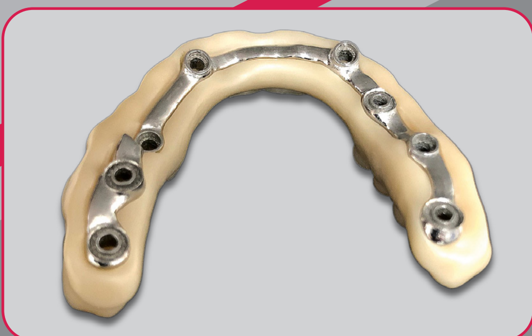
MESTRA

Microwave technology in the sintered of dental Zirconium

Ref. 080114



By engineers
of the Mestra Research and Development Center

The heating of ceramic materials by electromagnetic waves is a technique used by the industry since the early 1980s. Initially it was used for drying materials. (basically water removal) and later in the heating/sintering of ceramic elements.

After all this time, the technology has acquired an optimal degree of maturity and more and more industrial applications are being found for it.

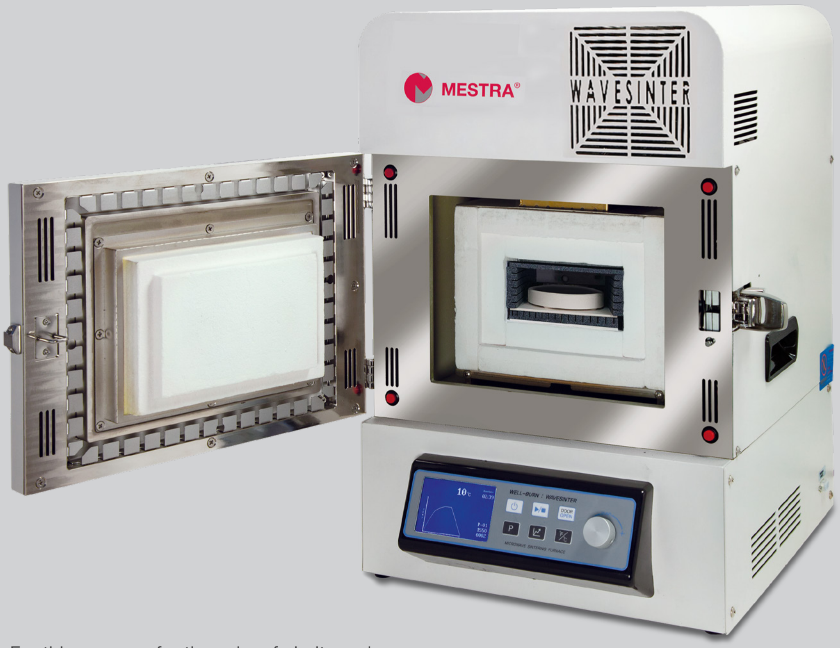
Focusing on the dental sector, the ZrO_2 sintering is probably the most interesting utility.

At the moment, only a few companies in the world master this technique to the point of to be able to offer the market reliable products, efficient and economical.

However, due to its novelty and revolutionary concept, there are many doubts and uncertainties that assail the dental laboratory technician.

This writing is born with the intention of clarifying ideas and solve doubts to a user interested in the subject, but who does not have a solid base scientific: its character is merely informative.

An in-depth look at technology microwave sintering would force us to address issues that are rooted, among others, in quantum mechanics, wave mechanics or electrochemistry.



For this reason - for the sake of clarity and ease of understanding - it has been decided simplify the exposition.

Microwave operation

Perhaps the best way to get started in the world of microwaves is Analyzing the performance of a microwave oven like the one we all have in our kitchen.

It is known that a water molecule is made up of two hydrogen atoms and one oxygen atom. Likewise, the ion of Hydrogen has a positive charge and oxygen has a negative charge.

Due to this asymmetry of the molecule, two differentiated zones will be generated in space: one with a positive charge and another with a negative charge. Or what is the same: a tiny magnet.

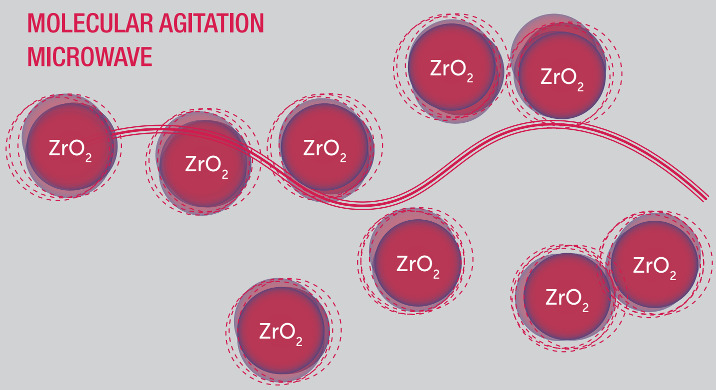
On the other hand, we know that placing a magnet in a field electromagnetic field, it will be oriented in the same way that the magnetic needle of a compass is oriented following the lines of the earth's electromagnetic field.

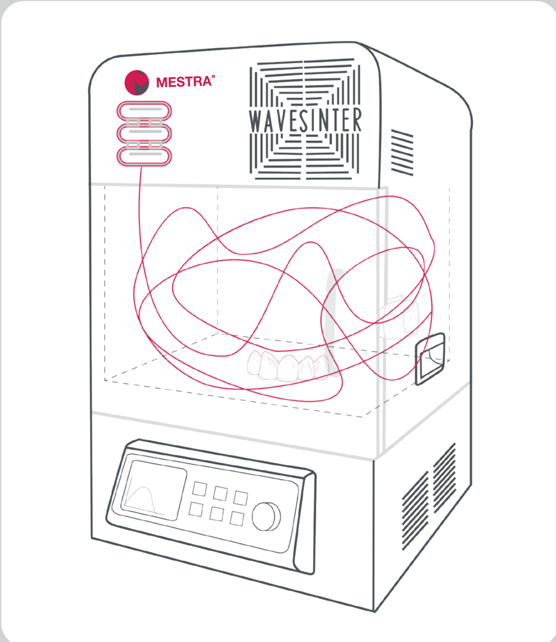
But, what would happen if instead of a static field like the terrestrial one, the magnet is immersed in an electromagnetic field that oscillates in the weather?

In that case, it would begin to vibrate at the same rate, trying at all times to maintain alignment with the field.

The foods that we put in the microwave in our homes have a high water content. We have already seen that one way of understanding water molecule would be like a tiny magnet.

When you press the start button, a device called a magnetron generates an electromagnetic wave high energy oscillation. Immediately, the tiny "water magnets" start to vibrate trying to orient themselves in the field created by the magnetron. This frenetic molecular dance produces friction and consequently, the heating of the food.





We have to make a series of remarks:

- ✓ The frequency of the wave generated by the magnetron is extraordinarily high. It oscillates approximately 2.4 billion times per second (2,400,000,000). Molecular friction is very high.
- ✓ The electromagnetic wave penetrates the food reaching its interior and making vibrate not only the water molecules from the outer shell, but also those found inside the food.
- ✓ Because all the water molecules in the food are oscillating at the same time, heating occurs homogeneously and simultaneously throughout the mass of the food.

- ✓ As the casing of the device is metallic and closed, the electromagnetic waves cannot escape from the interior (Faraday cage effect), therefore, no energy is wasted. Almost all of the energy is used in the food heating.

  At the end of the process, the walls of the microwave are not very hot.

- ✓ There is a clear difference between heating in a classic resistance oven and in a microwave oven: in the conventional oven the radiation strikes the surface of the food and from there it is transmitted towards the interior of the food by conduction. For this reason, the surface of the food is roasted due to the direct incidence of the radiation that is unable to penetrate into the interior of the food. However, in the case of the microwave oven, the mechanics followed in heating prevent toasting.

- ✓ In practice, the energizing mechanism of ceramic materials (eg ZrO_2) within the field electromagnetic, it is not of the dipole type as in the water (magnet). It is actually produced by agitation of the free electron-hole pair, with oscillation space and without intermolecular shock. To become energized, a molecule can vibrate; move and collide with others molecules; rotate about one of its atoms; or what is more probable: a combination of all the previous actions.

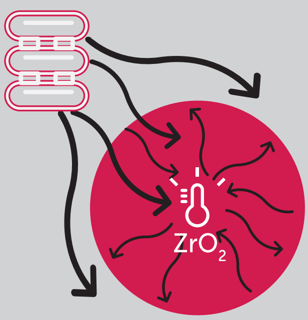
  For reasons of clarity and simplicity in the exposition, we will continue to approach the subject following the same initial philosophy.

CLASSIC OVEN

RESISTORS

- ✓ **In the conventional oven, the radiation falls on the surface and from there it is transmitted towards the interior by conduction.**
- ✓ For this reason, **the surface is roasted** due to the direct incidence of radiation that is unable to penetrate inside.

MICROWARE OVEN



MAGNETRON

- ✓ Its wave frequency > 2.4 GHz.
- ✓ **The electromagnetic wave penetrates to the interior.**
- ✓ All water molecules oscillate at the same time, **heating occurs homogeneously and simultaneously.**
- ✓ The metal casing of the device works as a Faraday cage, **the waves and heat do not go outside.**

Classic sintering problems

CRACKS AND DEFORMATIONS ARE AVOIDED

Suppose a hollow sphere that contains another sphere of the same material inside. between the two spheres initially there are none separation. Starting from this condition, suppose now that we only heat the outer sphere while keeping the inner one cold. The outer sphere will begin to dilate due to the effect of heat and little by little a separation will appear between both spheres that will be more and more large as the temperature difference.

- ✓ If we now assume that both spheres meet strongly welded, it will happen that the outer sphere will pull the inner one and that they will originate material stretching. Its elasticity will try to absorb the gap between the two spheres. Obviously, when the elastic limit of the material is exceeded and the breaking stress is reached, the material will tear, producing a crack. If instead of imagining that the outer layer is the one that gets hotter, we now suppose that it cools, we will reach the same conclusion: the differences in expansion between the different imaginary layers that make up a material, they must be absorbed by its elasticity. Otherwise, cracks will occur both in the heating and cooling phases.

- ✓ It is important to note that, depending on the geometry of the piece, the homogeneity of the material and the temperature difference to which it is subjected, the crack can appear on the outside (visible) or, what is more serious: it can remain inside the piece without anyone being able to see it and cause a break when it is later apply forces to the material.

- ✓ It may also happen that the traction/compression stress caused by the temperature difference is not high enough to produce a break (crack), but high enough to produce a permanent deformation in the material called strain plastic. This will happen whenever exceed the elastic limit without reaching the breaking stress. If that's the case, after the heating cycle the material would be warped and unusable due to the deformations that may be corrected.

The afore mentioned is accentuated if we take into account three peculiarities of dental zirconium:

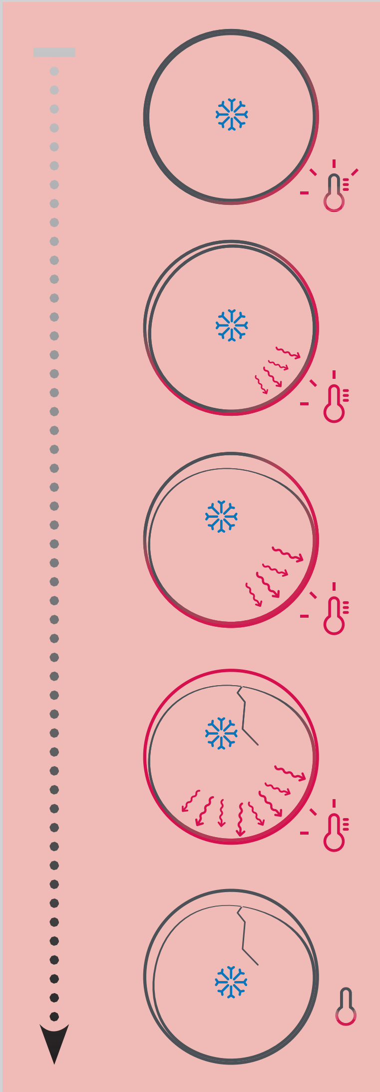
- ✓ **It is an extraordinary insulator thermal. For this reason,** heating/cooling processes by simple heat conduction take a long time if we want to avoid differences of temperature. It is difficult to conduct heat from the outside to the inside of the part due to the high thermal reactance of the material.

- ✓ **It is a material with a very limited elasticity.** any tension produced by a difference of temperatures can cause a crack.

- ✓ **The sintered material is extremely fragile.** The ZrO2 that put in the oven to sintering is not a substance homogeneous, but is "pressed powder". These are tiny particles of material held together very weakly by pressure.

During the treatment in the oven These particles merge generating a more resistant product. Obviously, before complete sintering is achieved, it will be a very brittle material, because the tensile/compressive strength of the "powder pressing" is very limited. Any slight stress due to temperature difference will cause cracks.

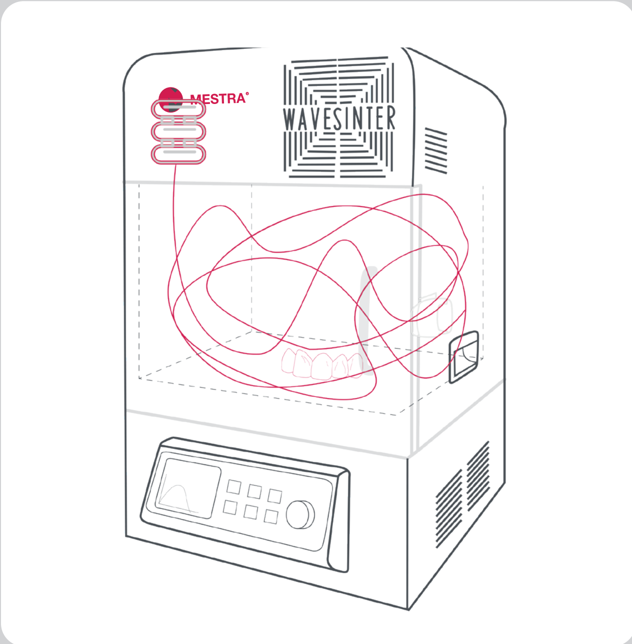
When we heat a piece of ZrO_2 with a conventional furnace, the thermal radiation produced by the resistors hits the crust exterior of the material and from there it is transmitted by conduction to the interior part. The refractory character of zirconium does not help in this heat transfer process. If we increase the radiation power to reduce process times, the only thing that we will achieve is to "toast" the outer crust of the piece keeping the cold inside. Or what is worse: generate a differential temperature between the crust and core so high that cause a crack. In short, heating/cooling times with sintering furnaces conventions must be maintained elevated.



However, because **the microwaves are capable of penetrating about 30/40 mm into the zirconium,** the molecular oscillation - and therefore the heating of the material - is performed uniformly at all points of the piece.

In this way, the risk of cracking due to the temperature difference between different areas is eliminated.

Advantages of microwave sintering



ENERGY SAVING

Conventional zirconium furnaces are built with resistors that radiate energy in all directions addresses.

To prevent it from being lost through the oven walls, it is necessary to use thick thermal insulation systems. **Of all the energy emitted by the resistors, only a fraction is absorbed by the part being heated.** The rest is lost as heat in the muffle and equipment.

Electrical consumption is high. However, using microwaves, the energy produced by the magnetron is concentrated almost **exclusively in the material to be heated.** We said that after a heating cycle in a home microwave, the walls are not hot.

Users of our oven by microwaves confirm that the cost **reduction in your electricity bill is significant.**

SIGNIFICANT REDUCTION OF CYCLE TIMES

Using technology for microwave, also processing times are significantly reduced:

- ✓ By eliminating the need for slow and gradual heating material to prevent breakage and deformations, **it is not necessary to extend the heating time,** because there are no significant differences in temperature between the inside and outside of the part.
- ✓ The refractory nature of zirconium does not have such an impact on the cycle, **because the heating originates in all points of the material.** Therefore, there is no need to transmit it from one area of the part (outside) to another (inside).
- ✓ The furnace has a lower mass and it also remains hot for less time than in a sintered conventional. **Therefore, the thermal inertia is much lower in the microwave oven.** This point is especially relevant during the cooling phase: room temperature will be reached in less time than with a conventional oven.
- ✓ The transmission speed of energy of an electromagnetic wave in matter is greater than that of the radiated energy. According to the laws of quantum mechanics, the photon absorption mechanisms are different in both cases and consequently also the rate of change temperature.

SIMPLE MAINTENANCE

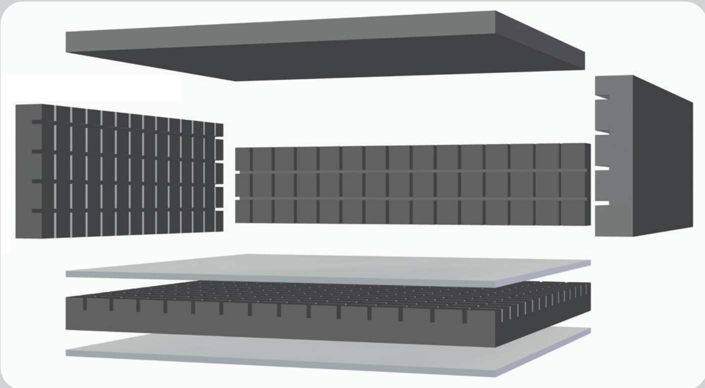
The resistances of a zirconium furnace for conventional sintering they have to reach temperatures that in some cases exceed 1800 ºC., Generally, these resistors are made of $MoSi_2$, an expensive, delicate material (it is very brittle and brittle), used only for very specific and limited applications, and susceptible to contamination by steam inside the muffle.

In addition, they have a high electrical conductivity, which is why the use of very high currents is required (they can exceed 100 Amperes), with reduced voltages. This feature requires the use of very sophisticated electronic power and regulation systems. To further aggravate the problem, over time the resistances go degrading and need to be replaced. Its cost is very high.

The magnetron is an element compact that is easy to replace in case of failure, cannot produce any of contamination within the camera, it is cheap and rare time fails.

For its part, the magnetron of a microwave oven is an element compact, easy to replace in case of failure, which cannot produce any type of contamination inside the muffle, relatively cheap, with a practically unlimited life (depends on the working conditions, but in any case its life is very long), reliable and highly tested in all types of industrial systems.

What are susceptors?



A recurring question that our customers and friends often ask is the function of the refractory susceptors that line the interior of the microwave oven muffle. We will try to explain it as curiosity.

For this we need to introduce two basic concepts: the effect Greenhouse and energy radiation mechanism.

- ✓ Starting with the first of the concepts, we will say that a greenhouse is a glass enclosure exposed to solar action. The sun's rays pass through the glass because it is transparent at the solar emission frequency. Once inside, the radiation heats the interior, raising the temperature. This increase in temperature causes the interior of the greenhouse to in turn emit energy to the outside.

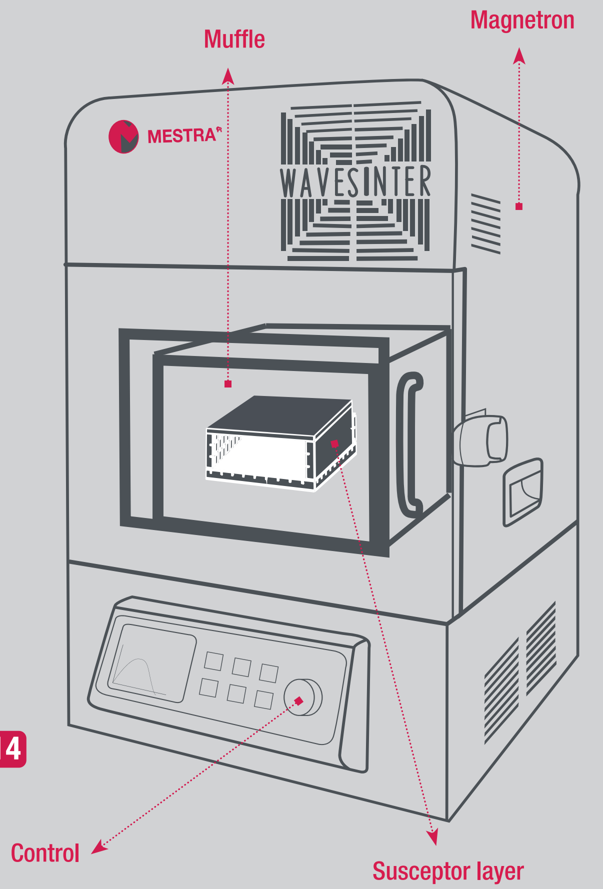
- ✓ Now we must mention an important detail: the solar radiation has a very high emission frequency elevated because it has been produced by an element, the sun, which is at an enormous temperature. On the contrary, the radiation emitted when the interior of the greenhouse is heated is of low energy, because the temperature is also low. The sun's rays pass through the glass easily and they heat the interior of the greenhouse, but that same glass prevents the reflected radiation from leaving. Energy enters, but does not leave, raising the temperature inside.

- ✓ The second of the concepts was introduced by the Austrian physicist Ludwig Boltzman, who proposed that the energy emitted by a hot body was proportional to its temperature raised to the fourth power (E = σT4). The sun is at a temperature of several million degrees. If we raise it to the fourth power, it is easy to intuit the enormous amount of energy that radiates into space and the reason why our planet receives it despite being many millions of kilometers away. On the contrary, a body at a low temperature will have a very limited energy emission capacity.

- ✓ Looking at both concepts, when heating food in a domestic microwave, the temperature does not usually exceed 100 ºC, so the radiated energy is very poor. But if we talk about dental zirconium, the temperature of sintered temperature is around 1550 ºC, about 15 or 16 times higher than that of the kitchen microwave. Raising this value to the fourth power, we have that the amount of energy irradiated by a block of zirconium at 1550 ºC will be about 50,000 times higher than that radiated by food that we usually heat in our microwave ovens domestic.

- ✓ Such an amount of heat could damage the mechanisms and internal systems of the oven as well as be an energy waste. For this reason, our engineers chose to create a "small greenhouse". Let's not forget that sunlight, radio waves, microwaves, X-rays etc. they are all electromagnetic waves that obey the same principles and equations.

- ✓ Continuing with the simile, the interior of the muffle would be the greenhouse itself. The susceptors would fulfill the function of the crystal, which is transparent to the microwaves generated by the magnetron, but highly opaque to the radiation emitted by the heating of the zirconium. Energy can enter the furnace chamber through the susceptors, but not escape from it, resulting in energy savings



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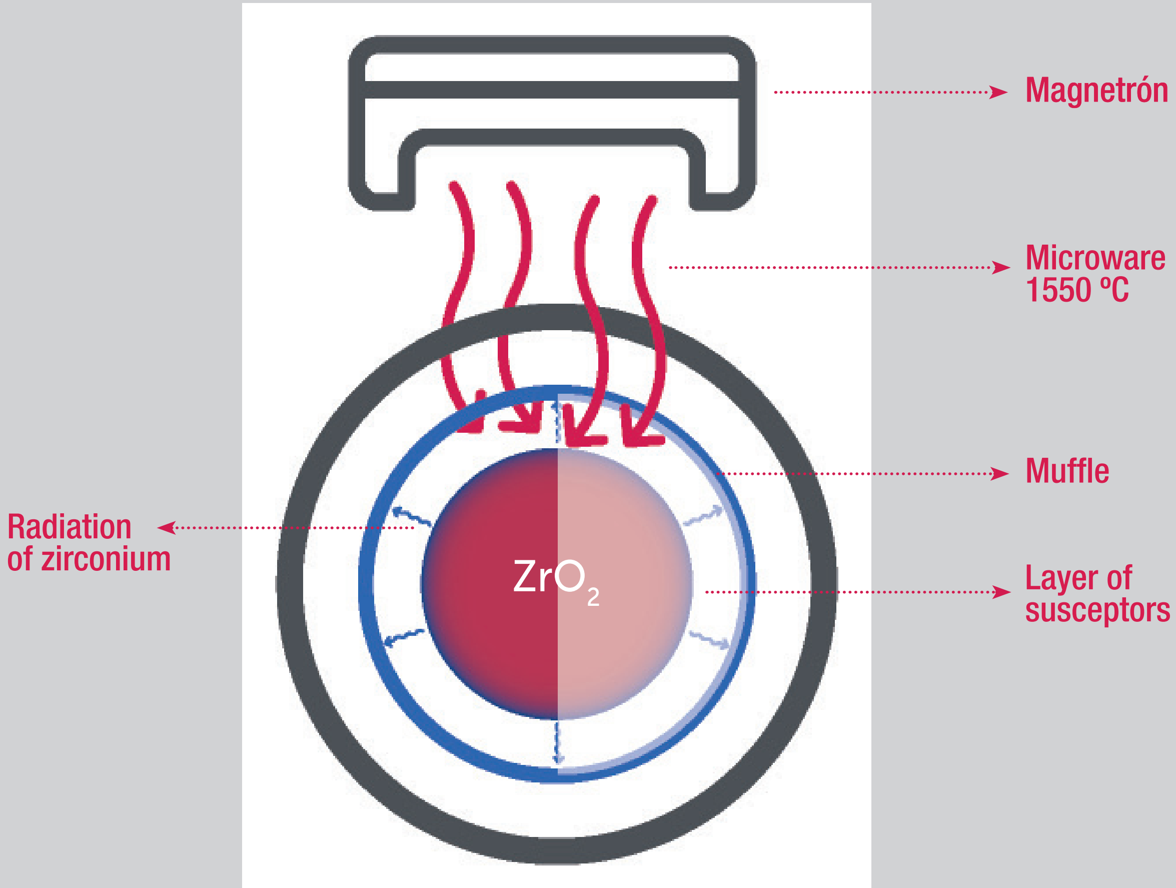
What are susceptors?

Actually, the susceptors are not 100% transparent to the energy produced by the magnetron, so a part of it is absorbed by them causing them to heat up. This heat produces two positive effects:

- ✓ It heats the air surrounding the zirconia part being sintered, reducing the zirconia/air temperature difference. Let us not forget that sintering is carried out in the presence of air and that air is transparent to microwave, so it gets hot. If there is a lot temperature difference between air and zirconium can cause a crack.
- ✓ In the initial moments of heating, when the free electrons of zirconium are in their lower energized state, the radiation of the susceptors aids in the vibration of the electron pair free/hollow As the zirconium gains energy, this effect is dampened.
- ✓ Another function of susceptors is to protect electrical and mechanical systems from radiation emitted by zirconium when it is at high temperature (about 1550 ºC). So much energy radiated at a short distance could damage the elements of the oven.
- ✓ Since the susceptors are elements that do not suffer wear, in principle its duration is unlimited. Nope However, the shocks and frictions produced accidentally when inserting the material to be sintered, Along with chemical contamination and degradation of the material with high temperature, recommend Replace these items periodically to maintain oven efficiency.

In addition, the susceptor material above 800 ºC can cause certain chemical reactions that deforms them. This is not a problem due to the ease of replacement and the reasonable cost of the oven.



SINTERED BY MICROWAVE

BREAKS ARE AVOIDED

TIME SAVING

ENERGY SAVING

MAINTENANCE SAVINGS

AHORRO DE ESPACIO

RETRENCH OF SPACE

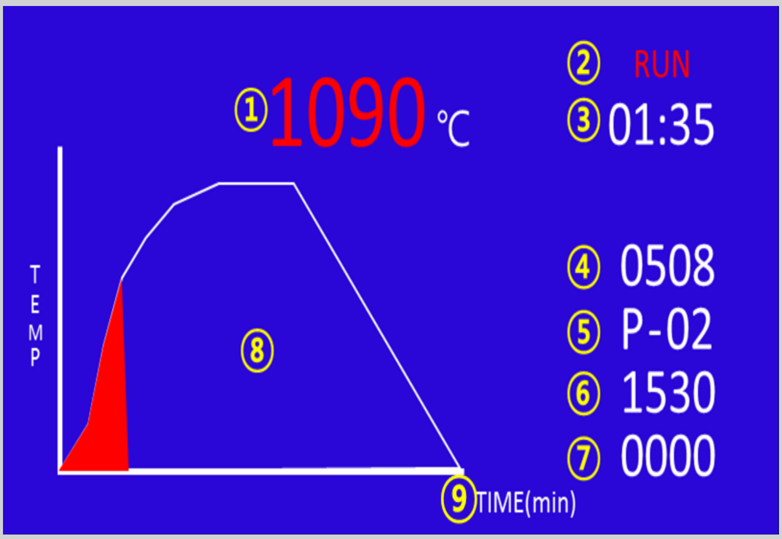
INCREASED PRODUCTION CAPACITY

QUALITY IMPROVEMENT

The particular advantages of the **MESTRA** microwave sintering furnace are not limited to just those listed above. To them should also be added:

- ✓ **Compact model that occupies a small space in the laboratory.** The dimensions of the equipment are practically similar to those of a conventional dental cylinder preheating oven.
- ✓ **Simple and intuitive operation.** There is no learning curve.The equipment is supplied with a series of pre-recorded programs, so it is enough to press a button to start and end a cycle. The optimal result is guaranteed.
- ✓ **Huge production capacity.** With conventional technology, a sintering cycle takes a long time, so it is difficult to do more than one in a single day. As microwave technology is much faster, on the same day it is possible to launch two -and even if planned well- up to three cycles.
- ✓ **Significant quality improvement.** Sometimes the cracks and deformations of a sintered dental material do not appear on the outside of the piece, but remain inside it, being impossible to detect. However, this does not mean that there is no potential risk breakage. It may happen that, when subjecting the prosthesis to daily use, it ends up breaking due to an internal failure that was not detected in the visual inspection after sintering. This risk is significantly reduced by employing microwave heating technology.

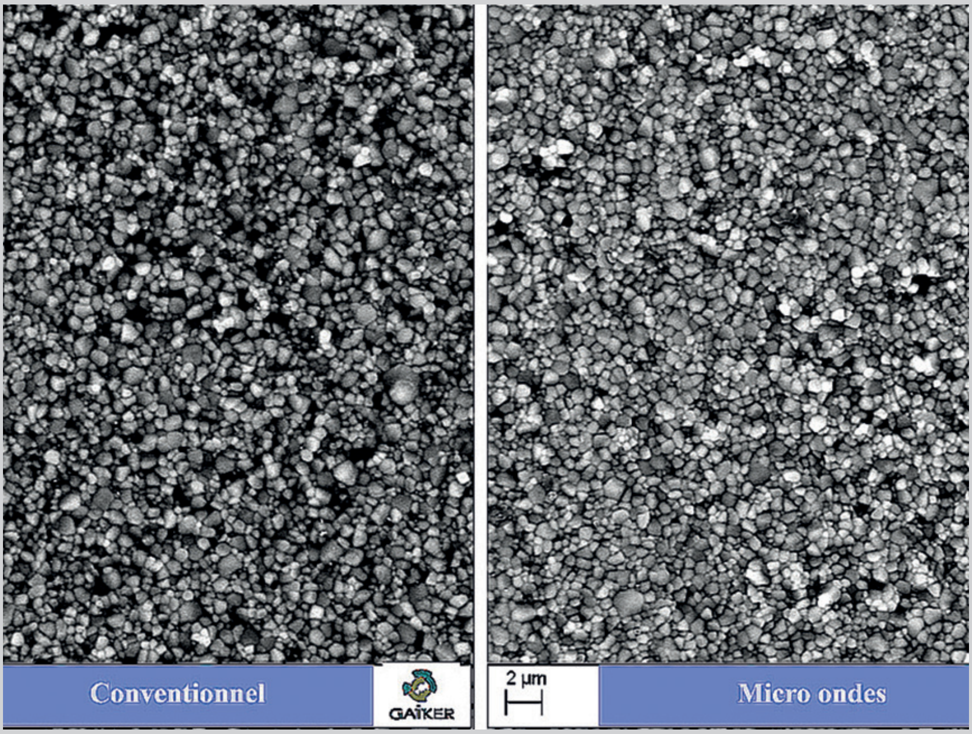
CONTROL PANEL



1. Temperature actuelle interieure.
2. Etat – (run –end –stand by).
3. Tiemps restant du cycle.
4. Algorythme magnetron.
5. Programme selectionne.
6. Temperature finale programmee.
7. Compteur de cycles du four.
8. Graphique du programme.
9. Temps.

The practice

After this theoretical contribution to the technology of sintering by microwave to Below are some illustrations showing the possibilities and benefits offered to the prosthetist thanks to this oven.



Two sintered zirconium discs, one with a conventional oven and the other with a **MESTRA** microwave: Under the electron microscope, a size slightly finer grained with technology of microwave.

Realization of a complete bridge without stabilizers.
Disc output of the milling machine: work done without stabilizers. The homogeneity of microwave sintering prevents deformations often due to currents of air that are produced due to the differences temperature during sintering in a furnace of resistance.

Sintered part.

The practice

Perfect adjustment!

Respect for zirconia = Hardly out of the oven:
respect for colors and translucency

Accuracy of fit and esthetics after
of the glazing. Monolithic piece.

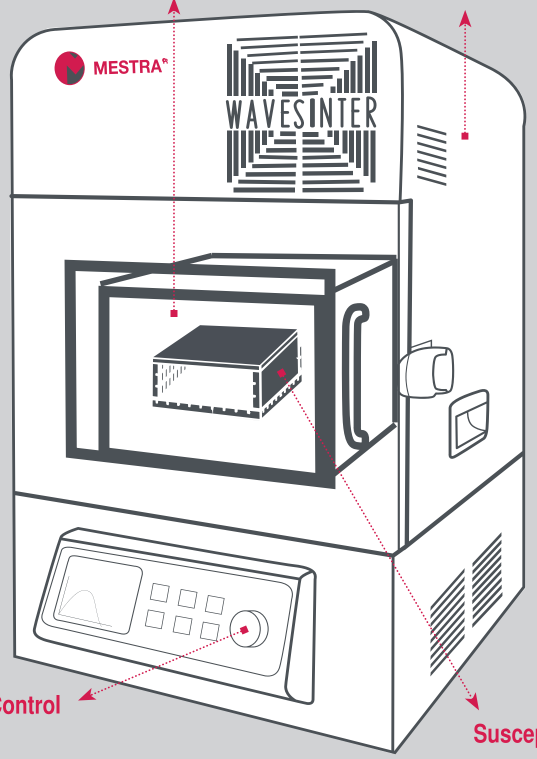
Aesthetics, precision and risk
of microcracks almost non-existent.

After the glazing operations, an ideal esthetic result is obtained, but with an excellent fit and sintering time reduced by half. There is no doubt that microwave technology represents the future of dental zirconia sintering.

*Photographs taken by José Carlos Gómez Parrilla,
Prosthetist from Lucerne-(Spain)*

Zirconium Microwave Furnace

Ref. 080114



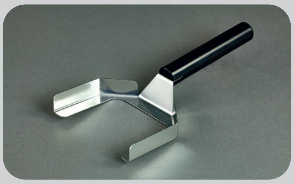
Specifications:

Height 547 cm • Width 440 cm • Depth 385 cm
Weight 31 kg • Voltage AC 230 V, 50Hz
Power 2000 W • Max. temp. 1550 ºC

Consumables and Accessories

080114-07
Crucibles

080114-09
Shot (100 g.)



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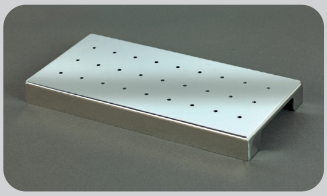
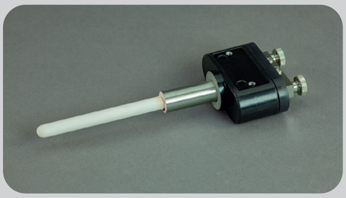
Useful crucible



080114-11
Crucible stand



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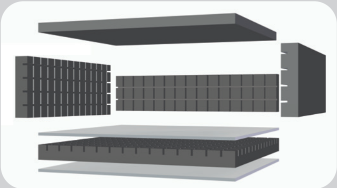
Temperature sensor



080114-13
Susceptors + plates set

At MESTRA we are specialized in the manufacture and distribution of dental machinery and appliances. We are a Spanish company based in Bizkaia. We currently export to clients in more than fifty countries on five continents and we have more than a thousand references in our catalogue.

We have maintained a line of constant expansion since our foundation in 1945, thanks to our best qualities: the high quality of our products that have earned the ISO 9001:2015 certification by TÜV Rheinland, a close and attentive relationship with our customers, and a constant technical innovation in the design of our products.

Our design philosophy is based on three fundamental pillars: the needs of our clients, the observation of the techniques used in dental laboratories and our more than 77 years of experience providing creative and contemporary solutions to the daily problems of professionals in the sector.

Do you want to take a virtual visit to our training and exhibition center?

Contact us and we'll show you!

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