Effect of Thermal Tempering on Bonding Strength of Ceramic Veneered to Yttrium Partially Stabilized Tetragonal Zirconia Polycrystal (Y-TZP) Ceramic System

ผลของการลดลงของอุณหภูมิในอัตราส่วนการเย็นตัวต่างๆกันต่อการยึดติดของโครงอิตเทรียมเททระโกนอลเซอร์โคเนียโพลีคริสตอลที่ใช้วีเนียร์ในแต่ละระบบ

Wuddhinan Phanomlaksanajid (วุฒินันท์ พนมลักษณจิต)* Dr.Niwut Juntavee (ดร.นิวัตร จันทร์เทวี)**
Dr.Supaporn Chatrchiwiwatana (ดร.สุภาภรณ์ ฉัตรชัยวิวัฒนา)***

ABSTRACT

The aim of the present study was to evaluate the effect of thermal tempering after procedures of veneering porcelain on shear strength between veneering porcelain and a zirconium dioxide(zirconia;ZrO_2) ceramic material, whereby all core materials are IPS e.max® ZirCAD. The total of 144 ZrO_2(IPS e.max® ZirCAD) disks were divided into three groups including conventional veneering technique,heat press veneering technique, and CAD-on veneering technique. Each group (16 specimens) was divided into three groups then cooled using a fast, slow or ultraslow cooling rate. After shear bond testing was conducted. The results showed that shear bond strength differed significantly in all three methods and also differed significant by fast and ultraslow cooling rate.

บทคัดย่อ

วัตถุประสงค์ของการศึกษานี้เพื่อศึกษาผลของวิธีการขึ้นรูปเซรามิคและการลดลงของอุณหภูมิหลังการขึ้นรูปต่อแรงยึดติดระหว่างวัสดุวีเนียร์และเซอโคเนียร์ ซึ่งการทดลองนี้ได้เตรียมชิ้นงานเซอโคเนียร์ยี่ห้อ ไอพีเอส อีแมกเซอแคดทั้งหมด 144 ชิ้น มาทำการขึ้นรูปด้วยวิธีการขึ้นรูปแบบดั้งเดิม แบบใช้ความร้อนพร้อมแรงดัน และแบบแคดออนอย่างละ 48 ชิ้น หลังจากนั้นแบ่งเป็น 3 กลุ่มกลุ่มละ 16 ตัวอย่าง นำแต่ละกลุ่มมาทำการเผาครั้งสุดท้ายหลังการขึ้นรูปและลดอุณหภูมิลงจนถึงอุณหภูมิห้องในอัตราเร็วสามอัตราคือเร็ว ช้า และช้าที่สุด หลังจากนั้นนำชิ้นงานทั้งหมดมาทดสอบแรงยึดติดระหว่างวัสดุวีเนียร์และเซอโคเนียร์แกนกลาง จากผลการทดสอบพบว่าการขึ้นรูปวีเนียร์เซรามิคทั้งสามวิธีและอัตราการลดลงของอุณหภูมิสู่อุณหภูมิห้องแบบเร็วและช้าที่สุดในการเผาครั้งสุดท้ายมีผลต่อแรงยึดติดระหว่างวัสดุวีเนียร์และเซอโคเนียร์แกนกลางอย่างมีนัยสำคัญ

Key Words: Zirconia, Thermal tempering, Shear bond strength
คำสำคัญ: เซอโคเนียร์ การลดลงของอุณหภูมิ แรงยึดติดระหว่างวัสดุ

** Student, Master of Science in Prosthodontics, Faculty of Dentistry, Khon Kaen University*
*** Associate Professor, Department of Prosthodontics, Faculty of Dentistry, Khon Kaen University*
**** Associate Professor, Department of Prosthodontics, Faculty of Dentistry, Khon Kaen University*

Introduction

Ceramics have been interesting and widely used in restorative and esthetic dentistry because they have good optical properties, mechanical properties and biocompatibility(Kelly, 2004; Aboushelib et al., 2006). There are many techniques to fabricate all ceramic restoration such as heat pressing, slip casting and computer aid design-computer aided machining (CAD-CAM). Since ceramic is brittle in nature, it needs to be strengthened by a stronger core when an extensive restorative procedure is considered. This leads to the layering technique of ceramic veneer over the ceramic core that has become more popular since it provides both esthetic and strength and has been suggested for use as both a single crown and fix partial denture (Guazzato et al., 2004). However chipping of the veneering porcelain has been identified as one of its main problems, which has been the instigation for a large number of studies(Al-Amleh et al., 2010). Chipping of the veneering porcelain has been identified as a major setback for zirconia-based restorations(Al-Amleh et al., 2010). The literature has cited several explanations as to why zirconia-based all-ceramic restorations have a higher incidence of chipping fractures (cohesive rather than adhesive fractures) compared to metal-ceramic and other all-ceramic restorations. These include the mismatch of the coefficient of thermal expansion between the zirconia and veneering porcelain (Fischer et al., 2009), mechanically defective micro-structural regions in the porcelain, areas of porosities (Ohlmann et al., 2008), surface defects or improper support by the framework (Marchack et al., 2008), overloading and fatigue (Coelho et al., 2009), and low fracture toughness of the veneering ceramic (Beuer et al., 2009). Nevertheless the most accepted explanation so far is the development of high residual tensile stresses within the veneering porcelain caused by fast cooling zirconia restorations as proposed by Swain(Swain, 2009). Indeed, slow cooling firing programmes have recently been introduced by zirconia manufacturers in order to reduce the risk of chipping fractures (Gostemeyer et al., 2010). Now it is believed that the development of high residual tensile stresses within the veneering porcelain caused by the differential cooling rate of the porcelain around its glass transitional temperature may result in an unstable bilayered system prone to chipping (Swain, 2009). Zirconia is a very poor thermal conductor so the heat is trapped in the porcelain close to the zirconia core which leads to large thermal gradients within the veneer. This is exacerbated by the rapidly cooling zirconia restoration which then forms a high porcelain sintering or glazing temperature(Taskonak et al., 2008). The purpose of this study is to evaluate the role of thermal tempering on the bond strength of ceramic veneered to yttrium partially tetragonal zirconia polycrystal(Y-TZP) ceramic restoration and the influence of the veneering technique.

Materials and methods

One ceramic core material (IPS e.max ZirCAD) and three veneering porcelains (IPS e.max CAD, IPS e.max Ceram, IPS e.max ZirPress) were chosen for this study (table1). Each core material group contains three subgroups based on the veneering technique as follows conventional veneering technique (CV), heat press technique (HP), CAD-on technique (CAD) . Each subgroup was divided into three portions after they were veneered. In the final glazing, the duration of this process went from cooling to glazing temperature to room temperature. To determine the shear bond strength, a shear force was applied to the substrate/veneer interface using a universal testing machine (Lloyd®, Leicester, England) at a speed of 1 mm min^{-1} until fracture.

Table 1 Three commercial veneering ceramics and their veneering techniques according to the Manufacturer

Commercial veneering ceramic	Veneering tecnique	Manufacturer
IPS e.max ® Ceram	Conventional technique	Ivoclar-vivadent, Schaan, Leichtenstein
IPS e.max®ZirPress	Heat press technique	Ivoclar-vivadent, Schaan, Leichtenstein
IPS e.max® CAD	CAD-ON technique	Ivoclar-vivadent, Schaan, Leichtenstein

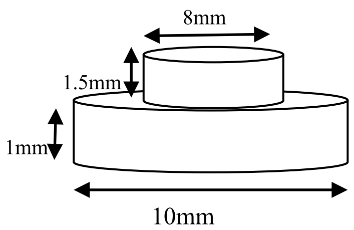

Fig 1 Schematic drawing of a sample preparation for shear bond strength

The results of the shear test were statistically analyzed with one-way ANOVA, followed by a post hoc Bonferroni test (SPSS Inc., Chicago, IL, USA; $p = 0.05$).

Preparation of the core specimen

For the IPS e.max ZirCAD groups, the specimens were dried prior to the sintering procedure. When the specimens were completely dry, the sintering procedure was conducted at a temperature of 1500^{0}c. All specimens were then place on a wet ground with 180, 300,500,600 and 800 grit silicon carbide papers to the dimensions of 10 mm. in diameter and 1 mm. in thickness

Conventional technique

IPS e.max® Ceram is used for veneering on core specimens. A creamy mixture which consists of the body of the porcelain is applied on the surface of the specimen and positioned in the metal mold to assist with the condensation procedure, it is then blotted dry with an absorbent tissue, and then fired in the porcelain furnace (ProgrammatP100 furnace, Ivoclar-Vivadent, Schaan, Leichtenstein) at a temperature which is in accordance to the manufacturer's instruction. All specimens were then place on a wet ground with 180, 300,500,600 and 800 grit silicon carbide papers to the dimensions of 8 mm. in diameter and 1.5 mm. in thickness

Heat press porcelain veneering technique

IPS e.max® ZirPress is used for veneering on core specimens. Forty-eight zirconia ceramic specimens were seated in a VPS mold (Aquasil Ultra LV fast set) with its dept adjusted to provide a 1.5 mm layer of the wax material and the specimens were sprued and invested according to the manufacture's recommendations. Heat-pressed fluorapatite glass-ceramic ingot (IPS e.max® ZirPress) was used for veneering porcelain and pressed for 15 minutes (IPS empress). All specimens were then place on a wet ground with 180, 300,500,600 and 800 grit silicon carbide papers to the dimensions of 8 mm. in diameter and 1.5 mm. in thickness.

CAD-on porcelain veneering technique

IPS e.max CAD material is milled to a final dimension of 8 mm diameter and 1.5 mm thickness. IPS e.max CAD Crystall/Connect is a fusion glass-ceramic for the IPS e.max CAD-ON technique. It is used to create a homogeneous bond between the IPS e.max ZirCAD framework and the IPS e.max CAD veneering structure during the IPS e.max CAD-on technique Fusion/Crystallization firing. After the IPS e.max CAD-on technique the fusion/crystallization firing at 840^{o}c which occured for a minute. The manufacturers' firing cycles consist of a ultraslow, slow and a fast cooling firing cycle which followed in the last firing.

Shear bond strength test

Finished specimens were fixed in a special sample holder and placed in a universal testing machine(Lloyd®, Leicester, England). The ceramic block was loaded up to failure with a chisel-shaped piston at the interface parallel to the zirconia surface with a crosshead speed of 1 mm/min. The shear bond strength was calculated as the mean of the 10 specimens from the load at the fracture and the surface area of the zirconia-veneer interface.

Results

The results of the shear bond strength tested were reported in terms of the mean and standard deviation (X±SD) of shear bond strength as shown in table2-5 and graph in figure2,3. An analysis of the variance (ANOVA) and post hoc bonferroni were evaluated and indicated that there were significant differences in the shear bond strength of the fast cooling rate and ultraslow cooling rate (P<0.05).

Table 2 The mean shear bond strength and standard deviation

method	tempering	Mean	N
conventional	slow	19.9219	16
	fast	19.0594	16
	ultraslow	21.0188	16
	Total	20.0000	48
Heat-press	slow	14.2719	16
	fast	14.3781	16
	ultraslow	14.8469	16
	Total	14.4990	48
CAD-on	slow	24.3044	16
	fast	21.1925	16
	ultraslow	26.9725	16
	Total	24.1565	48

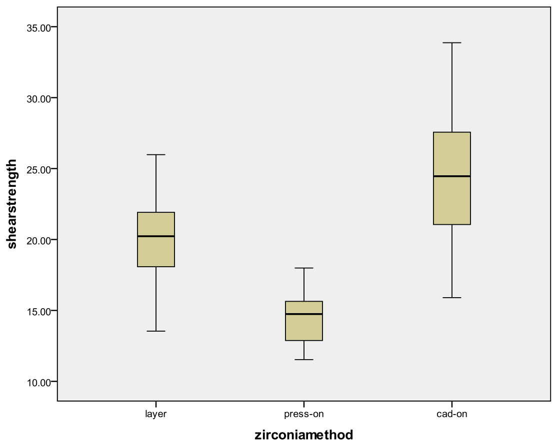

Fig 2 Mean shear bond strength NB:layer= Conventional technique,press-on=Heat press veneering technique,cad-on=CAD-ON veneering technique.

Table 3 The mean shear bond strength and standard deviation

tempering	method	Mean	N
slow	conventional	19.9219	16
	Heat-press	14.2719	16
	CAD-ON	24.3044	16
	Total	19.4994	48
fast	conventional	19.0594	16
	Heat-press	14.3781	16
	CAD-ON	21.1925	16
	Total	18.2100	48
ultraslow	conventional	21.0188	16
	Heat-press	14.8469	16
	CAD-ON	26.9725	16
	Total	20.9460	48
Total	conventional	20.0000	48
	Heat-press	14.4990	48
	CAD-ON	24.1565	48
	Total	19.5518	144

Table 4 Post hoc bonferroni comparison

(I) tempering	(J) tempering	Mean Difference (I-J)	Sig.[a]
slow	fast	1.289	.109
	ultraslow	-1.447	.057
fast	slow	-1.289	.109
	ultraslow	-2.736*	.000
ultraslow	slow	1.447	.057
	fast	2.736*	.000

Table 5 Post hoc bonferroni comparison

(I) zirconiamethod	(J) zirconia method	Mean Difference (I-J)	Sig.
layer	press-on	5.5010*	.000
	cad-on	-4.1565*	.000
press-on	layer	-5.5010*	.000
	cad-on	-9.6575*	.000
cad-on	layer	4.1565*	.000
	press-on	9.6575*	.000

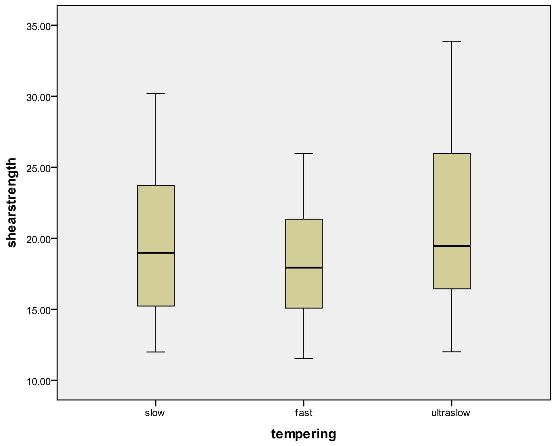

Fig 3 Mean shear bond strength NB:layer= Conventional technique,press-on=Heat press veneering technique,cad-on=CAD-ON veneering technique.

Discussion

In this study the shear bond strength of the IPS e.max CAD was higher than the IPS e.max ceram and IPS e.max Zirpress. A reason that accounted for these differences in bond strength was due to the different surface characteristics of the veneering ceramics (in terms of composition, strength, CTE, or firing shrinkage). The combination of CAD veneering technology offered a controlled environment in which the design and processing of the veneer ceramic are both optimized. The superior quality of the CAD-veneered zirconia interface may also explain the improved bond strength between the two ceramics, the higher fracture strength value, and the reduced tendency toward delamination failure compared to the manually layered specimens.

And the present study evaluated whether the cooling rate of the cooling from the firing temperature and veneering method of porcelain affected the bond shear strength between the veneering porcelain and zirconia material. The importance of the cooling cycle was especially important when the cooling rate was faster. The faster cooling rate would result in a lower shear bond strength. Tempering-induced residual tensile stress develops within the porcelain layer when it cools below the glass transition phase (M.V. Swain.,2009). Above this temperature, stresses are relieved by plastic deformation. Temperature gradients through the cooling porcelain can result in areas that are above and below this glass transition phase. These temperature gradients will be affected by the cooling rate. The faster the cooling rate, the greater the temperature gradients through the porcelain. The external regions will cool faster, thus concentrating stresses near the surface. Therefore, the faster the cooling rate, and the slower the thermal diffusivity (thermal conductivity), then the greater the stress development will be.

Conclusion

Within the limitations of the current investigation it could be concluded that the shear bond strength between a zirconia core and a ceramic veneer is reduced by the use of a fast cooling rate. And CAD-ON porcelain veneering technique has the highest shear bond strength.

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