

Programat[®] S1 1600

The exceptional sintering furnace



Programs for
IPS e.max[®] ZirCAD
beginning with software V5.0

Guidelines

for the processing of ZrO₂ materials
in the Programat S1 1600

ivoclar
vivadent[®]
passion vision innovation

Overview

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1 Brief overview of the system

The system idea is in the foreground and represents the key to success.

Ivoclar Vivadent optimally coordinates its equipment and materials. This enables the best possible results and minimizes the risk for users and patients. This philosophy of Ivoclar Vivadent distinguishes us from many manufacturers in the dental industry which manufacture and distribute either only equipment or only materials. However, particularly for processes as complex as sintering various ZrO_2 materials in high-temperature furnaces, this aspect has to be ascribed special importance. Imagine the long-term consequences if one component in this system is not excellently coordinated. Therefore, we have ideally coordinated the ZrO_2 material with the equipment and vice versa. As a user, you may thus rely on the system and you will certainly achieve excellent results with it.

The system from Ivoclar Vivadent consists of the following components:

- IPS e.max® ZirCAD
- Programat® S1 1600
- IPS e.max® Ceram
- IPS e.max® ZirPress
- IPS Ivocolor



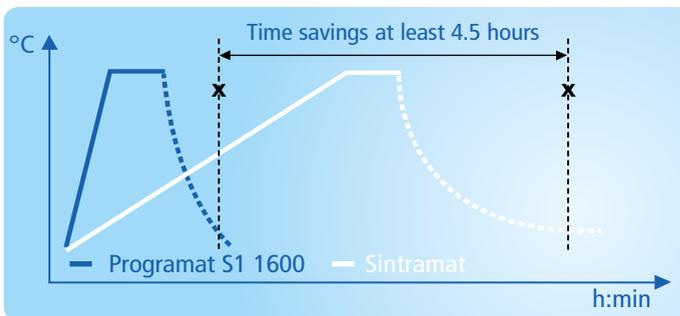
Programs for the fast sintering of translucent full-contour zirconium oxide restorations have also been developed especially for the Programat S1 1600.

Is sintering in 75 minutes possible?

2

Sintering in 75 minutes is possible if the following conditions are met:

- The sintering process must be exactly adjusted to the pre-sintered material.
- The span width has to be observed: Depending on the material type (e.g. IPS e.max ZirCAD MO), only crown copings may be sintered in 75 minutes. Bridge frameworks of up to 4 units can be sintered in 90 minutes, larger objects in 165 minutes. Translucent full-contour restorations (e.g. made of IPS e.max ZirCAD MT) can be sintered in 2.5 hours. Given the high translucency in the incisal of IPS e.max ZirCAD MT Multi, optimum results are achieved with a sintering time of 4.25 hours.
- It is imperative, as usual, to pre-dry all the frameworks.
- The furnace must be able to withstand the extreme demands from a technical standpoint: The high heating and cooling rates must not damage the furnace even in the long run and an exact and homogeneous heat distribution in the firing chamber must be ensured despite these extreme firing curves.



The times refer to the entire sintering process, from the start of the program until the removal of the objects from the sintering furnace.

3 Which materials are suitable for this purpose?

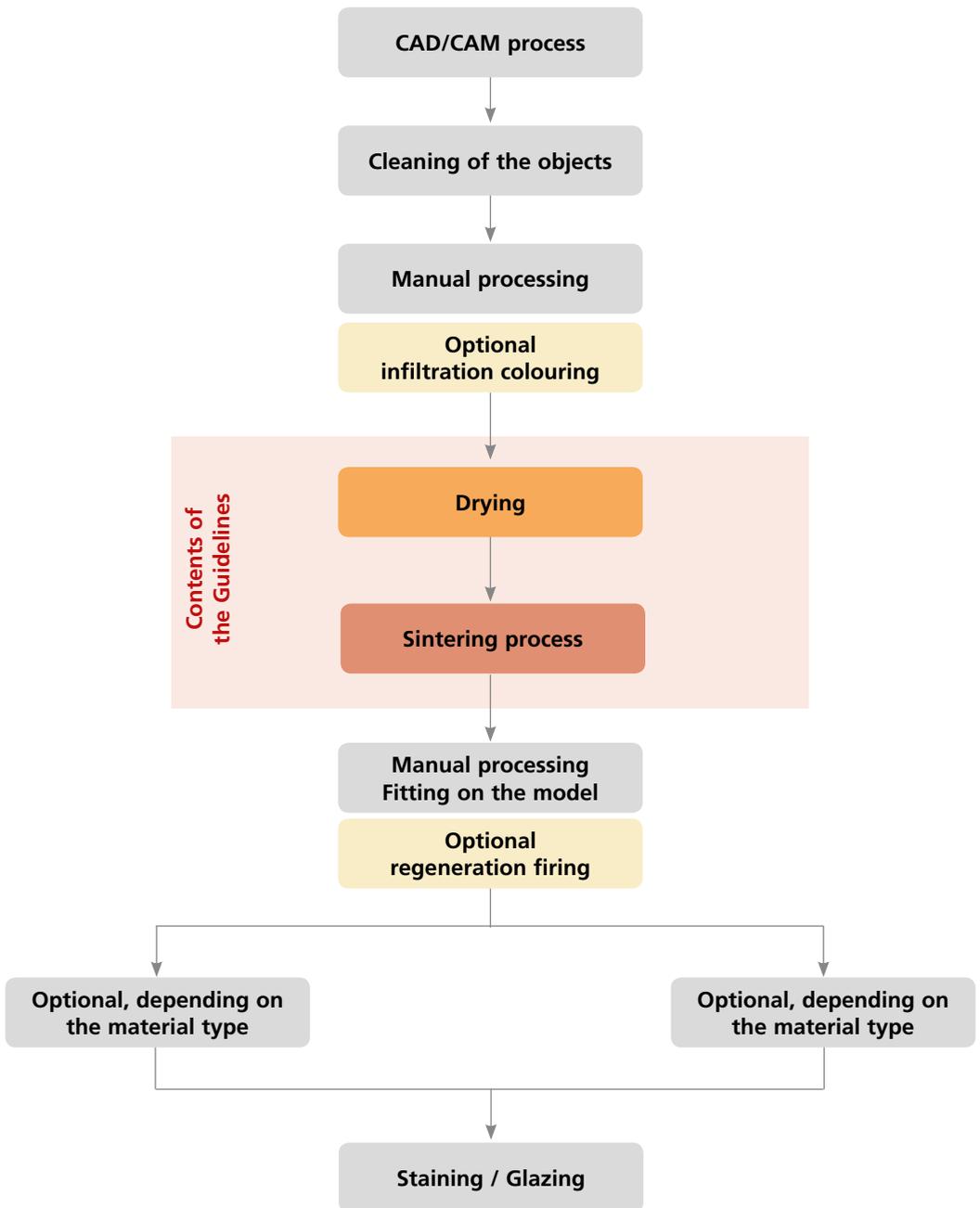
The quick sintering of dental ZrO₂ ceramics is primarily made possible because one thermal treatment has already been conducted to achieve what is known as the “white” state. During that process, the material has already been pre-sintered to such a degree that the first sintering necks have been formed and the initial stage of sintering has been reached or even partially completed. Moreover, all volatile and organic components were burned out during the debinding procedure so that their decomposition can no longer cause any blemishes in the non-solidified, porous structure. This enables a very quick temperature increase up to a certain limit, particularly in the lower temperature range. Nevertheless, this possibility does not apply to all dental ZrO₂ materials. How quickly a material can be sintered mainly depends on its thermo-physical properties, such as the heat conductivity and heating capacity, the bulk of the components, the mass distribution, its thermal pretreatment and the homogeneity of the structure, particularly the local density differences, the pore distribution within the component and the sinter activity of the raw material included in the material. The more homogeneous the material, the easier it will be to achieve the same sintering status within the entire component at all times during the sintering process. Furthermore, this may also minimize the distortion during sintering. If the entire manufacturing process from pressing to sintering of a material is well known, the firing curve with regard to its sintering cycle may be optimized. The quick sintering programs were thus reduced to a time of 75 minutes.

Given the precise coordination of the reproducible manufacturing process, the continuously checked quality of the blocks, the especially developed sintering process and the optimization of the conventional furnace technology in the high temperature range, Ivoclar Vivadent has made it possible that the quick sintering process of only 75 minutes works.

Fact Box

- Basic requirements and conditions
- Course of the 3 sintering stages
- Green compact or white compact state
- Pre-sintering degree
- Thermo-physical parameters
- Time-savings
- Time limit for the application
- Framework size and application
- Block homogeneity
- Density gradient and pore distribution
- Comprehensive quality checks of the material
- Optimized sintering cycle
- Coordination of material, manufacturing, test and sintering processes
- System idea and advantages
- Temperature distribution
- Furnace construction
- Programat design

Step by step – An overview of the entire process

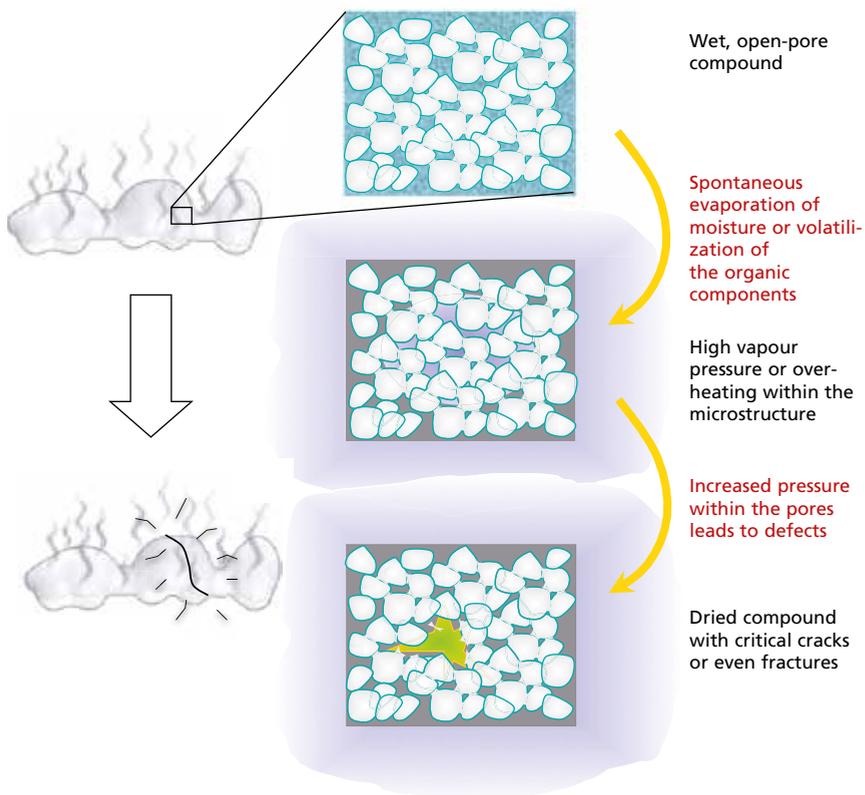


4 What needs to be given particular attention to during pre-drying prior to the sintering process?

Drying the ZrO_2 framework is a decisive process step during the fabrication of dental restorations and absolutely imperative to achieve optimum results.

What happens if the material is not pre-dried?

The high temperatures and the quick temperature increase in the sintering furnace result in a quick evaporation / volatilization of the liquid in the object. If the evaporation / volatilization process happens too quickly, blemishes within the microstructure may result.



How is optimum pre-drying performed?

The temperatures for drying the ZrO₂ frameworks should be in the range of 70–140 °C/ 158–284 °F. Higher temperatures are not recommendable, since the quick evaporation of the moisture may lead to blemishes in the microstructure.

The drying times depend on the temperature, atmospheric humidity, size of the frameworks and/or their maximum wall thickness, the pore size and/or the material density and, of course, the moisture of the object. The following table lists the drying times for various framework geometries. Drying cabinets with circulating air, infrared lamps (output: e.g. 250 W, distance to the object: approximately 5–20 cm), hot air blower, etc. are particularly suitable as drying devices.



Drying times for IPS e.max ZirCAD depending on the restoration size and temperature

	Temperature ~70 °C/158 °F	Temperature ~140 °C/284 °F
Single-tooth restorations	≥ 15 min	5–10 min
2- to 4-unit bridge restorations	≥ 40 min	≥ 25 min
5- and more-unit bridge restorations	≥ 50 min	≥ 25 min

Fact Box

- Optimum drying
- Drying times
- Drying temperatures
- Drying devices
- Errors during drying
- Program selection
- Evaporation of moisture
- Steam pressure
- Volatilization
- Development of micro-structure defects

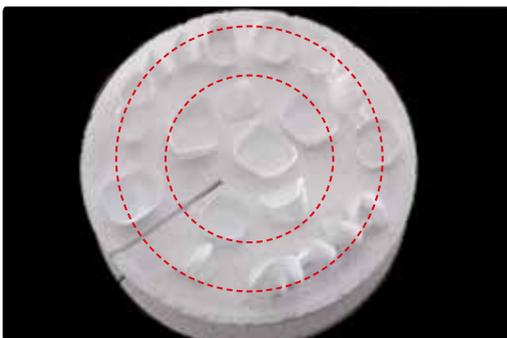
5 Sintering in the Programat S1 1600

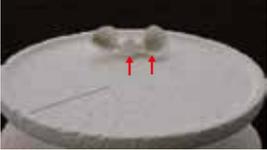
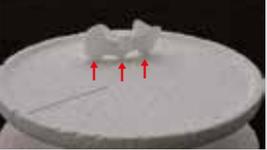
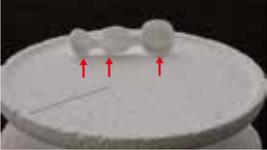
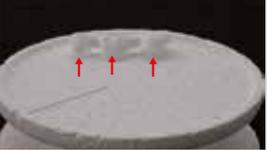
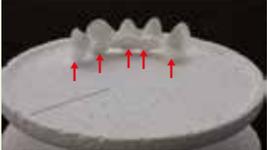
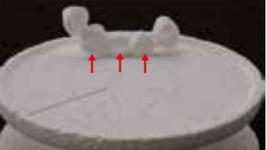
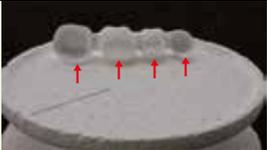
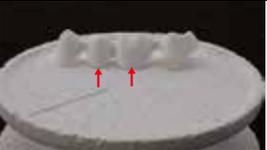
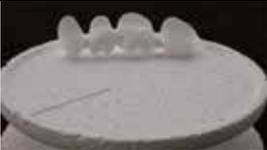
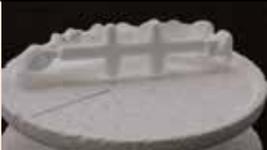
Before starting the sintering process, wet restorations have to be sufficiently dried according to their size (see Table on page 9).

Restorations which are sintered while still wet, may be damaged by the high heating rate during sintering.

Observe the following points when sintering in the Programat S1 1600:

- **Do not use any ZrO₂ sintering beads** in the Programat S1 1600.
- The sinter tray can be entirely filled with restorations. Make sure that the restorations do not touch each other.
- Single and bridge constructions as well as restorations with sinter support structures may be sintered simultaneously.
- Observe the program selection.
- The restorations have to be evenly supported to prevent distortion during sintering.
- Bridge frameworks should not exclusively be supported by the abutment crowns on either side. Preferably provide support to the pontics. The abutment crowns do not necessarily have to come into contact with the sinter tray.
- Ideally, arrange bridge constructions in particular in concentric circles on the sinter tray. **Note:** Do not place any restoration over the separation in the sinter tray.
- Place the loaded sinter tray in its intended position in the centre of the S1 1600 sintering chamber using the sinter tray fork.



	correct	OK	wrong
Single-tooth restorations anterior region	 <p>Place the restorations on their labial surface.</p>	 <p>Place the restorations on their oral surface.</p>	 <p>Do not place the restorations on their crown margins.</p>
Single-tooth restorations posterior region	 <p>Place the restorations on their occlusal surface.</p>		 <p>Do not place the restorations on their crown margins.</p>
3-unit anterior restorations	 <p>Place the restorations on their labial surface and provide support to the pontic. If the framework "tilts", change the positioning.</p>	 <p>Place the restorations on their incisal surfaces. The pontic must also rest on the sinter tray.</p>	 <p>Do not support the restorations solely on their marginal edges.</p>
3-unit posterior restorations	 <p>Place the restorations on their buccal or oral surfaces, depending on the curvature. Abutment crowns do not necessarily have to come into contact with the sinter tray. The pontic must be supported.</p>	 <p>Do not support the restorations solely on their crown margins. The pontic must be supported on the basal side.</p>	 <p>If the pontic does not support the restoration, the restoration must not be placed on its occlusal surface.</p>
4- and multi-unit anterior restorations	 <p>Place the restorations on their incisal surfaces. Make sure the pontics are supported.</p>	 <p>Depending on the curvature, the framework can be placed on its labial surfaces. All the pontics must come into contact with the sinter tray. Abutment crowns do not necessarily have to come into contact with the sinter tray.</p>	 <p>Do not support the restorations solely on their marginal edges.</p>
4- and multi-unit posterior restorations	 <p>Depending on the curvature, the framework can be placed on its buccal surfaces. All the pontics must come into contact with the sinter tray. Abutment crowns do not necessarily have to come into contact with the sinter tray.</p>	 <p>Do not place the restoration solely on its crown margins. The pontics must be supported on the basal side.</p>	 <p>If the pontics do not support the restoration, the restoration must not be placed on its occlusal surface.</p>
Restorations with sinter support structure	 <p>Place the restoration on the sinter support structure onto the sinter tray.</p>	 <p>The restoration may also be placed on the sinter support structure / incisal or occlusal surfaces of the pontic. For this purpose, the sinter support structure must face the centre of the sinter tray.</p>	 <p>Do not place the restoration on its crown margins.</p>

6 The sintering programs

It is very important that the respective programs are selected for the various ZrO₂ materials and the different restoration types in the Programat S1 1600 sintering furnace. If this point is not observed, failures may occur. The following table provides an overview of which programs to use for which materials and the duration of the respective sintering process.

Program table for Programat S1 and Programat S1 1600 for software version V5.0

Program	Name	Description	Duration	Programat® Dosto Tray
1	IPS e.max ZirCAD MT Multi crown/bridge	Program for the quick sintering of IPS e.max ZirCAD MT Multi crown/bridge	4 h 25 min	
2	IPS e.max ZirCAD MT crown/bridge	Program for the quick sintering of IPS e.max ZirCAD MT crown/bridge	2 h 30 min	
3	IPS e.max ZirCAD MT Multi/MT/LT/MO standard	Standard program for the conventional sintering of IPS e.max ZirCAD MT Multi/MT/LT/MO restorations and dried, infiltrated IPS e.max ZirCAD MT and LT restorations.	9 h 50 min	✓
4	IPS e.max ZirCAD LT crown	Program for the quick sintering of IPS e.max ZirCAD LT crowns	2 h 55 min	
5	IPS e.max ZirCAD LT bridge (up to 14 units)	Program for the quick sintering of IPS e.max ZirCAD LT bridges with up to 14 units	4 h 30 min	
6	IPS e.max ZirCAD MO crown	Program for the quick sintering of IPS e.max ZirCAD MO crown frameworks	75 min	
7	IPS e.max ZirCAD MO bridge (up to 4 units)	Program for the quick sintering of IPS e.max ZirCAD MO bridge frameworks with up to 4 units	90 min	
8	IPS e.max ZirCAD MO bridge (up to 14 units)	Program for the quick sintering of IPS e.max ZirCAD MO bridge frameworks with up to 14 units	2 h 45 min	
9	IPS e.max ZirCAD MO standard	Standard program for the sintering of IPS e.max ZirCAD MO frameworks	7 h 20 min	✓
10	Zenostar MT crown/bridge	Program for the quick sintering of Zenostar MT	2 h 30 min	
11	Zenostar MT/T standard	Standard program for the sintering of Zenostar MT/T	9 h 50 min	✓
12	Zenostar T crown	Program for the quick sintering of Zenostar T crowns	2 h 55 min	
13	Zenostar T bridge (up to 14 units)	Program for the quick sintering of Zenostar T bridges with up to 14 units	4 h 30 min	
14	Zenostar MO crown	Program for the quick sintering of Zenostar MO crown frameworks	75 min	
15	Zenostar MO bridge (up to 4 units)	Program for the quick sintering of Zenostar MO bridge frameworks with up to 4 units	90 min	
16	Zenostar MO bridge (up to 14 units)	Program for the quick sintering of Zenostar MO bridge frameworks with up to 14 units	2 h 45 min	
17	Zenostar MO standard	Standard program for the sintering of Zenostar MO frameworks	7 h 20 min	✓
18	Zenotec Zr Bridge crown	Program for the quick sintering of Zenotec Zr Bridge crown frameworks	75 min	
19	Zenotec Zr Bridge bridge (up to 4 units)	Program for the quick sintering of Zenotec Zr Bridge bridge frameworks with up to 4 units	90 min	
20	Zenotec Zr Bridge bridge (up to 14 units)	Program for the quick sintering of Zenotec Zr Bridge bridge frameworks with up to 14 units	2 h 45 min	
21	Zenotec Zr Bridge standard	Standard program for the sintering of Zenotec Zr Bridge frameworks	9 h 50 min	✓
22	Regeneration firing	Program for the regeneration of IPS e.max ZirCAD frameworks after excessive working	60 min	
23–50	Individual programs			

**Important information**

The individual pre-drying times of the ZrO_2 objects must be observed. They depend on the size of the restoration and the pre-drying temperature. For more detailed information, please refer to the Instructions for Use of the corresponding material.

**Important information about colouring liquids**

If colouring liquids are used, several points must be observed:

- After the sintering process, clean contaminated areas of the furnace with a soft cloth.
- In case of severe contamination of the sinter chamber or the insulation, conduct a Cleaning firing.
- The restorations stained with colouring solutions must be adequately pre-dried in a pre-drying furnace. Air drying is not sufficient in these cases and may result in cracks in the objects during the sintering process.

Remove the sinter tray from the furnace after the completion of the sintering process using the sinter tray fork. Always allow the frameworks to cool to room temperature before proceeding.

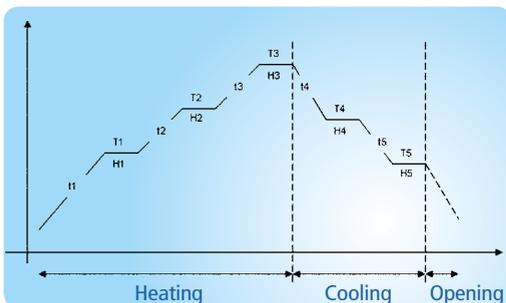
What must be observed for the free programming of the firing programs?

Why is the maximum firing temperature limited to 1600 °C / 2912 °F?

What is the risk if even faster sintering programs are used?

Same as the sintering process, the program structure to enter the firing programs has also been divided into several segments. There is a total of 3 heating stages and 2 cooling stages as well as an adjustable furnace opening time. With free programming, all the segments have to be taken into consideration and the desired firing parameters have to be adjusted to the program structure. The individual program stages were limited to certain parameters with regard to the dense-sintering of partially stabilized zirconium dioxide for dental applications. For example, the maximum heating and cooling rates, but also the maximum final temperatures were defined. Competitor materials can also be sintered in the Programat S1 1600 at 1600 °C / 2912 °F. However, the sintering parameters of the respective manufacturer have to be observed and entered manually into the program.

Graphic overview of the program parameters



Individual programs

The program parameters and their limit values which can be set for the individual programs are listed in this table.

Symbol	Parameters		Value range °C			Value range °F		
			min	max	Unit	min	max	Unit
t1	Heating stage 1	Temperature increase rate	5	90	°C/min	9	162	°F/min
T1		Holding temperature	700	1200	°C	1292	2192	°F
H1		Holding time	00:00	05:00	hh:mm	00:00	05:00	hh:mm
t2	Heating stage 2	Temperature increase rate	1	50	°C/min	2	90	°F/min
T2		Holding temperature	0/700	1530	°C	0/1292	2786	°F
H2		Holding time	00:00	05:00	hh:mm	00:00	05:00	hh:mm
t3	Heating stage 3	Temperature increase rate	1	50*	°C/min	2	90**	°F/min
T3		Holding temperature	0/700	1600	°C	0/1292	2912	°F
H3		Holding time	00:00	05:00	hh:mm	00:00	05:00	hh:mm
t4	Cooling stage 1	Temperature decrease rate	1	50	°C/min	2	90	°F/min
T4		Holding temperature	100	1100	°C	212	2012	°F
H4		Holding time	00:00	05:00	hh:mm	00:00	05:00	hh:mm
t5	Cooling stage 2	Temperature decrease rate	1	50	°C/min	2	90	°F/min
T5		Holding temperature	0/100	1100	°C	0/212	2012	°F
H5		Holding time	00:00	05:00	hh:mm	00:00	05:00	hh:mm
O	Opening time	Opening time	00:15	05:00	hh:mm	00:15	05:00	hh:mm

Graphic overview of the program structure and the possible setting ranges

* If T3 ≤ 1530°C: t3 max 50°C/min
If T3 > 1530°C: t3 max 10°C/min

** If T3 ≤ 2786°F: t3 max 90°F/min
If T3 > 2786°F: t3 max 18°F/min

What is the risk if even faster sintering programs are used?

During the development of the fast sintering programs, the speed limits for the various program stages were carefully tested and precisely adjusted to the properties. Program P6 with a duration of 75 minutes was developed as the fastest possible sintering program with which all the properties necessary for the application were achieved at a very high quality and with consistent reproducibility. This only applies for MO versions (medium opacity), such as IPS e.max ZirCAD MO. Every deviation to this sintering process may severely jeopardize the properties, such as density, average grain size (and grain distribution), strength, fracture toughness, accuracy of fit, translucency, etc. Hence, no liability can be accepted for such a procedure. It should also be absolutely refrained from using sintering parameters other than the ones tested, approved by the manufacturers and clinically proven. Moreover, users should not only rely on the optical appearance of the material. In order to ensure long-term clinical success, all the material parameters must be taken into consideration.

Fact Box

- Sintering programs
- Program selection
- Cycle times
- Sinter tray, sinter tray fork (firing auxiliaries)
- Loading the furnace and position
- Sinter support structure
- Contact points
- Replacement for ZrO₂ beads
- Program parameters
- Program limitations
- Quick sintering
- Influence of sintering temperatures and holding times
- Ageing resistance
- Microstructure and material properties

What is regeneration firing?

If the surface of a sintered framework is treated too roughly, e.g. large-area finishing, the surface phase transition – from tetragonal to monoclinic – increases. This phase transition may have a lasting unfavourable effect on the bond to the glass-ceramic; the risk of delamination of the layering material is increased. In order to reverse the monoclinic phase back to the tetragonal phase, a regeneration firing is used. It is conducted at a maximum temperature of 1050 °C / 1922 °F. It can be selected as a preset sintering program (Program 22).

Note: Cracks in the surfaces cannot be “healed” with the regeneration firing. The surface roughness remains after the thermal process.

8 What must be given special attention to when working with sinter furnaces?

Visual inspection of the sintering chamber

Visually inspect the sintering chamber before every sintering procedure.

No foreign objects or dirt particles must be in the sintering chamber during sintering.

Contamination may result, among other things, from flaking of the oxide / protective layer of the heating element surface. Impurity caused by such contamination may jeopardize the optical appearance (discolouration) of the sintered object.

Impurities resulting from a flaking oxide layer can be divided into two categories:

Type of contamination	Appearance
Glass particles	Glassy, transparent particles are well visible on the insulation of the furnace base and/or the receptacle for the sinter tray.
Fine glass dust	Fine glass dust has accumulated on the insulation of the furnace base and/or the cooling tray. This type of contamination is more difficult to recognize, but may also contribute to the discolouration of the objects.

If glass particles or fine glass dust are noticed during visual inspection, the sintering chamber must be cleaned and a no-load run with Program 1 (IPS e.max ZirCAD crown) must be conducted. This means that the furnace is not loaded with ZrO_2 objects. Running the cleaning program or replacing the heating elements is recommended if the contamination reappears.



Check the sinter tray on a regular basis to see if it is free of dust and free it from dust if necessary. Contact reactions at high temperatures may lead to damage of the zirconium oxide surface. They can be detected as white spots, for example.

Cleaning of the sintering chamber

Use the cleaning brush supplied for this purpose for cleaning. Do not use compressed air under any circumstances. After cleaning, Program P1 must be run with no load (IPS e.max ZirCAD crown). Running the cleaning program is recommended in case of severe contamination.

Cleaning of the heating elements

With the cleaning program, the flaked oxide protective layer on the heating elements is restored. If no even protective layer on the heating elements is noticeable after the cleaning program, it is possible that running the cleaning program several times in a row is required. Do not sinter any ZrO₂ frameworks when running the cleaning program.

Clean the sintering chamber before running the cleaning program. If the heating elements show no improvement even after multiple cleaning cycles, we recommend replacing the heating elements.

A large area of the protective layer of the left heating element has flaked off. The right heating element is in good, stable condition with its oxide / protective layer intact. Repeat the cleaning program several times until the surface of the heating elements is free from contamination and appears glassy.



Fact Box

- Regeneration of the material
- Phase transition
- Surface treatment
- Handling of the heating elements
- Oxide / protective layer
- Maintenance and cleaning of the furnace
- Conditioning of the sintering chamber
- No-load run with Program 1
- Contamination
- Cleaning firing
- Replacing the heating elements

9 On economic efficiency

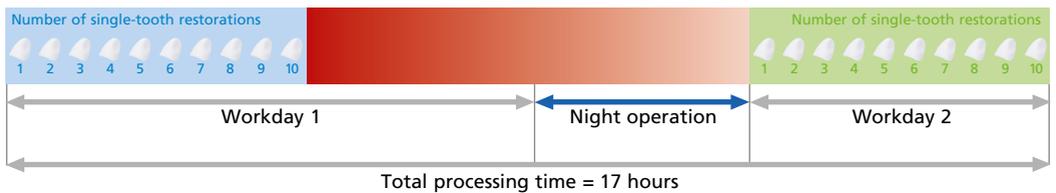
What are the economic advantages of quick sintering?

With the Programat S1 1600, you increase your laboratory capacity due to the shortened sintering process. This saves time and costs. As a result, the laboratory gains a competitive edge over their competitors. While at least two workdays were necessary to fulfil an urgent customer demand thus far, this can now be achieved in a few hours. With this innovative process, it is possible for the first time to fabricate a ZrO_2 -supported restoration within one workday.

This opens up new opportunities and leads to new, substantially more efficient processes, which are depicted in the following images.

Conventional sintering process

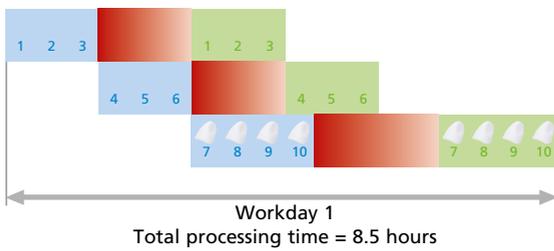
This sintering process takes an average of seven hours. In most cases, therefore, the ZrO_2 objects were milled on the first day, sintered over night and further processed the next day. To increase the capacity by up to 40% we recommend using the Programat Dosto Tray for the conventional overnight operation.



Programat S1 1600 – staggered working process

The new sintering process creates new opportunities, since a restoration can be milled, sintered and veneered in one day. This creates a competitive edge, as orders can be processed in a short time and at lower costs.

Another advantage of the staggered working process is the increased production capacity. If several processes are superimposed (see figure), it becomes clear that the capacity can be increased many times over.

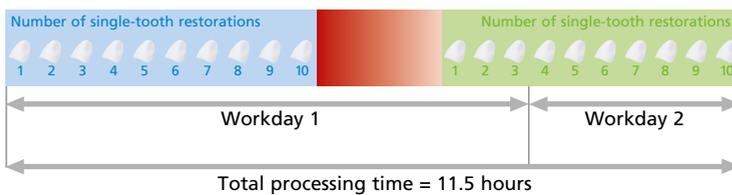


Programat S1 1600 – conventional working process

If desired, the Programat S1 1600 can also be used to conduct the conventional working process with a quick sintering program. This also results in advantages over conventional sintering.

Important work can be given priority and completed within one workday (objects 1 to 3), the other objects will be finalized the next day.

This working process results in considerable savings as regards energy costs.



- CAD/CAM fabrication (scanning, milling)
- Sintering process
- Layering process (finalized by the dental technician)

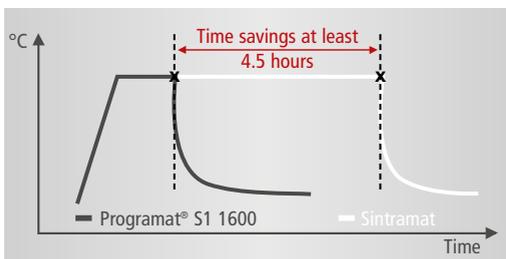
Power Saving Technology:



Saving energy with the Power Saving Technology:

With the Programat S1 1600, Ivoclar Vivadent continues its successful "Power Saving Technology" concept. The conventional technique in the Programat S1 1600 makes it possible to save up to 64% of energy compared to a conventional sintering process.

The conventional sintering furnace "Sintramat" has a connection power of 3000 Watt and requires an average of 3.8 kwh for one sintering process. In contrast, the Programat S1 1600 has a connection power of 1800 Watt and, depending on the respective program, requires only 1.35 kwh of energy (see diagram).



What does this mean for your energy savings?

Up to 64% of energy can be saved per sintering process with the Programat S1 1600. This corresponds to energy savings of 2450 Watt per sintering process.

An extrapolation for a year with 200 cycles shows average energy savings of 490 kwh per year.

Fact Box

- Economic efficiency
- Time savings
- Cost savings
- Staggered working process
- Output
- Environmental awareness
- Energy savings
- Power Saving Technology
- Low connection power
- Flexibility
- Innovative process
- Customer focus
- Competitive edge

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