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Key points to the successful laboratory processing of press ceramics

On the occasion of the release of GC Initial™ LiSi Press/LiSi PressVest

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Introduction - two major problems in laboratory processing of press ceramics

Press ceramics have many advantages over zirconia when placed in the mouth because they are more esthetic and have less of an impact on opposing teeth. The fact is, however, the laboratory processing accompanies substantial difficulties. The possible problems can be classified into two major types.
Unlike metal casting, these problems cost more due to non-reusable press ceramics, relatively expensive investment materials, and other factors. Furthermore, the re-fabrication takes substantially more time than metal casting.
With all these factors of the current situation of the dental laboratory market taken into account, it is quite understandable that one would shift to materials other than press ceramics after having failed more than once.
No matter how hard you try, you cannot overcome failures without

Two major problems in the laboratory processing of press ceramics

Problem 1: Investment failure during pressing. Even when no external breakage is observed, internal cracks cause fins and a fractured abutment part results in restorations with filled inner cavities.

Problem 2: Incomplete margins and rough surfaces of press objects.

knowing the causes. Even well intended actions to prevent failures may sometimes lead to unexpected problems, which make finding the causes more difficult.
On the occasion that GC releases the press ceramic Initial LiSi Press/LiSi PressVest, I present how to manage such problems based on my experience and results from experiments.

Press ceramics or zirconia?

For all ceramic restorations, we currently choose either press ceramics such as Initial LiSi Press or zirconia.
We consider various selection criteria for individual cases as we actually and clinically choose materials. In the cases of the splinted multiple unit restoration, zirconia is advantageous for its mechanical strength, whereas press ceramics have superior esthetics.

From a functional viewpoint of (wear) compatibility with opposing teeth, it is not always true to say "hard materials = less wear". One may assume "hard = more resistant to abrasion", but in fact, the same material presents dramatically different outcomes depending on "conditions of the polished surface", "characteristics of wear surfaces", and "lubrication conditions". Here, I focus on the "conditions of the polished surface", and for more detailed explanations, you can look for in "Tribology".[*1]

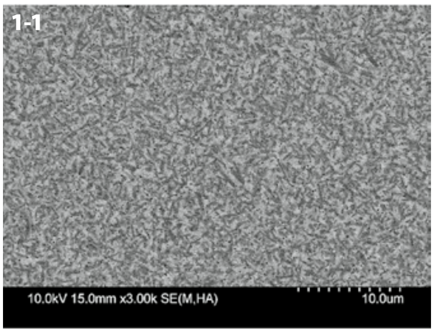


Figure 1-1: The SEM image of Initial LiSi Press.

You can polish the functional cupids of full-contoured zirconia restorations to a high luster. Highly polished zirconia has been reported to be less-wearing than press ceramics.*

However, it should be difficult to polish the triangular ridges on the occlusal surface to a high luster when considering all the current technical factors and materials used in dental laboratory work together. Polishing is still more difficult during the adjustment in the patient's month. Therefore, inadequately polished zirconia restorations can cause more severe two-body abrasive wear.[*2]
In contrast, we can polish press ceramics relatively easily and so the ridges on the occlusal surface have a high luster. In addition, refined crystals of lithium disilicate included in LiSi Press allow mechanical polishing to provide a smooth and lustrous surface texture featuring a surface property of less abrasion of opposing teeth if any wear occurs (Fig. 1-1). With all things considered, press ceramics now seem to be advantageous.

How to Prevent Cracks in Investments.

Even materials with advantageous features cannot be useful if they fail frequently. LiSi PressVest is phosphate-bonded; therefore, you need to observe general precautions for phosphate-bonded investment materials. Now, I will discuss the troubleshooting.

Small cracks that develop during burnout of rings (Fig. 2-1 left) may play a role in breaking the investment on pressing (Fig. 2-1 right). Additionally, even in the absence of cracks on the surface, internally developed cracks may lead to fracturing the abutment

Figure 2-1: Left: Cracks after burnout. When the ring is placed in the ring furnace at 500°C and then the temperature is raised to 900°C, the ring may crack as shown in the figure. Right: As shown in the figure, the investment having a decreased compressive strength may fail when pressed.

*1 Tribology
Tribology is the science and engineering that deal with what happens at the interacting surfaces in relative motion and studies all the phenomena, including "wear", "seizure", and "rolling contact fatigue" caused by friction to prevent and reduce the damage of friction surfaces or to utilize them.
For example, the load causing seizure between highly polished ceramics and metals is far greater than that at the metal-to-metal or ceramic-to-ceramic rubbing surfaces.
Thus, one cannot simply assume "hard = less wear" or "soft = more wear", and friction involves a wide variety of factors, including the quality of materials, states of motions, surface conditions, contact conditions, and small particle inclusion between friction surfaces.
The branch of engineering comprehensively studying these factors is called Tribology.

*2 Abrasive wear
Abrasive wear takes place when a rough, hard surface glides across a relatively softer surface or any hard foreign bodies are included between friction surfaces. Two-body abrasive wear takes place when hard projections on one surface eliminate material from the opposing surface. Three-body wear occurs when the hard inclusions between friction surfaces exist.

*) Seiji BAN: "Polishing and Finishing of Full-contoured Zirconia Crowns and Wears of Opposing Teeth." QD" Vol. 37 2012.

portion. These cracks are attributable to less compressive strength of the investment materials than that intended to be attained (Fig. 2-2).

To prevent cracks, the following precautions should be followed.

Compressive strength of LiSi PressVest (MPa)		
After solidification (after 120 minutes)	Burnout at 900°C	After cooling following burnout
4.0	20.3	6.3

Figure 2-2: Compressive strength of LiSi PressVest (MPa)

How to Prevent Cracks in Investments

(i) The ring should be placed in the ring furnace between 20 minutes to 3 hours after investing. After 3 hours, the rings have higher risks of causing cracks.

(ii) To avoid the dangerous temperature zone causing cracks as much as possible, the temperature of the ring furnace must be set to 900°C, and it should be completely heated before the ring is placed (never placed if the furnace is not heated to 900°C). Once the ring is placed in the ring furnace, the temperature setting should be lowered to 850°C.

(iii) Do not place rings in the ring furnace with any investment rings for metal casting. (The metal rings excessively lower the temperature of the ring furnace. At maximum, four 100 g rings or two 200 g rings can be placed at the same time in the furnace, but you need to check the capacity of your ring furnace.)

(iv) The holding time should be not less than 45 minutes. (The holding time up to about 5 hours will not significantly decrease the strength.)

(v) Avoid lowering the temperature by opening the ring furnace during the holding time for burnout. In placing the ring in the press furnace, the ingot should be inserted as quickly as possible to prevent the ring from cooling down as much as possible.

- Place the ring into the ring furnace heated to 900°C.
- Do not place the ring together with those for metal casting.
- The holding time should be not less than 45 minutes.
- Evenly distribute rings in the ring furnace.

2-3

Reasons for (ii), (iii), and (v): As shown in the graph (Fig. 2-4), if the phosphate-bonded investment material is "slowly heated", it once expands at around 250 °C during cristobalite transformation and then shrinks from around 350°C in association with decomposition of ammonium phosphate. Repeated thermal expansion and shrinkage promote the formation of fine cracks. Therefore, as shown in the graph of "rapidly heated" in Fig. 2-4, heating up at the maximum possible rate in this temperature zone results in a relatively constant expansion of the investment. Accordingly, we can preserve the strength of the investment material and avoid the formation of cracks. Additional elevation and lowering of the temperature during the holding time may cause additional destruction of crystal structures, leading to reduced compressive strength. So the ring should be transferred to the press furnace as quickly as possible to avoid heat loss of the ring.

Reasons for (iv): The more heated the phosphate-bonded investment materials, the greater the compressive strength. The short holding time in the furnace as well as larger investments such as 200 g rings may prevent the middle part of the investment to be heated up completely, which result in the incomplete compressive strength causing problems (Fig. 2-2).

Key points to the successful laboratory processing of press ceramics On the occasion of the release of GC Initial™ LiSi Press/LiSi PressVest

Causes of investment failure besides insufficient strength of investments

The investments may fail due to causes other than those discussed above. Such causes include too high temperature for melting the press ceramics or too long holding time in the press furnace. If the press ceramics are melted more than necessary, it would infiltrate into the investment. Thereby the press ceramics exert wedge effects to generate cracks in the investment, leading to the formation of fins and the investment failure.
When troubleshooting such problems, you certainly need to use an appropriate press temperature and an adequate holding time for the press ceramics whereas you can also routinely attach longer sprues to be prepared for unexpected problems. Longer sprues can prevent investment failure. Completely different from metal casting, sufficient pressing can be done with longer sprues. The longer distance between the base part and the wax pattern even favors preventing the wedge effect and thus reduces the risk of investment failure.

2-4

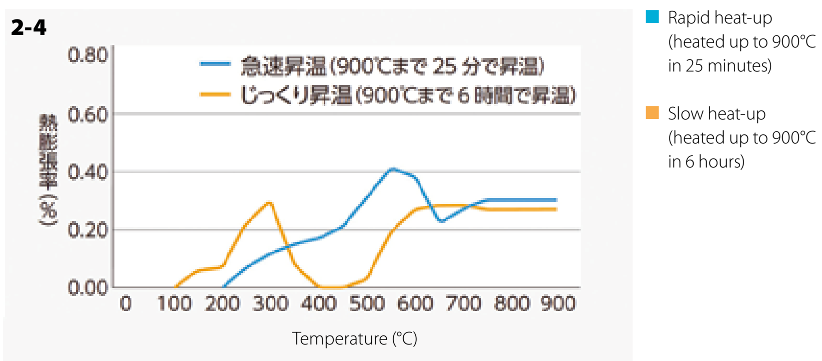


Figure 2-4: Variation in thermal expansion coefficient by different heat-up protocols.

Sprues of different length result in different press results even when the pressing is performed with other conditions being the same.

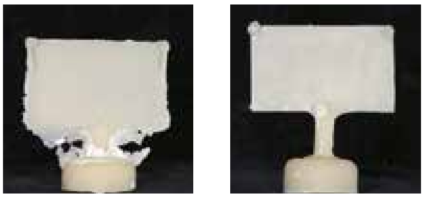


Figure 3-1: The length of each sprue in the left and right figures is 3 mm and 5 mm, respectively. The Ready Casting Wax R25 was used for both sprues and 0.46 mm-thick sheet waxes for press molding.

Figure 3-2: Press ceramics infiltrate into the investment when the melting temperature is too high.

Processing and handling of the investment material.

First, the mixing ratio should strictly be adhered to. The colloidal silica designed for each product of phosphate-bonded investment material has different concentrations and in turn, different specific gravities. Colloidal silica should be measured with graduated cylinders or syringes because it has a different specific gravity from that of water, which disables the accurate measurement with scales (Fig. 4-1) (What is important here is to measure the volume rather than the weight).
The second most important point is the temperature control of the investment material. Especially in phosphate-bonded investment materials, the lower temperature retards the intended hardening reaction, resulting in decreased strength and setting expansion.

- Adhere to the mixing ratio.
- Closely control the temperature.
- Mix thoroughly.

Figure 4-1: You can quickly and accurately measure using a syringe rather than a graduated cylinder.

To prevent any problems, powders and liquids should essentially be stored at 23°C. Especially in January and February, powders and liquids stored in a cold room should be handled with due care. It may take 3 to 4 hours to allow the powder that once became cold to reach room temperature. Therefore, in winter, when the investment material is stored at cold room temperature, you need to wait until around noon to confirm its having been warmed to 23°C to start the investing procedures.
On the contrary, in summer, the temperatures of powders and liquids are elevated, which only shorten the hardening time and does not significantly influence physical properties such as setting and thermal expansion.

LiSi PressVest normally has a working time of about 7 minutes. It is reduced to about 5 minutes when the temperatures of the powder and the liquid are raised to 30°C.

However, it inherently has high flowability, which ensures enough time for investing (Fig. 4-2).
In addition, thorough mixing is important to obtain the intended physical properties. The mixing program of the Twister Evolution from Renfert tested in my experiment is listed below (Fig. 4-3).

Figure 4-2: Flowability of LiSi PressVest.

Premixing	15 seconds
Revolution speed	300 rpm
Mixing time	1 minute
Inverse rotation	30 seconds

Figure 4-3: Twister Evolution from Renfert and the mixing program time I use.

Melting conditions of ingots

Problems of "incomplete margin" and "rough surface" can occur depending on the melting conditions of the press ceramics. To prevent such problems, we need to slightly adjust the holding time and temperature from those specified by the manufacturers. The variation in temperature by each furnace requires such adjustment.
The next is about melting of press ceramics.
We, dental technicians, are apt to compare the melting of press ceramics to those of metals that transform from a solid to a liquid state. However, unlike metals transforming from a solid to a liquid state at solid and liquid phase points, ceramics and rubber convert at the glass transition point (Fig. 5-1).
Even when the temperatures exceed the glass transition points, they show no such significant changes as those observed in metals. For example, if rubber is soft enough to be bent easily, its temperature is beyond the glass transition point, and it remains soft over a wide range of temperatures despite the variation in softness.

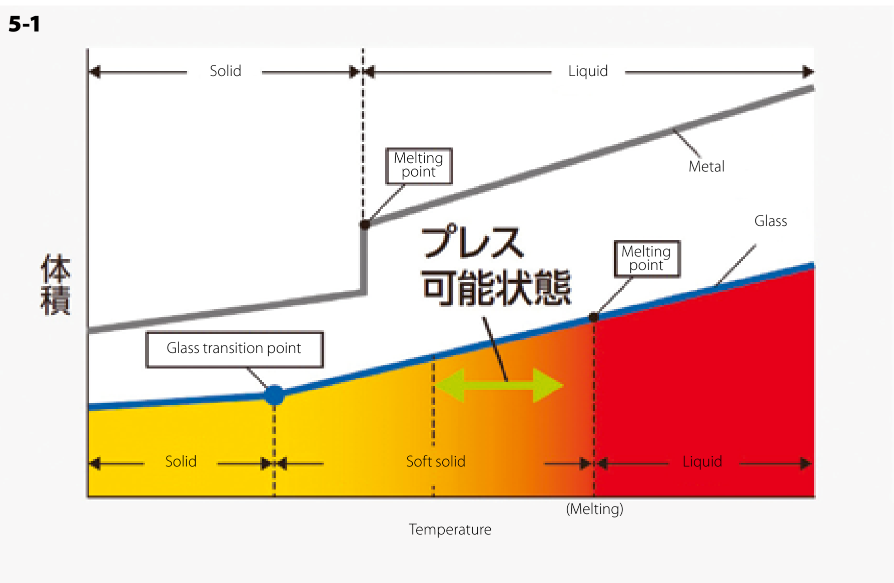


Figure 5-1: Schematic graph of the glass transition point.

5-2

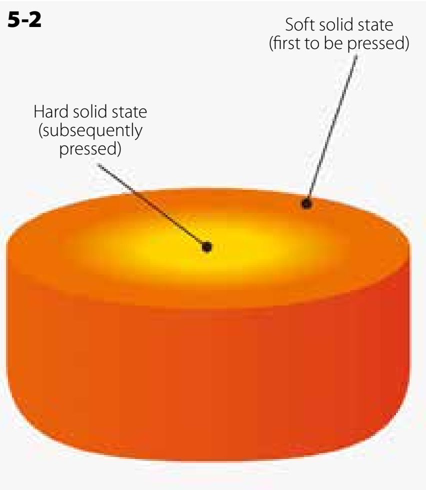


Figure 5-2: State of a melted ingot in cross section.

Ceramics and rubber, when they are melted, feature plasticity over a wider range of temperatures while they maintain an appearance like solids. Thus, they never convert into liquids when they are melted. So, press ceramics are simply softened to be pressed (the glass transition point of LiSi PressVest is 520°C, which is lower than the pressing temperature). Furthermore, glass has substantially lower thermal conductivity than metal (Fig. 5-3), which results in substantially different melting rates between the surface and middle areas even in small-sized ingots; therefore, it takes a few hours to be uniformly melted (Fig. 5-2, Fig. 5-3).
Because it is clinically impractical to take several hours to uniformly soften ceramics, the program shown in Fig. 5-4 is developed to obtain the intended softness in a shorter time.

Thermal conductivity (W/mK)	
Gold	295
Silber	418
Palladium	70
Glass	0,76
Quarts glass	1,35

Figure 5-3: Thermal conductivity (W/mK)

Panamat Press / Austromat 644 (GC / DEKEMA)				
Ingot type	HT, MT, LT		MO	
Ring size	100g	200g	100g	200g
Start temperature	700°C		700°C	
Temperature rise rate	60°C / min		60°C / min	
End (holding) temperature	893°C	913°C	907°C	923°C
Holding time	25min		25min	
Pressing time	5min		5min	
Pressing pressure level	5		5	

Figure 5-4: Recommended programs of Initial LiSi Press by GC.

In light of these properties, attention should be given to the following.

Things to be considered in view of the characteristics of press ceramics:

(i) The surface conditions of pressed objects may differ depending on the size of the sprue patterns even if the ingots are similarly melted. Especially in the case of smaller patterns, the well-melted outer part of the ingot (Fig. 5-2) is readily pressed into it, leading to the increased risk of a rough surface. For troubleshooting it, a second (dummy) sprue can be placed to obtain consistent press results, as shown in Fig. 5-5.

(ii) As shown in Fig. 5-6, the space within the mold is filled as the ingot is pressed. During this process, the pressure is applied in a certain direction as the melted ingot is not a true liquid (Fig. 5-7, Fig. 5-8). Therefore, the sprue press objects and the second sprue should be attached at an angle of 60° or less between them (Fig. 5-5).

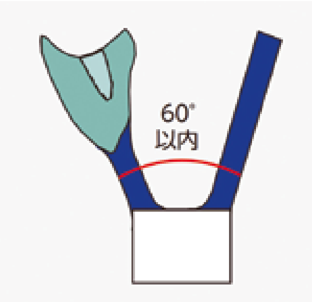


Figure 5-5: Attach to have an angle of 60° (30° or less from the center on both sides).

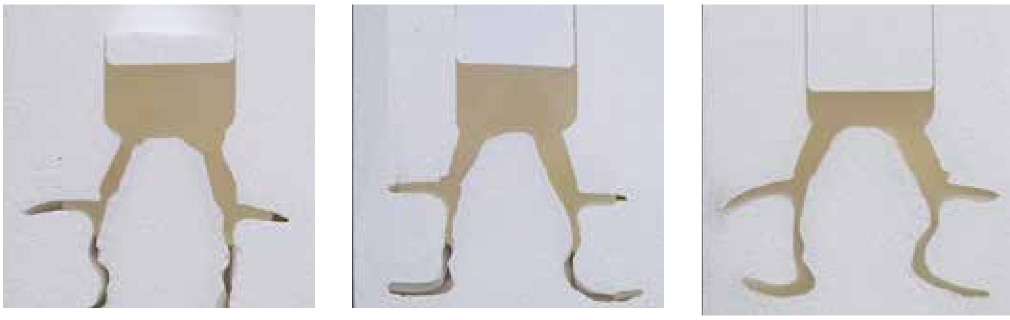


Figure 5-6: Press molding in an investment mold.

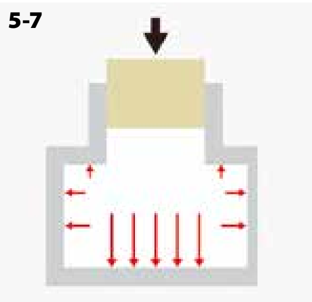


Figure 5-7: Schema of the press pressure. Pressure is more applied in the vertical direction. Therefore, press objects should be sprued so that the margins are in such a direction.

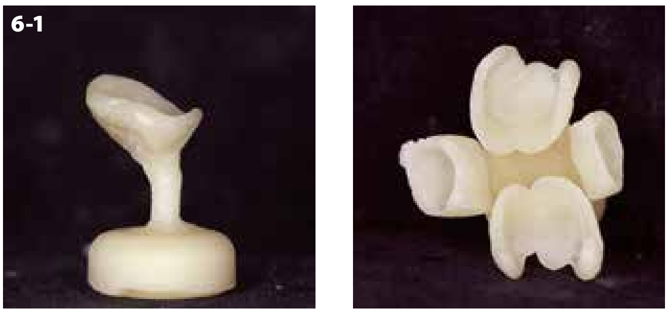
Figure 5-8: When sprued as shown in this figure, pressure cannot completely be applied to the deepest part of the object, leading to failure.

Troubleshooting incomplete/short margins of press objects.

Here I discuss incomplete margins of press objects as classified into two categories.

Two patterns of the incomplete margin of press objects to be discussed are as follows:

(i) Large marginal discrepancy with an extensively incomplete margin (Fig. 6-1).



(ii) Generally good marginal fit with some gaps in part (Fig. 6-2).

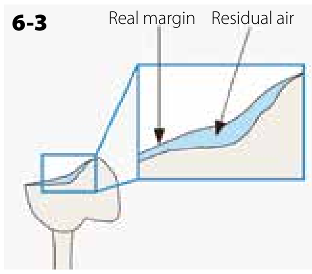


Figure 6-3: Schema of residual air. Air incompletely vented is entrapped around the margin to cause a short margin. This defect can mislead us to have an impression of a crown being seated incompletely as the shortened margin presents a similar shape to that of the real margin.

The cause of (i) may be insufficient melting of ingots and can thus be solved by extending the holding time in the press furnace. If it is not effective, you need to raise the press temperature or extend the pressing time.
The optimal softening conditions can be explored by pressing with mesh patterns. In such a case, the result as shown in Fig. 6-4 should be qualified as good.
If you have any incomplete margins, you first extend the holding time by about 5 minutes. If it is not effective, you can raise the softening temperature by 5°C.

As shown in Fig. 6-3, the air incompletely vented causes the defect such as (ii). So, this type of problem can be solved by placing open vents to the pattern to eliminate the entrapped air in the mold (Fig. 6-5).

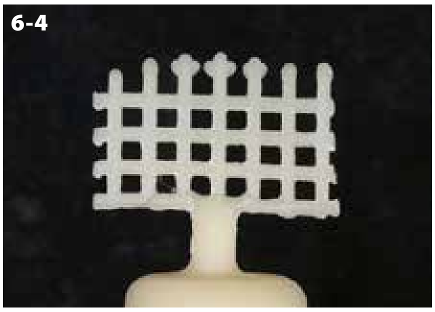


Figure 6-4: Ideally pressed condition into mesh pattern. (The wax pattern of GEO retention grid, fine from Renfert and the sprue of R25 are used.)

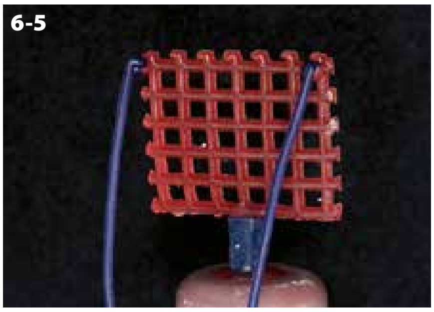
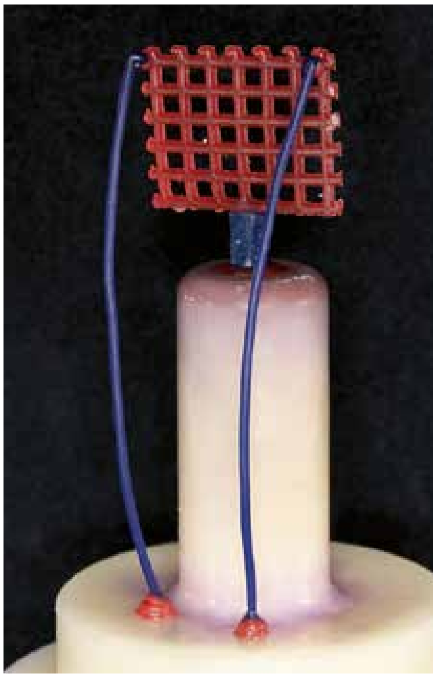
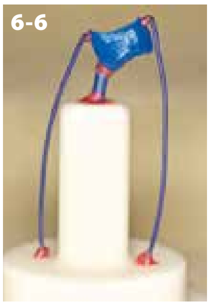


Figure 6-5: Ready casting wax R07 is used to place the open vent.



- Place open vents
- Adjust the holding time and temperature to heat ingots adequately

Figure 6-6: When the pattern is sprued in such a direction as shown in the figure, the air is likely to be entrapped in the area indicated by the arrow leading to locally incomplete margins.



Open vents

The press furnace is vacuumed during pressing by a vacuum pump but still contains enough air to cause defects. As shown in Fig. 5-6, while the space in the mold is filled as the ingot is pressed, the air remaining in the mold may escape through the sprue during the pressing process (Fig. 7-1) or pushed around the sprue to be entrapped (Fig. 7-2).
Because the air pushed to the margin also causes incomplete pressing, such as short margins (Fig. 6-3), open vents should be placed to promote the elimination of air from the mold (Fig. 7-3).

The length of pressed open vents can also serve as an indicator of appropriate conditions including melting temperature and holding time (Fig. 7-4).

Especially when using a furnace utilizing air pressure to press ceramics, you should have difficulties in eliminating such air and must place open vents (because the remaining air is to be pushed by the air pressure).

Open vents should be placed at the last parts where press ceramics reach while they are press-filled, and multiple vents may be required depending on the shapes of the patterns.
I hope you enjoy laboratory work as you pay attention to the key points discussed here to eliminate any difficulties.

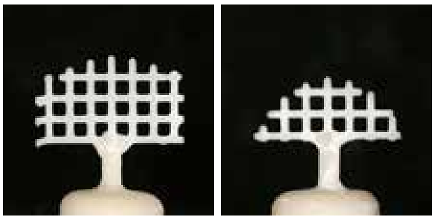


Figure 7-1: Left: with vents. Right: without vents. The open vents, which are placed at the last point where the pressed ceramics reach as shown in Fig. 6-5, help eliminate the residual air and can make a difference in pressing results as shown above even with other conditions being the same.

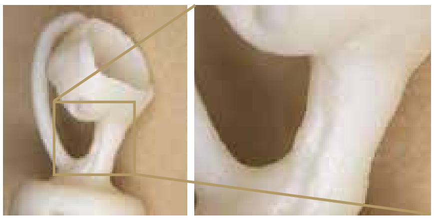


Figure 7-2: Trace of the escaping air through the sprue.

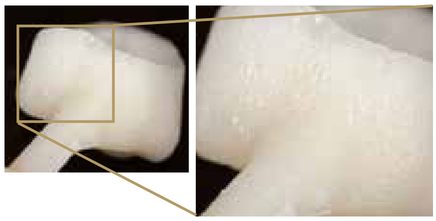
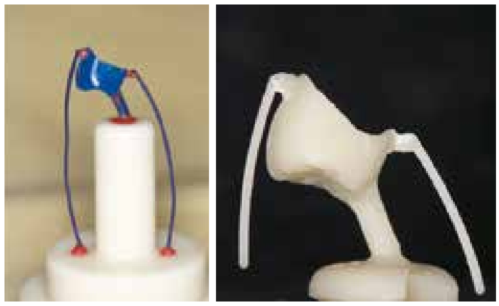


Figure 7-3: Many random crater-like air bubbles are shown.

Figure 7-4: The length of pressed vent under appropriate pressing conditions. The pressed vent becomes shorter when ceramics are insufficiently softened, and in contrast, it becomes longer when softened too much. The parameters of the press furnace should be adjusted depending on the conditions of pressed vents.



Press-fitting plunger of the press furnace (when an aluminum plunger is used)

Repeated pressing increasingly causes the attachment of press ceramics on the press-fitting plunger that comes down from the ceiling part of the press furnace. The attached ceramics work to stick the press-fitting plunger to the plunger, and thus the plunger placed on the investment will be lifted up as the press-fitting plunger is elevated at the end of pressing program (Fig. 8-2). Accordingly, the ceramics once pressed into are sucked back, which may lead to the incomplete margins.

Therefore, the press-fitting plunger should periodically be scraped and cleaned.

Figure 8-1: As shown in the figure, press ceramics are increasingly accumulated on the surface of the press-fitting plunger if the attached press ceramics are left unremoved. Therefore, press ceramics attached to this part should periodically be scraped off.

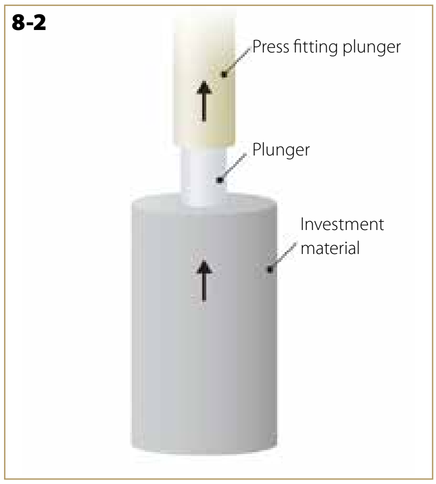


Figure 8-2: When pressing is completed, the press-fitting plunger lifts the plunger to cause the suck-back of press ceramics.

Conclusion

I have shared techniques for the successful laboratory processing of press ceramics. As a matter of fact, I have learned how to avoid failures only after I had taken supposedly well-intended actions based on my experience and assumption that only led to poor results, and I realized it through repeated experiments and the continuing process of trial and error.

For example, I previously thought that I could get good results if I placed the ring in the furnace at a lower temperature before it was completely heated to 900°C, which in fact, caused problems.