Comparison of Two Heat-pressed All-ceramic Crown Systems

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There is increasing demand for all-ceramic crowns to improve esthetics and avoid the intraoral use of metal. There are several ways to fabricate all-ceramic prostheses. The heat-press method is easily handled, creates less porosity than the conventional powder slurry method, produces consistent quality, and avoids firing shrinkage. Each of the popular brands of heat-press ceramics has its own heat-press furnace. The purposes of this study were to determine whether it was possible to use one heat-press furnace to make different all-ceramic prostheses, and to compare the fit and hardness of two commercial heat-press all-ceramic systems made using the staining technique. Ceramic ingots were analyzed by X-ray diffraction analysis before heat press. Finesse® All-Ceramic and OPC 3G® specimens were both heat-pressed using a porcelain pressing furnace designed for Finesse®. Mesio-occluso-distal inlays were cemented to the metal die with temporary cement. Marginal accuracy was measured using a three-dimensional coordinate measuring machine. Vickers hardness was measured using a microhardness tester. X-ray diffraction analysis of the ceramic ingots showed that the main peak position for Finesse® was leucite ($KAlSi_2O_6$) and for OPC 3G® was lithium disilicate ($Li_2Si_2O_5$). The marginal gap for Finesse® was statistically lower than that for OPC 3G® (62.5 ± 15.5 vs 99.4 ± 11.6 μm; $p < 0.05$). There was no statistically significant difference in hardness between Finesse® and OPC 3G® (613.8 ± 49.2 vs 660.0 ± 34.0 kgf/mm^2; $p > 0.05$). The marginal gaps for Finesse® and OPC 3G® were clinically acceptable. Therefore, it is possible to use one heat-press furnace to cast different all-ceramic systems.

Key Words: full ceramics, heat-pressed, marginal discrepancy
(*Kaohsiung J Med Sci* 2004;20:341–6)

There is increasing demand for all-ceramic crowns to improve esthetics and avoid the intraoral use of metal. Heat-pressed ceramic is one of the most popular all-ceramic restorations because of several factors: ease of use (conventional lost-wax technique), occlusal accuracy, better marginal integrity and less porosity than the conventional powder slurry method, consistent quality, and lack of firing shrinkage. Manufacture of prefabricated ceramic ingots allows the addition of more strengthening crystals to achieve higher strength. Thus, the heat-press all-ceramic system is a good one. Each heat-press all-ceramic system has its own unique heat-press furnace along with expensive equipment. If it is possible to make different all-ceramic systems using a single furnace, all-ceramic prostheses can be made less costly and there will be more choice of distinguishing features for each ceramic system.

The Finesse® All-Ceramic System (DENTSPLY Ceramco, Burlington, NJ, USA) is characterized by a life-like appearance, and OPC 3G® (Pentron Corp, Wallingford, CT, USA) has higher strength than optimal pressable ceramic (OPC). Both can be manufactured using the staining and layering technique. The staining technique involves preparing a full-contour wax pattern for heat pressing full ceramic ingot, followed by surface pigmentation. The layering technique involves preparing a wax copy for heat pressing, then adding porcelain veneer.

Received: March 2, 2004 Accepted: May 4, 2004
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Marginal fit is an important criterion used in the clinical evaluation of fixed restorations. The larger the marginal discrepancy and subsequent exposure of the dental luting agent to oral fluids, the more rapid is the rate of cement dissolution [1]. This may lead to subsequent caries and periodontal disease. The marginal discrepancy of various all-ceramic restorations has been studied [2–11]. Variations in mean or median marginal discrepancy are as follows: In-Ceram® crowns, 8.75–161 μm [7,11]; IPS Empress® crowns, 47–63 μm [9,11]; Procera® crowns, 56–145 μm [2,3]; and Celay® System crowns, 45–99 μm [8,9]. This large variation is due to the different methodologies of the studies.

Several papers mention the hardness of dental ceramic material [12–15]. Gorman et al reported that the Vickers hardness of OPC was 7.28 ± 0.62 GPa, and of Empress® was 6.94 ± 0.69 GPa [12]. Albakry et al reported that the hardness of IPS Empress® was 6.6 ± 0.4 GPa, and of Empress® II was 5.3 ± 0.2 GPa [15].

The purposes of this study were to determine whether it was possible to use one heat-press furnace to make different all-ceramic prostheses and to identify the different phase of ceramic ingots. The fit and hardness of two commercial heat-press all-ceramic systems made by the staining technique were also compared.

Materials and Methods

Ingot, plunger and investment

Two commercial heat-press all-ceramic systems were investigated. Finesse® is a glass matrix that is strengthened by leucite (K_2O-Al_2O_3-$4SiO_2$) without significantly diminishing its translucency. Ingots of Finesse® have varying shades and can be used to fabricate single crowns, inlays, and onlays. OPC 3G® is strengthened by lithium disilicate crystal ($Li_2Si_2O_5$) and is stronger than OPC. Ingots of OPC 3G® are in a single shade, and the manufacturer claims that it can be used to fabricate inlays, onlays, crowns, and bridges before the premolars.

The investment for Finesse® was Finesse® All-Ceramic investment powder and liquid (DENTSPLY Ceramco). The investment for OPC 3G® was refractory investment powder and liquid (Pentron Corp). Both investments were made from phosphate-bonded investment material. The expansion can be adjusted by changing the liquid/water ratio. The plunger for Finesse® was made of alumina and was reusable. The plunger for OPC 3G® was disposable.

Heat-press furnace

The MULTIMAT Touch & Press porcelain pressing furnace (DENTSPLY Ceramco) accommodates all ceramics, including low-fusing, high-fusing, and pressable porcelains and even sintered ceramics. The pressing program for Finesse® was set up in its original design, and its other parameters can be customized, e.g. starting temperature, rate of temperature rise, vacuum level, pressing temperature, high temperature holding time, and press time.

X-ray diffraction analysis

X-ray diffraction was carried out to investigate the crystalline phases in the materials studied. X-ray diffraction verification was performed on the ingots before pressing. The specimen was placed in the holder of a D5000 Diffractometer (Siemens, Munich, Germany) and scanned using a Cu Kα X-ray at a diffraction angle of 10° to 90°. Data were collected using a scintillation counter and a graphite diffracted-beam monochromator.

Marginal discrepancy measurement

Wax patterns for mesio-occluso-distal (MOD) inlays (Figure 1) were made using a tapered metal die (8 mm diameter, 7 mm high, 2 mm thick) with Inlay Wax Medium (GC Co Ltd, Tokyo, Japan). A mark was made on one side of the wax pattern for repositioning of the MOD inlays. The sprue (3 mm diameter, 6 mm long) was attached to the isthmus area of the MOD wax patterns. For each 100 g packet of Finesse® or OPC 3G® investment used, the amount of distilled water and liquid varied depending on the manufacturer's instructions: 16 mL liquid and 11 mL distilled water for Finesse®, and 11 mL liquid and 12.5 mL distilled water for OPC 3G®. These ingredients were placed in a mixing bowl, and the material was hand-mixed for 15 seconds. Under a full vacuum, the materials were mixed at slow speed (45 seconds for Finesse®, 1 minute for OPC 3G®).

The investment was poured into a paper ring (35 mm diameter, 58 mm high). After bench set (15 minutes for both Finesse® and OPC 3G®), the paper ring was removed and investment was displaced through the top hole in the leveling ring to ensure parallelism. The ring was placed open-side down in a traditional burnout oven with plunger. The temperature of the furnace was raised 15°C/minute from room temperature to 850°C. The rings and plungers were allowed to heat soak for 45 minutes under 850°C. When the heat-press furnace reached the start temperature, the ceramic ingot was inserted into the burnout ring. The ring and plunger were then removed from the burnout oven and transferred to the heat-press furnace.

The pressing program for Finesse® raised the temperature of the heat-press furnace 60°C/minute from a starting temperature of 700°C to a high temperature of 930°C, with a 20-minute hold and 7 minutes for pressing at this temperature. The pressing program for OPC 3G®, according to the manufacturer's firing chart, was to raise the temperature of the heat-press furnace 60°C/minute from a starting temperature of 700°C to a high temperature of 890°C, with a 10-minute hold and 10 minutes for pressing at this temperature. A 1.5 mmHg vacuum was maintained for both systems, from the Finesse® instructions. A vacuum level was not given in the OPC 3G® instructions.

As soon as the heat-press furnace finished its cycle, the platform was removed onto a cooling block. The ring was cool to the touch after about 25 minutes. The investment was divested with sandblasting around the button using glass beads at a pressure of 60 psi until the restoration was exposed. The pressure was lowered to 30 psi and any remaining investment on the specimen was removed. The fitting procedure was performed using a fit-checker, and a half-diamond low-speed bur was used for grinding.

Five MOD specimens were fabricated for each all-ceramic system. MOD inlays were cemented onto the metal die with temporary cement and held by hand until the cement set. Marginal gaps were measured using a three-dimensional coordinate measuring machine (CE503; Chien Wei Precise Technique Co Ltd, Kaohsiung, Taiwan). Eight data points per specimen were equally spaced around the margins (Figure 1).

Hardness measurement of all-ceramic material

Wax plates ($5 \times 4 \times 1$ mm^3) were made using the same methods to measure Vickers hardness number (VHN). Three plates were fabricated for each all-ceramic system, then all plates were mounted in the pattern resin blocks and polished using the Shofu porcelain adjustment kit (Shofu Dental Corp, San Marcos, CA, USA). VHN was measured using a microhardness tester (MXT50; Matsuzawa Seiki Co Ltd, Tokyo, Japan) (loading force, 1,000 gf; loading time, 15 seconds). Each plate was randomly measured at 10 points.

Statistical analysis

Since the data were not normally distributed, they were analyzed using Wilcoxon rank sum tests. Differences in marginal discrepancy and hardness are reported at the 0.05 level of significance.

Results

All samples were heat pressed successfully without refractory fractures, visible porosities, or incomplete pressing. Two Finesse® MOD inlays fractured during the divesting and try-in procedure. No porosity was noted under inspection with a microscope or microhardness tester.

The X-ray diffraction pattern of Finesse® ceramic ingots showed major peaks at diffraction angles of 25.99°, 27.17°, and 30.41°, identical with the expected intensities from the JCPDS (Joint Committee on Powder Diffraction Standards) diffraction data of randomly-aligned leucite ($KAlSi_2O_6$) crystal (Figure 2). X-ray diffraction of OPC 3G® ceramic ingots showed an amorphous background signal, which indicated glass content. Major peaks were detected at diffraction angles of 23.73°, 24.30°, and 24.81°, matching the crystallographic plane of lithium disilicate ($Li_2Si_2O_5$) but not lithium phosphate (Li_2PO_4) (Figure 3).

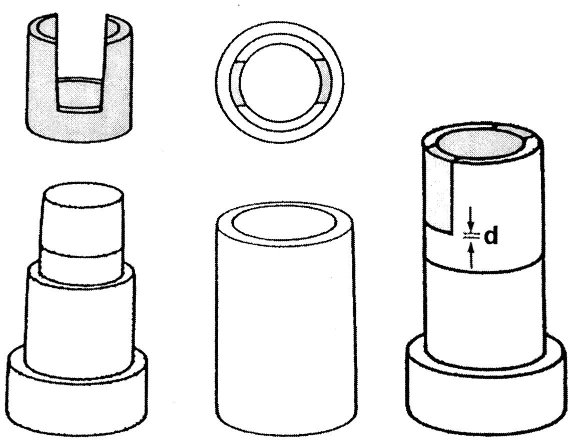

Figure 1. *Standard steel mesio-occluso-distal inlay model; measuring points were equally spaced around the margin. d = marginal discrepancy between the outer margin of the specimen and the edge of the steel model.*

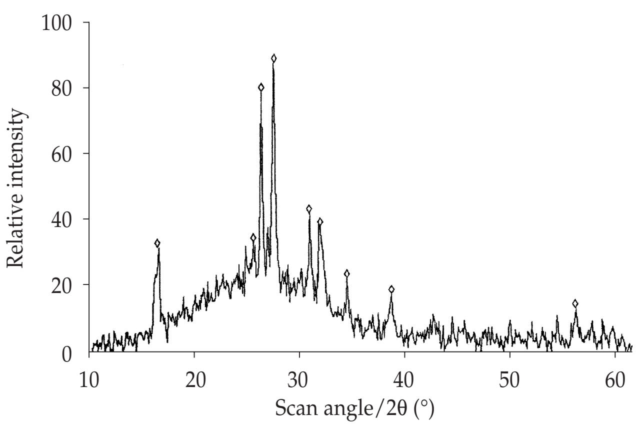

Figure 2. *X-ray diffraction results of a Finesse® ceramic ingot.*

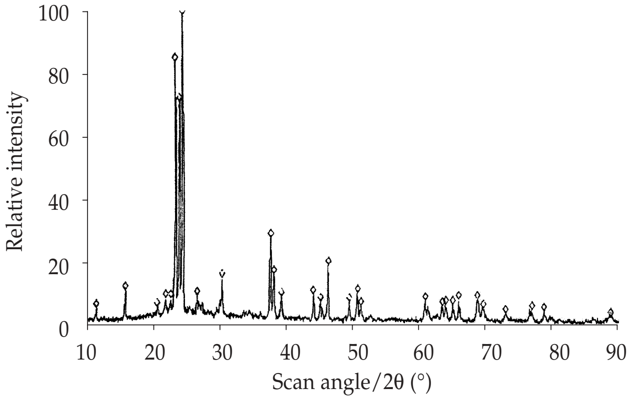

Figure 3. *X-ray diffraction results of an OPC 3G® ceramic ingot.*

Marginal integration was good. No chipping or marginal fracture was found. Mean marginal discrepancies in the MOD inlays were 62.5 ± 15.5 µm for Finesse® and 99.4 ± 11.6 µm for OPC 3G®. Over the 40 measurements of both systems, the marginal discrepancy ranged from 13 to 117 µm for Finesse®, and from 57 to 181 µm for OPC 3G®. The median of the mean marginal discrepancy was 63.4 µm for Finesse® and 98.8 µm for OPC 3G®. Wilcoxon rank sum test indicated that the mean marginal discrepancy of Finesse® was significantly smaller than that of OPC 3G® ($p < 0.05$) (Figure 4).

VHN indentations on both materials were not easy to measure because of subsequent fracture after 15-second pressure loading. The scale of subsequent fractures did not have specific size. The mean VHN was 613.8 ± 49.2 kgf/mm^2 for Finesse® and 660.0 ± 34.0 kgf/mm^2 for OPC 3G®. Over 30 measurements of both systems, the VHN ranged from 474.7 to 781.8 kgf/mm^2 for Finesse®, and from 536.3 to 785.1 kgf/mm^2 for OPC 3G®. The median of the mean VHN was 626.6 kgf/mm^2 for Finesse® and 649.3 kgf/mm^2 for OPC 3G®. Wilcoxon rank sum test indicated that there was no significant difference between the VHN of the two systems ($p > 0.05$) (Figure 5).

Discussion

Experimental technique and measurement methodology may significantly affect marginal accuracy results of all-ceramic systems. Sulaiman et al compared the marginal fit of three all-ceramic crown systems (In-Ceram®, Procera®, and IPS Empress®) [11]. In-Ceram® exhibited the greatest marginal discrepancy (161 µm), followed by Procera® (83 µm), and IPS Empress® (63 µm). These differences were significant. Beschnidt and Strub compared marginal accuracy for three all-ceramic systems, In-Ceram®, Empress® and Celay® [9]. Empress® (staining technique) crowns showed the smallest marginal gaps (47 µm), and all the tested all-ceramic crowns had clinically acceptable margins.

The marginal fit of Finesse® (62.5 ± 15.5 µm) and OPC 3G® (99.4 ± 11.6 µm) in this study were compatible with the findings for heat-press ceramic IPS Empress® crowns (62.77 ± 37.32 µm) [11], Empress® staining technique (47 µm), and Empress® veneer technique (62 µm) [9]. The marginal fit for the two all-ceramic systems in this study was clinically acceptable.

Marginal accuracy can be affected by many factors,

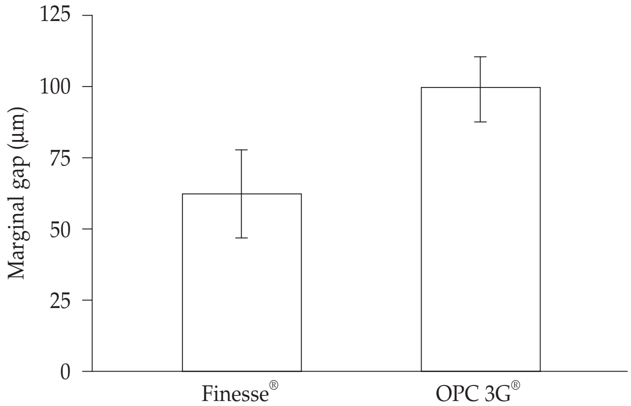

Figure 4. *Marginal discrepancy in two heat-pressed all-ceramic systems* (n = 5)*; the value for Finesse® was significantly less than that for OPC 3G®* (p < 0.05)*.*

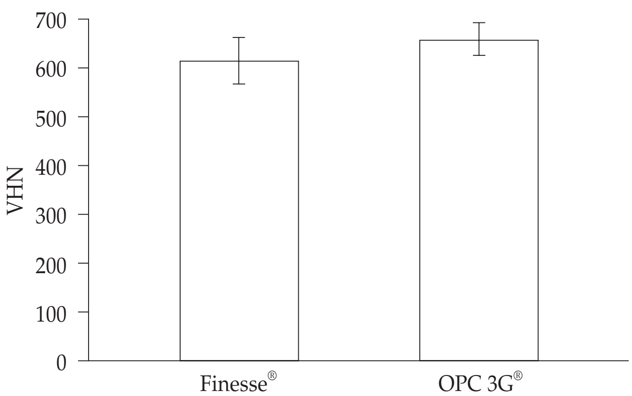

Figure 5. *Vickers hardness number (VHN) in two heat-pressed all-ceramic systems* (n = 3)*; there were no significant differences between Finesse® and OPC 3G®* (p > 0.05)*.*

especially the expansion coefficient of the investment material and ceramic. The two kinds of specimens in this study were fabricated according to each manufacturer's instructions, but using only one heat-press furnace. The small differences in temperature, pressure, and vacuum level may affect the results. The marginal gap for OPC 3G® was higher than that for Finesse® in this and previous studies [9,11], but was still clinically acceptable.

The hardness of different all-ceramic systems has been studied. Seghi et al evaluated the relative hardness of 11 commercially available dental restorative ceramics [13]. In-Ceram® (9.82 GPa; 1 GPa = 101.901 kgf/mm^2) had substantially greater hardness than all other materials tested, while Dicor® MGC (3.72 GPa) showed the lowest value. Gorman et al compared the Vickers hardness of two heat-press ceramic systems: OPC (7.28 ± 0.62 GPa) and Empress® (6.94 ± 0.79 GPa) [12]. Albakry et al reported the hardness of IPS Empress® (6.6 ± 0.4 GPa) and Empress® II (5.3 ± 0.2 GPa) [15]. The VHNs of Finesse® (613.8 ± 49.2 kgf/mm^2) and OPC 3G® (660.0 ± 34.0 kgf/mm^2) were much higher than that of enamel. Thus, prostheses made from these two all-ceramics may lead to wearing.

The potentially destructive effect of porcelain occlusal surfaces on the opposing dentition has been described previously [16]. However, recent evidence suggests that the hardness of a restorative material alone is not a reliable predictor of the wear of opposing enamel [17]. Especially in brittle material, wear does not occur by plastic deformation but by fracture. In our study, although the data indicate no statistical difference in hardness between the two materials, there was a difference in fit in the two systems. It was harder to grind OPC 3G® specimens than Finesse®.

From this study, porcelain surrounding the indentation may crack (catastrophic failure) outward from the edges of the indentation. Morena et al observed conventional high-expansion feldspathic porcelains and found that indentation cracks were deflected away from leucite crystals and, consequently, favored the glassy matrix for propagation [18]. If specimens can be observed with higher magnification, the reliability of the experimental data can be examined.

Conclusion

The marginal fit in both all-ceramic systems was clinically acceptable. Microhardness data should be considered as a comparable result but not a definite value because the relationship between hardness, tensile strength, and fracture toughness in brittle material is difficult to define precisely.

Acknowledgments

This investigation was presented, in part, at the Asian Academy of Prosthodontics in Taipei, Taiwan, 2003. Financial support from the National Science Council, research grant NSC91-2314-B037266, is greatly appreciated.

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兩種壓鑄式全瓷修復系統的比較

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因牙齒美觀的需求日益受到重視，除了避免口內採用金屬修復體外，更突顯出全瓷冠的重要性。製作全瓷冠有好幾個方法;其中以熱壓鑄法最為簡單，製作出的贋復物與傳統燒瓷法比較不僅氣泡少且質地均勻，並且沒有燒瓷時可能的收縮。目前市面上幾種壓鑄式全瓷系統，都有各自專用的壓鑄爐及專用壓鑄瓷塊。本研究的目的在探討是否可能採用一種壓鑄爐製作不同系統之全瓷贋復體並比較兩種具代表性全瓷熱壓鑄系統以外染法製作的修復體其邊緣貼合度和硬度。以 **X-ray diffraction** 分析儀分析未經壓鑄前的瓷塊成分。**Finesse®** **All-Ceramic** 及 **OPC 3G®** 的全瓷試片均以 **MULTIMAT Touch & Press Porcelain Pressing Furnace** 壓鑄，此壓鑄爐為 **Finesse®** 全瓷系統專用。以暫時黏著劑將 **mesio-occluso-distal** 嵌體黏著在單齒模上，以 **3-D** 自動掃描儀測量邊緣縫隙。以微硬度測試機測量其硬度。以 **Wilcoxon rank sum test** 分析數據。**X-ray diffraction** 分析結果顯示 **Finesse®** 瓷塊含有白榴石 (**$KAlSi_2O_6$**)；而 **OPC 3G®** 瓷塊含有雙矽鋰化物 (**$Li_2Si_2O_5$**)。有關邊緣貼合度方面，**Finesse®** 顯著低於 **OPC 3G®** (**62.5 ± 15.5 vs 99.4 ± 11.6 μm; p < 0.05**)。至於硬度方面 **Finesse®**，**OPC 3G®** 兩者並無顯著差異 (**613.8 ± 49.2 vs 660.0 ± 34.0 kgf/mm^2; p > 0.05**)。實驗結果顯示兩種全瓷系統的邊緣貼合度為臨床可接受的程度。並且使用同一壓鑄爐壓鑄不同系統之全瓷系統是可行的。

關鍵詞：全瓷，壓鑄，邊緣貼合度
（高雄醫誌 **2004;20:341－6**）

收文日期：**93** 年 **3** 月 **2** 日
接受刊載：**93** 年 **5** 月 **4** 日
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