraOne components (DCA127) are regarded as the first choice for single crowns and show better global adaptation compared to In-Ceram, IPS Empress and Fortune ceramic systems[11]. Procera AllCeram system exhibits high flexural strength and density, with less porosity in the bulk of the material[3,17], and clinically acceptable internal adaptation as measured by cement thickness[12]. However, in our study both Procera AllCeram and CeraOne restorations presented different adaptation patterns on abutment and on analog. Rotational freedom of all restorations on abutment was always smaller than on laboratory analog.

In the literature, CeraOne[2,19], In-Ceram[9,15,16], and Procera AllCeram[3,12] show clinically acceptable marginal misfit. Our results demonstrate that single implant-supported restorations made with these all-ceramic systems present rotational movement, but this may be clinically acceptable. Further studies are necessary to verify the relationship among rotational freedom, luting agent thickness, and marginal adaptation to establish clinical parameters for long term success.

CONCLUSIONS

Rotational freedom increases with the number of ceramic firings but its magnitude is dependent on the all-ceramic system. In-Ceram system does not exhibit the same accuracy pattern of Procera AllCeram and CeraOne systems, which show similar increase of rotational freedom along the process of restoration fabrication. Rotational accuracy of ceramic restorations on abutment was better than on analog except for In-Ceram system.

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