GUIDE TO THE USE OF **MESA ALLOYS**

MESA®

PRODUCER OF SPECIAL ALLOYS SINCE 1975


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This guide, strongly supported by Mesa Italia and written by a team of industry specialists, aims to provide precise information on non-precious alloys and to deliver to professionals a proper protocol for dental laboratory procedures that involve their use.
Aligning with the state-of-the-art in the field, this manual simplifies processing procedures, analyzes the necessary treatments to maximize the potential of the chosen alloy, and summarizes key information regarding the advantages and challenges associated with its use.
The intended audience for this work includes both dental technicians who carry out traditional procedures and those who have embraced digital technologies.
Each section of this guide is accompanied by extensive visual documentation to facilitate the reader's immediate understanding of the steps.
Equally user-friendly is the "problem-solving" section, where each issue is addressed with the most thorough and precise solution, validated by our expert team of dental technicians.

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MESA®

PRODUCER OF SPECIAL ALLOYS SINCE 1975

MESA ITALIA S.R.L. is a distinguished Italian company with a long-standing family tradition, recognized as a leader in the production of Chromium-Cobalt metal alloys. Founded with the mission of combining tradition, innovation, and quality, the company has consistently set industry standards.

Quality and Innovation

Mesa Italia stands out for its use of top-tier raw materials, meticulously selected to ensure maximum reliability and performance in its products. By adopting cutting-edge production technologies and implementing stringent quality control processes, the company delivers alloys with technical properties that meet the highest market standards.

100% Factory-Made Production

Mesa Italia offers a complete range of products for both dental laboratories and clinics, ensuring that every step—from design to production—is fully factory-made and entirely **"Made in Italy."**

Global Leadership

Mesa Italia exports its alloys to over 60 countries, leveraging a well-established distribution network that spans all continents.
Its ability to adapt to the specific needs of each market has solidified its position as a global benchmark in the sector.

Reliability and Customer Service

What sets Mesa Italia apart is its strong commitment to customer satisfaction. Every stage, from production to shipping, is meticulously planned to deliver precise, timely, and personalized service. This dedication has enabled the company to build long-term relationships with partners and clients worldwide. With **50 years of experience** in the industry, Mesa Italia continues to grow with a vision focused on excellence, innovation, and quality.

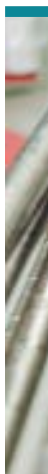
International Certifications and Authorizations

Mesa Italia's rigorous selection of raw materials ensures that every product is completely free from Beryllium and Cadmium and that all Cobalt-based alloys are Nickel-free.

Mesa Italia has obtained marketing authorization for its devices from entities in the 5 MDSAP member countries: Food & Drug Administration FDA, United States of America - Anvisa, Brazil - Ministry of Health Labor and Welfare MHLW, Japan - Health Care Ministry, Canada - Therapeutic Good Administration TGA, Australia.
For all dental alloys, the company has received CE certification according to Regulation (EU) 2017/745 (MDR) and ISO 13485 certification for Quality Management System.

Guaranteed performance

Using state-of-the-art alloy testing instruments, Mesa Italia is able to constantly monitor the quality and performance of its products, guaranteeing results that exceed the standards of Chrome-Cobalt alloys on the market.



Global export

Material processing

High quality raw materials

1

NON-PRECIOUS ALLOYS

1.1 COMPOSITION AND CHARACTERISTICS

MESA non-precious alloys are available in the form of milling discs and blocks for lost-wax casting.

These alloys have various types of application areas based on the mechanical and physical characteristics sought by the operator; they exhibit high mechanical properties thus offering excellent performance both at room temperature and at higher temperatures; they are also formulated so that they have excellent corrosion resistance.

Alloys are divided into categories according to the element that is present in a higher percentage such as, for example, Cobalt alloys combined with Chromium, the most widely used in the dental field, in which the main constituent is Cobalt.

In these alloys, good mechanical properties depend mainly on the fact that the elements added to Cobalt form a solid solution with it, thus modifying its crystal lattice.

In this type of alloys, the percentage of Cobalt varies from 40% to 70%, its presence giving great mechanical strength, hardness and rigidity; the second component in percentage is Chromium, which varies from 20% to 35% and gives the alloy corrosion resistance due to its ability to passivate and form a stable oxide that prevents the progression of oxidation.

The use of Nickel in the dental world is still widespread because this element has excellent mechanical properties and great corrosion resistance; its melting temperature (1455°C) is lower than that of Cobalt (1495°C).

Nickel, being less expensive than Cobalt helps to keep down the cost of the alloys in which it is present.

However, Nickel is a potent allergen that can trigger allergic reactions, especially in women (it is estimated that 9.7 percent of women may be allergic compared to 0.8 percent of men), which is why it is used less and less in Italy and Europe.

Other metals present in smaller quantities in MESA dental superalloys are:
1) **Carbon**: when used in low proportions, it increases hardness and strength. However, in high quantities, it can make the alloy harder but also more brittle.
2) **Molybdenum**: present in concentrations between 3% and 6%, it enhances mechanical strength and improves resistance to pitting corrosion.
3) **Tungsten**: increases mechanical strength.
4) **Silicon** and **Manganese**: improve fluidity, enhancing the castability of the alloys.
5) **Niobium**: refines the grain structure.

Mesa Laboratory Spectrometer

1.2 PHYSICAL AND MECHANICAL PROPERTIES

Density

The density of an element is obtained by dividing the mass of the body by its volume and is typically expressed in g/cm^3.
This value is particularly important in the case of extensive prosthetic rehabilitations since a material with higher density results in a heavier prosthesis.

Thermal Conductivity

The thermal conductivity value is crucial in prosthetic rehabilitations on natural teeth, especially if they are still vital.
The thermal conductivity of metals is significantly higher than that of natural teeth; therefore, metal provides less insulation against temperature fluctuations, which may cause discomfort to the patient.

Tensile/Flexural Strength

Tensile strength refers to the material's ability to withstand tensile loads and is expressed in N/mm^2.
Metals that exhibit similar responses under compressive and tensile stresses are evaluated through tensile strength testing.
For materials with more variable behavior, the ability to resist both tensile and compressive stresses simultaneously is assessed through flexural strength testing.
In the dental field, it is essential to consider the tensile and flexural strength of the material to be used.
For fixed prostheses with long cantilevers, materials with high flexural strength should be preferred to prevent fracture of the veneering material.
Conversely, for removable skeletal prostheses, materials with lower flexural strength may be chosen.

Tensile Test in the Mesa Laboratory

Elastic Modulus

The elastic modulus, expressed in GPa (10^3 N/mm^2), numerically represents the stiffness of a material.

If we compare two identical prostheses, differing only in material, the one made of a material with a lower elastic modulus will deform more under the same load compared to a prosthesis made of a material with a higher elastic modulus.

Thanks to the high elastic modulus of base metal alloys, it is possible to create thinner structures, which offers significant advantages in managing the thickness of aesthetic materials.

Resilience

Resilience is the ability of a material to absorb impacts without breaking or deforming.

Metallic materials generally have sufficient resilience for oral applications, whereas other materials—such as ceramics—may fracture due to mechanical impacts or thermal shocks.

Durezza

Hardness

Hardness measures a material's ability to resist penetration by another object. Hardness tests are conducted by measuring the indentation depth of a penetrating tip (often diamond) pressed onto a flat surface of the material under a known force.
In the dental technology field, the standard testing method for measuring hardness is the Vickers hardness test.

Mesa Laboratory Hardness Tester

Wear

Wear is a phenomenon that occurs when two materials move relative to each other, generating friction and leading to a reduction in size of the contacting surfaces.
For dental alloys, wear resistance primarily depends on: material hardness, grain size, surface roughness of the contact areas, presence of interposing fluids and other factors affecting deterioration.
Wear typically reshapes contacting surfaces and often damages them.
In the dental field, wear influences the maintenance of vertical dimension and occlusal surface integrity.
For this reason, it is crucial to ensure that occlusal surfaces are as polished as possible to minimize wear effects.

1.3 MANAGEMENT AND MODELING OF METAL STRUCTURES

In dentistry, the construction of a fixed prosthesis (crowns and bridges) requires a supporting substructure (called a framework), which can be made of metal and must have a precise anatomical design.
During the modeling phase of the metal substructure, starting from the final shape of the dental elements, a portion of the material is removed to ensure the necessary thickness for proper aesthetics and function with the selected material.
For both metal-ceramic and metal-composite restorations, the substructure must be under-dimensioned to provide the appropriate thickness for the aesthetic material.
The reduction values, whether in analog or digital workflows, can range from 1.8 mm to 0.5 mm, depending on the anatomical area of the element and the required dentin and enamel thickness. Additionally, it is essential to consider the difference in thickness between ceramic opaque layers and composite opaque layers, as the ceramic opaque layer is thinner than the composite one.

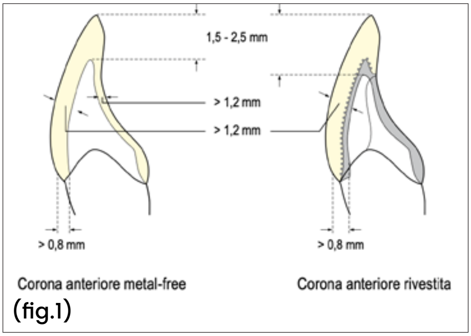
Key Steps to Follow:

1. Properly model the anatomical shape of the tooth (Fig.1).
2. The next step is to reduce the design to create an appropriate framework (Fig.2).
3. If performing a mathematical reduction using the CAD function, there is a risk of losing structural support in the incisal area, which may increase the risk of ceramic chipping (Fig.3a/3b).
4. Always verify the minimum thickness of the metal substructure in both analog and digital workflows (Fig.4).

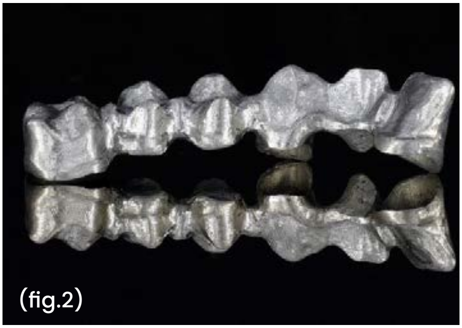
Additionally, the modeling process must be carried out considering the manufacturing method that will be used.

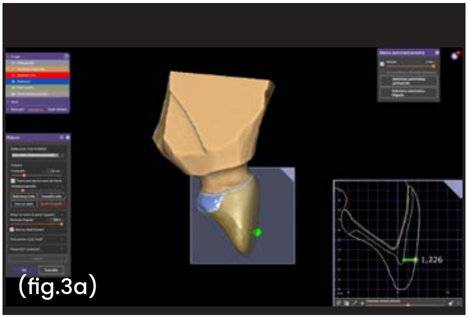
In the case of milling, various factors, such as the diameter of the milling cutters and the angles that can be reached by the milling machine, can condition the congruencies between the CAD design and the CAM production.

When designing frameworks, the type of abutment (natural or implant), the type of prosthesis attachment (screw-retained, cemented, or cone-retained), and the position of the elements (anterior or posterior) will need to be considered.

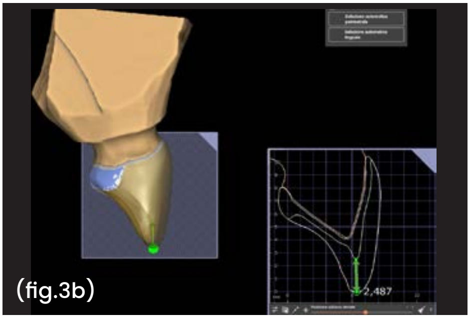


(fig.1)

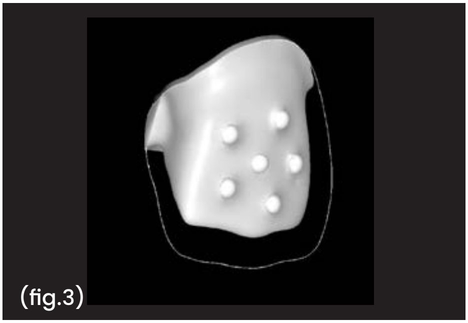

(fig.2)



(fig.3a)



(fig.3b)


(fig.3)

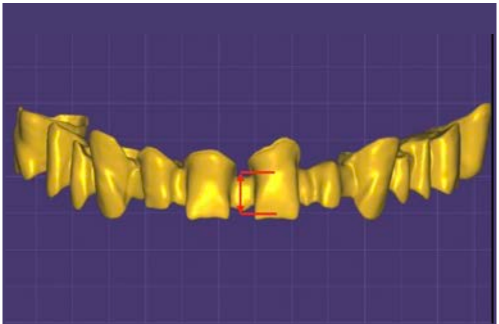

(fig.4)

When working with dental implants, it is essential to carefully evaluate:

- the reliability and stability provided by the shape and diameter of the implant connection.
- the stability of the tightening screw, which can have different performance levels depending on its design.
- the length of the transmucosal path.
- the diameter and possible angulation of the screw channel.

It is important to remember that, depending on the position of the elements to be restored, it is crucial to assess the directions of the loads that the structure will be subjected to. In posterior regions, these forces are mainly vertical.
In anterior areas, the forces are predominantly transverse.
Therefore, interdental connectors should be aligned with the direction of the forces they will experience to provide maximum support for the entire structure (Fig. 5).
The use of a distal cantilever is always risky and should be limited to cases of absolute necessity, as it requires compensation for the absence of a distal support element by designing a connector with a larger diameter.
Factors influencing the minimum thickness of abutment elements and connector size the minimum required thickness for abutment elements and the minimum connector size, as well as the choice of material, depend on:

- the length of the span.
- the ratio between the number of abutments and the number of prosthetic elements (Fig. 6-7).
- the distance between the abutments.
- the presence or absence of a lingual bar, which should be considered an additional support for the aesthetic veneering.



(fig.5)

(fig.6)

(fig.7)

2

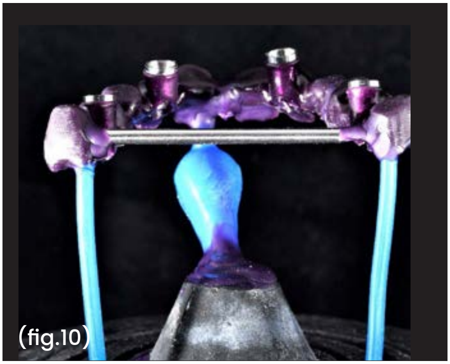
CASTING

2.1 CASTING PREPARATION

Once the structure to be cast has been produced according to the chosen material and the manufacturer's guidelines, a decision is made on whether to use a free expansion or controlled expansion (metal ring) coating system, with either a traditional or fast preheating technique.
The most commonly used coating material for MESA Cr-Co superalloys is a phosphate-bonded coating, primarily composed of quartz, which provides hardness and cristobalite, a ceramic material that contributes to smoother casting surfaces.
The expansion of these coating is regulated by the percentage of silicic acid (liquid) in proportion to demineralized water.
(Fig. 8-9-10-11-12-13)


(fig.8)


(fig.9)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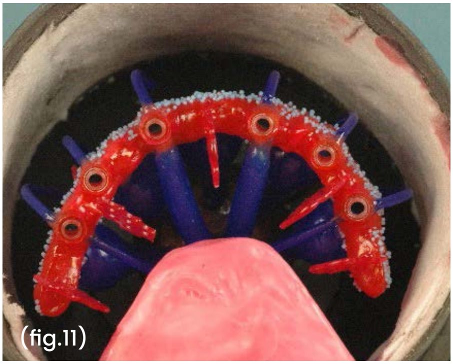
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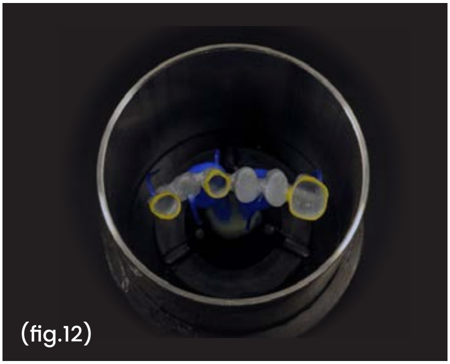
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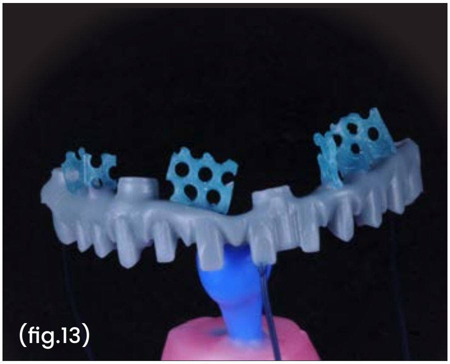

(fig.13)

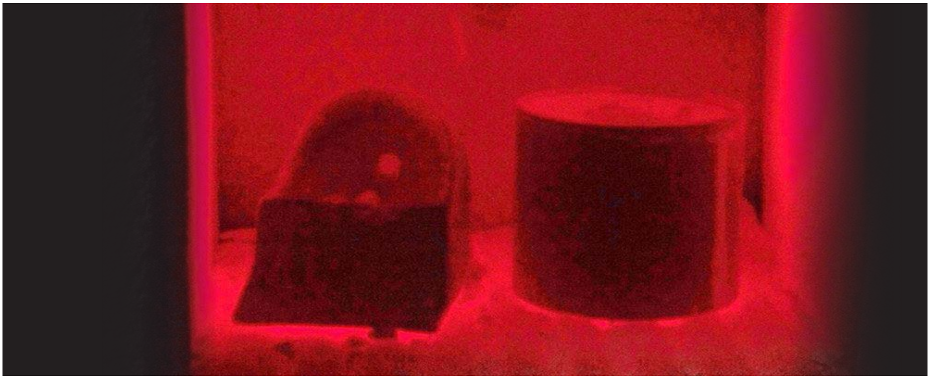
2.2 CASTING

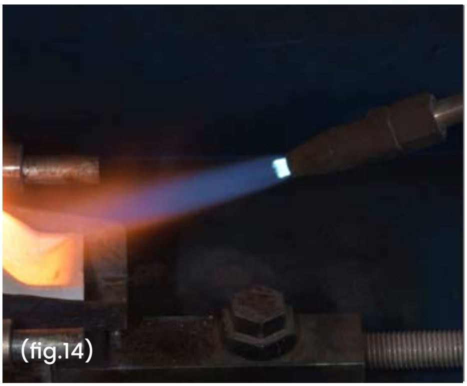
This is the oldest metalworking technique and, until recently, the only one available. Despite its age, it remains a highly effective and precise system. A few years ago, gold alloys were the primary choice for most prosthetic reconstructions. However, due to high costs and continuous improvements in non-precious alloys, the market has shifted towards the latter. With the lost-wax casting technique, it is possible to achieve highly precise crowns at the marginal fit, provided that the wax model's finishing margin is carefully checked—preferably under a microscope.

Types of Casting Techniques:

- Flame casting (blowtorch) (Fig. 14)
- Induction centrifugal casting (Fig. 15)
- Pressure casting (Fig. 16)

For blowtorch casting, it is important to use a mixture of propane (0.7 Bar) and oxygen (2 Bar) in a ceramic crucible.
Graphite crucibles must not be used, as they may release carbon, altering the properties of the alloy (Fig. 17). Additionally, they can release gases during ceramic firing, leading to bubbles in the ceramic layer or poor adhesion, which may ultimately affect the final color of the restoration.
Initially, the alloy pellets agglomerate into a single mass that is not yet fully liquefied. The casting process should begin as soon as the surface crust breaks open.
During casting, oxide residues may separate from the molten alloy and remain as deposits inside the crucible, since their density is lower than that of the alloy.
For induction casting, it is recommended to set the machine's final temperature approximately 100°C above the alloy's melting temperature to ensure proper flow and casting quality.
Pressure casting is the most advanced of the three techniques, as it allows full temperature control, ensuring optimal casting conditions.

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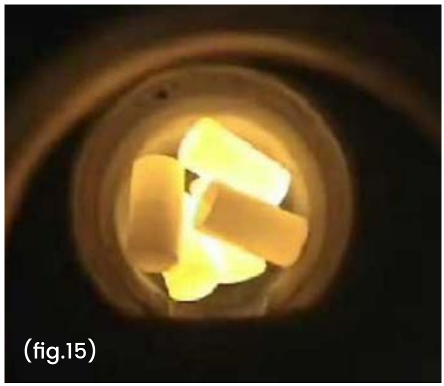
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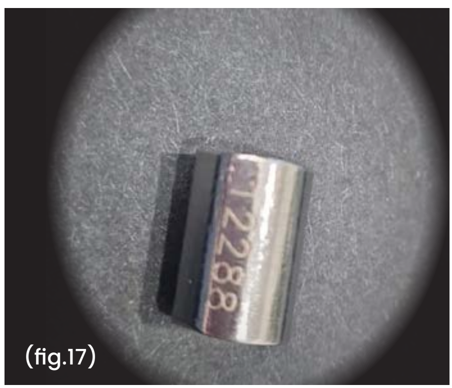
(fig.16)


(fig.17)

2.3 MESA ALLOYS FOR CASTING

MESA ALLOYS FOR CERAMICS

All Mesa ceramic alloys share the following characteristics:

- **produced in compliance with ISO 9693 and ISO 22674** standards;
- **strictly free from toxic elements**: Beryllium, Cadmium, Lead, Indium and Gallium;
- **universally applicable**, suitable for bridges and crowns, double crowns, superstructures on implants, bonding techniques, secondary parts in combined prostheses;
- **perfectly ceramic-compatible**, thanks to their thermal expansion coefficient ranging between (25 ÷ 500 °C) 14.1 x $10^{-6}K^{-1}$ and (25 ÷ 600 °C) 14.6 x 10^{-6} K^{-1}
- **high level of purity**;
- **excellent resistance to corrosion and heat**.

The most popular Mesa ceramic alloys on the market are:

- **MAGNUM LUCENS**
- **MAGNUM SPLENDIDUM**
- **MAGNUM CERAMIC Co**

The main chemical and mechanical properties of Mesa casting alloys for ceramics are as follows:

MAGNUM LUCENS
TYPE 4

COMPOSITION

Cobalt (Co)	63%
Chromium (Cr)	28%
Niobium (Nb)	4%
Tungsten (W)	3%
Others	Mn, Fe

PHYSICAL AND MECHANICAL PROPERTIES

Solidus-liquidus temperature	1253÷ 1304 °C
Coefficient of thermal expansion	(25 ÷ 500 °C) 14,1 x 10^{-6} K^{-1} (25 ÷ 600 °C) 14,5 x 10^{-6} K^{-1}
Melting point	1360 °C
Density	8,4 g/cmc
Vickers hardness	324 HV10
Percentage elongation at fracture	3 %
Yield load strength (Rp0.2)	475 MPa
Modulus of elasticity	194 GPa
Release of ions in 7 days	0.8 µg/cm^2
Maximum firing temperature	980 °C
Colour	White

MAGNUM SPLENDIDUM

TYPE 3

COMPOSITION

Cobalt (Co)	61%
Chromium (Cr)	28%
Silicon (Si)	1.5%
Tungsten (W)	8,5%
Others	Mn, Fe

PHYSICAL AND MECHANICAL PROPERTIES

Solidus-liquidus temperature	1308 ÷ 1384 °C
Coefficient of thermal expansion	(25 ÷ 500 °C) 14,2 x 10^{-6} K^{-1} (25 ÷ 600 °C) 14,4 x 10^{-6} K^{-1}
Melting point	1440 °C
Density	8,5 g/cmc
Vickers hardness	273 HV10
Percentage elongation at fracture	16 %
Yield load strength (Rp0.2)	360 MPa
Modulus of elasticity	183 GPa
Release of ions in 7 days	1.75 µg/cm^2
Maximum firing temperature	980 °C
Colour	White

MAGNUM CERAMIC CO

TYPE 5

COMPOSITION

Cobalt (Co)	64%
Chromium (Cr)	21%
Molybdenum (Mo)	6%
Tungsten (W)	6%
Others Si,	Mn, Fe

PHYSICAL AND MECHANICAL PROPERTIES

Solidus-liquidus temperature	1309 ÷ 1417 °C
Coefficient of thermal expansion	(25 ÷ 500 °C) 14,1 x 10^{-6} K^{-1} (25 ÷ 600 °C) 14,6 x 10^{-6} K^{-1}
Melting point	1470 °C
Density	8,8 g/cmc
Vickers hardness	286 HV10
Percentage elongation at fracture	10 %
Yield load strength (Rp0.2)	570 MPa
Modulus of elasticity	194 GPa
Release of ions in 7 days	0.6 µg/cm^2
Maximum firing temperature	935 °C
Colour	White

The table below highlights the key strengths of each alloy:

- **MAGNUM LUCENS:** during the casting process, its properties make it a highly fluid alloy with a very favorable oxidation behavior. Thanks to its high stability, it is recommended for the production of large prosthetic structures such as full-arch restorations, bars, and Toronto bridges.
- **MAGNUM SPLENDIDUM:** its key strength is its excellent workability, thanks to a Vickers hardness of 273 HV10.
- **MAGNUM CERAMIC Co:** a historical company alloy, offering exceptional reliability during the ceramic firing process.

ALLOYS FOR REMOVABLE PARTIAL DENTURES

The alloys for removable partial dentures (RPDs) produced by Mesa are characterized by:

- **high tensile strength** and **excellent workability**, allowing for smooth and compact surfaces with minimal oxide formation.
- **outstanding mechanical properties**, enabling even the most demanding technicians to create unique restorations with minimal thickness.

The most well-known Mesa RPD alloys are:

- **MAGNUM VIP-A**
- **MAGNUM HBA**

MAGNUM VIP-A
TYPE 5

COMPOSITION

Cobalt (Co)	64%
Chromium (Cr)	29%
Molybdenum (Mo)	6%
Others	C, Si, Mn, Fe

PHYSICAL AND MECHANICAL PROPERTIES

Solidus-liquidus temperature	1350 ÷ 1406 °C
Melting point	1460 °C
Density	8,4 g/cmc
Vickers hardness	386 HV10
Percentage elongation at fracture	6 %
Yield load strength (Rp0.2)	580 MPa
Modulus of elasticity	211 GPa
Release of ions in 7 days	1.1 μg/cm^2
Colour	White

MAGNUM HBA
TYPE 5

COMPOSITION

Cobalto (Co)	62%
Chromium (Cr)	31%
Molybdenum (Mo)	5%
Others	C, Si, Mn, Fe

PHYSICAL AND MECHANICAL PROPERTIES

Solidus-liquidus temperature	1340 ÷ 1400 °C
Melting point	1450 °C
Density	8,3 g/cmc
Vickers hardness	389 HV10
Percentage elongation at fracture	6 %
Yield load strength (Rp0.2)	610 MPa
Modulus of elasticity	200 GPa
Release of ions in 7 days	0.49 μg/cm^2
Maximum firing temperature	980 °C
Colour	White

2.4 OVERCASTING TECHNIQUE

The overcasting technique allows for the fabrication of screw-retained crowns on implants (Fig. 18-19-20).

Initially, implant connections were created using fully burn-out plastic components, which, however, resulted in connections with reduced precision (Fig. 21).

This practice is not recommended when castable implant components are available.

The most common castable abutments typically consist of a metal base combined with a burn-out plastic section (Fig. 22).

The diameter of the screw access hole is determined by the expansion of the investment material, which may require internal reaming.

The presence of small bubbles inside the screw channel, caused by the investment material flowing into a narrow space, which must be manually removed. Residual plastic material may not be completely eliminated at the metal-to-metal interface; since this interconnection area is very small, even tiny impurities can compromise the precision of the restoration.

By using **fully metallic Mesa overcastable components**, the above-mentioned issues are eliminated, resulting in optimal and highly reproducible outcomes (Fig. 23).

Mesa has developed **overcastable components in Magnum Splendidum** alloy, designed for use **with the recommended overcasting alloy Magnum Lucens.**

Thanks to its physical and chemical properties, Magnum Lucens ensures a true metallurgical bond between the two components without distorting the connection (Fig. 24).

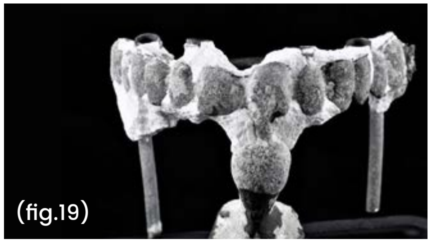
In digital design, using **Mesa libraries**, the selected structure can be designed with the pre-configured housing for the corresponding overcastable component.

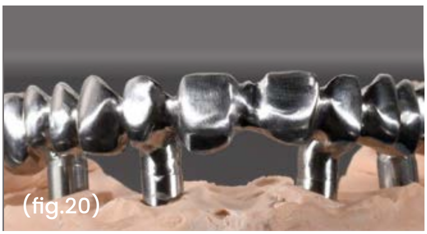
The design can then be produced using either milled burn-out materials or resins for 3D printers (Fig. 25).

***Precautions for Proper Overcasting*:**

- Extend the preheating time of the coating cylinder by at least 50% compared to the standard.
- Do not exceed 1410ºC during casting.
- The thermal expansion coefficient (CET) of the ceramic should be between 5% and 10% lower than that of the metal.


(fig.18)


(fig.19)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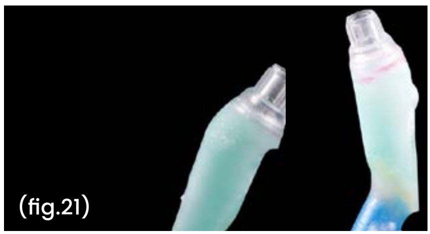

(fig.21)


(fig.22)


(fig.23)

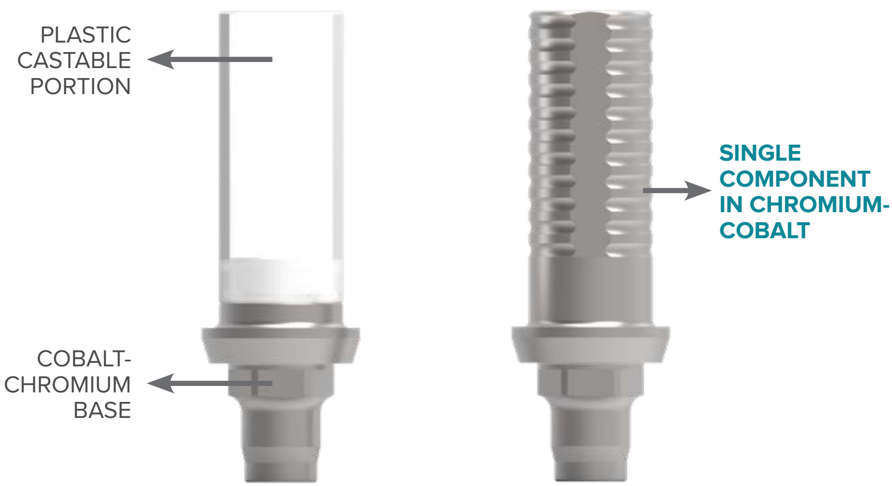

(fig.24)


(fig.25)

2.5 MESA OVERCASTABLE COMPONENTS IN Cr-Co

Mesa Overcastable Components, designed for optimal precision in implant engagement, offer distinct advantages due to the absence of the traditional burn-out plastic sprue.
The Mesa overcastable abutments are manufactured using the Magnum Splendidum Cobalt-Chromium alloy, which provides excellent properties, making it ideal for overcasting.

Advantages of Mesa Overcastable Components:
- replace the traditional plastic burn-out abutment system;
- compatible with the major implant systems;
- available in both rotating and non-rotating versions:
- allow for the fabrication of both single-unit crowns and screw-retained multi-unit structures.



CALCINABLE OVERCASTABLE

OVERCASTABLE MESA

OVERCASTABLE COMPONENTS IN Cr-Co

Mesa Overcastable Components are characterized by:

Indeformable Screw Channel:

In Mesa overcastable abutments, the internal part remains unaltered by casting, ensuring that screws fit perfectly within the hole.

Impurity-Free Casting in the Screw Channel:

No risk of combustion residues from burned-out plastic, leading to improved surface quality.

Optimal Welding Between the Two Metals:

The perfect bonding between the Magnum Splendidum and Magnum Lucens alloys during casting ensures optimal adhesion and guarantees maximum precision in welding, preventing the separation of the two metals. The oxidation of both alloys remains non-aggressive, clear, and aesthetically pleasant.

3

MILLING OF METAL ALLOYS FOR DENTISTRY


MESA
PRODUCER OF SPECIAL ALLOYS SINCE 1975

3.1 GENERAL GUIDELINES FOR MILLING STRATEGY

The milling process for dental metal alloys must adhere to strict mathematical and geometrical rules.

The four fundamental tool shapes used in milling are toric cutter, spherical cutter, cylindrical cutter, and drilling bit (Fig. 26).

Each of these tools has specific applications:

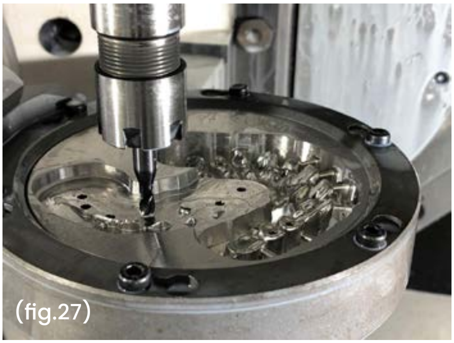
- toric cutters excel in roughing operations and bulk material removal; (Fig. 27)
- spherical cutters are primarily used for finishing operations, though they may also be used in roughing when necessary; (Fig. 28)
- cylindrical cutters are used almost exclusively for creating perpendicular surfaces, ensuring sharp angles between planes and walls. This is particularly important in implant connection geometries, where precise adaptation of prosthetic components is essential; (Fig. 29)
- drilling bits are highly efficient and optimized for hole creation, speeding up the production of screw channels and threaded holes. (Fig. 30)

In addition to these four primary shapes, there are less frequently used tools for specialized applications.

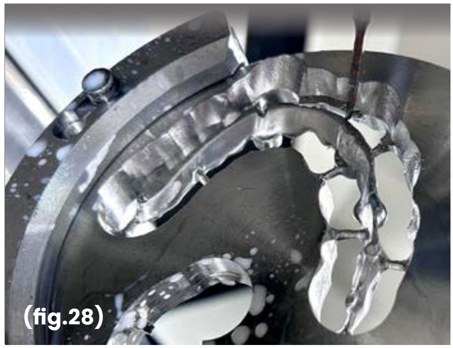
These include thread milling cutters, T-slot cutters, lollipop cutters, spot drills and chamfering tools, etc. (Fig. 31)

These specialized tools address specific needs that standard shapes cannot fulfill.

For example, thread milling cutters are designed for precise thread creation, essential for mechanical component fitting. T-slot and lollipop cutters are used for undercutting operations, where material must be removed from hard-to-reach areas. The rotational speed and feed rate of milling cutters follow a mathematical formula that considers multiple factors.



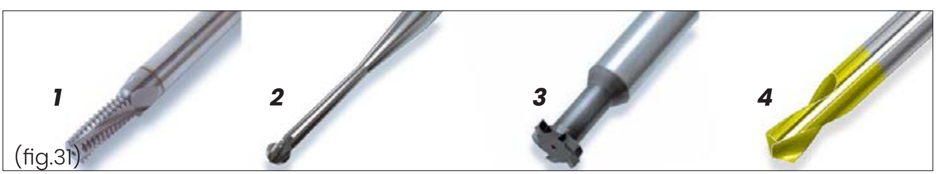
A toric milling cutter in the process of roughing the workpiece, slowly appearing to "emerge" from the raw material.



A spherical milling cutter engaged in a finishing or copy milling operation, where the cutter moves along the surface of the workpiece, grazing it tangentially.

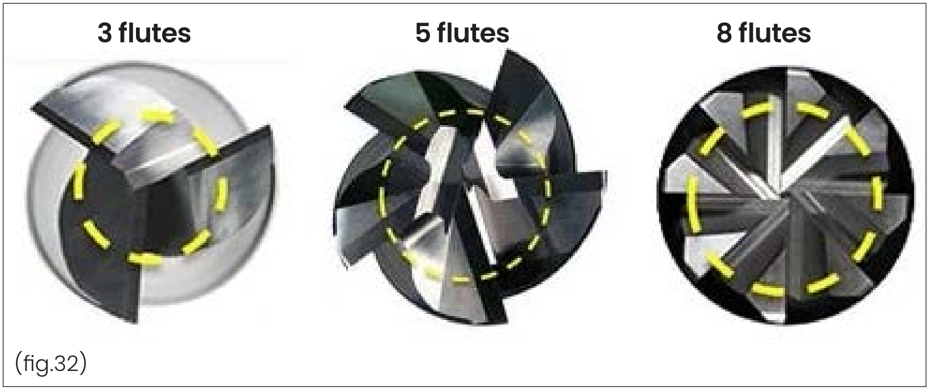
A cylindrical milling cutter.

A drill bit used in an intermittent drilling operation. Note the precisely calibrated hole created in the raw material.



1 *Thread milling cutter -* ***2*** *Lollipop cutter -* ***3*** *T-slot cutter for angled channels -* ***4*** *Centering drill*

The most important factors are: material of the milling cutter, material being milled, depth of cut (engagement of the tool in the material), number of cutting edges on the tool (Fig. 32), surface treatment/coating of the tool, which can significantly impact the performance. (Fig. 33)
Proper speed and feed rate adjustments are crucial to optimize tool lifespan and improve the surface quality of the milled material and prevent premature wear or breakage. The depth of cut determines the amount of material removed per pass, affecting both stability and efficiency.
The number of cutting edges influences the cutting frequency and distribution of workload across the tool. Surface treatments, such as titanium nitride coatings, can enhance wear resistance and reduce friction, allowing for higher cutting speeds.
A smaller cutter diameter requires a higher spindle speed. This is why CNC milling machines for dental applications are designed with low torque spindles but extremely high rotational speeds, sometimes exceeding 60,000 RPM.
A smaller cutter diameter demands higher rotational speeds to maintain the correct cutting speed, which is essential for achieving a smooth finish and preventing excessive tool wear. Dental CNC milling machines are specifically designed with high-speed spindles to accommodate these precision and efficiency requirements.
The chemical and physical properties of dental metal alloys (mainly titanium alloys and cobalt-chromium alloys) subject tools to both thermal stress and abrasive wear. This modifies the properties of the native alloy. Choosing high-quality milling tools is essential in fixed prosthetic applications, whether for natural teeth or implants (Fig. 34).

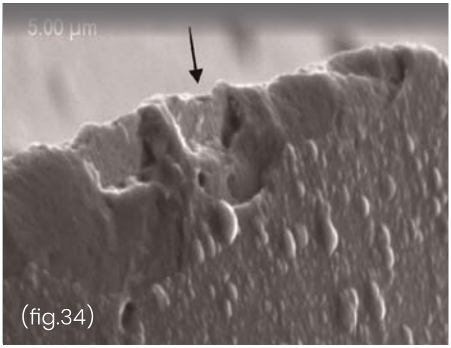


(fig.32)

From left to right, a front view of milling cutters with 3, 5, or 8 flutes. There are milling cutters with as few as a single flute and increasing from there. Note that as the number of flutes increases, the diameter of the cutter's central core also increases, while the chip space of each flute decreases.

(fig.33)

Milling cutters with different surface treatments often have a very different appearance and perform very differently depending on the material they are designed to machine.



(fig.34)

Microscopic photo of chipping and wear marks on the cutting edge of a milling cutter.

3.2 **MINIMUM THICKNESS, FRAGILE PARTS**

Although a milling machine has no difficulty meeting very tight dimensional tolerances, the metallic materials involved in dental CAD/CAM have notable elasticity and ductility, which results in deformability.

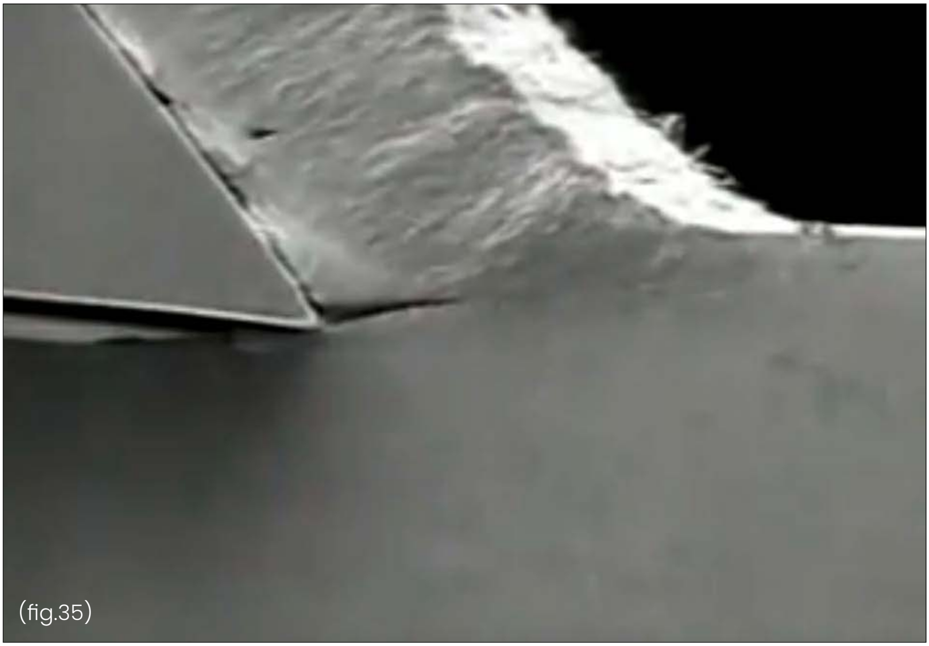
Modern milling machines are designed to work with high precision; however, the intrinsic properties of the materials used in the dental field, such as titanium alloys and chrome-cobalt, present unique challenges.

Elasticity and ductility, while advantageous for strength and workability, lead to a greater tendency to deform under stress, making tolerance management a complex task. (fig.35)

Areas of the milling file that are excessively long and thin (approximately above 5mm of protrusion and below 0.3mm of thickness) can react to the cutting tool by "dodging" the mill, thus bending rather than being cut. Thin edges, excessively protruding margin lines, or inadequately supported screw channels can then be pushed and moved by the mill involved in finishing the work.

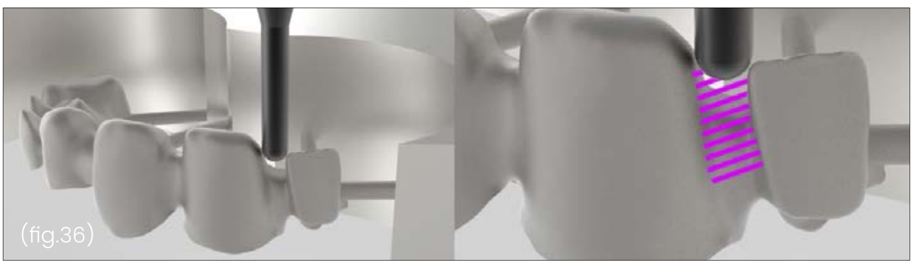
This phenomenon is more pronounced when using old and worn mills, whose cutting edges are no longer sharp and, like a dull knife, do not penetrate the material to be removed but rather strike it, "hammering" it dozens of times per second, generating heat and further deformations.

This not only worsens the quality of the finish but can also increase the wear of the tool itself and the milling machine spindle, reducing the operational life of the equipment.



Freeze-frame of a cutting operation on an alloy similar to medical-grade Cobalt-Chrome-Molybdenum. Note how the cutting process actually consists of a series of tears and deformations occurring at high speed.

It is therefore a good rule to avoid modeling files that have areas thinner than 0.3mm or particularly protruding edges. If the anatomy of the case to be prosthetized makes the modeling of very protruding edges indispensable, then it is necessary to compensate for their protrusion and minimize their fragility by increasing the material thickness at the margin lines. CAD/CAM design must take into account the physical limitations of materials and equipment. Another factor to consider during milling is the maximum resolution achievable during production. This data is not only related to the technical characteristics of the milling machine, which nowadays can easily achieve repeatable positioning to a hundredth of a millimeter, but it also depends, above all, on the choice of tools involved in the milling phases. (fig.36) The anatomy of pockets, narrow areas, and very reduced interdental spaces can only be reproduced if at least one milling cutter can access these areas to sculpt them. This is therefore dependent on the use of small cutters capable of gaining access to areas less than 1mm wide, long enough to reach deep areas far from the surface of the milled disc, and the relationship between these two characteristics of the tool. The flexibility of a milling cutter increases with the cube of its length and is inversely proportional to the fourth power of its diameter; therefore, the involvement of thin, needle-like long cutters (fig.37), while theoretically allowing for the sculpting of extremely minute and refined details on the modeled file surface, exposes the risk of frequent tool breakage, leading to an extension of the production time of the semi-finished product.


(fig.36)

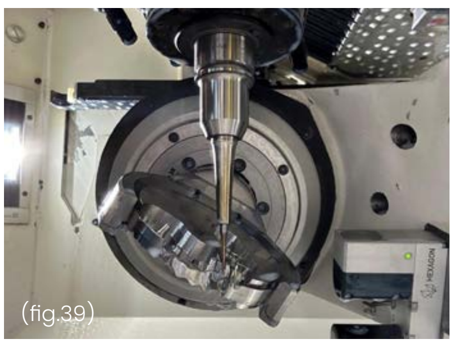
If the working part of the milling cutter has too large a diameter, it will be impossible for the cutter to access the entire surface of the file to be reproduced. As a result, certain areas of the file may not be reproduced at all unless 5-axis toolpaths or smaller cutters are used. In this example, the inaccessible area for a hypothetical spherical cutter with a Ø2mm diameter is marked.


(fig.37)

In dental prosthetics, it is very common to use very long and thin milling cutters to properly mill the cavities that accommodate natural abutments, reach deep details, and so on.

Very small milling cutters require extremely slow and minimal feed rates and material removal, which can easily turn a file that could be milled in 3 hours into one that takes 10 hours or more.
Additionally, it is important to consider the capability or difficulty of the CNC milling machine in reaching the areas of the file to be reproduced, which may be “hidden” by undercuts, even when using 5-axis positioned or interpolated machining. (fig.38)
Most milling machines in the dental sector allow, through the rotation of the A, B, or C axes, the tilting of the disc, enabling the milling tool to approach the file to be produced even at angles of 20 or 30 degrees relative to a hypothetical vertical vector. (fig.39)


(fig.38)



(fig.39)

Examples of machining with a heat-shrink spindle

3.3 **PARAMETERS FOR MILLING MESA ALLOYS**

The parameters to be set for milling include the spindle speed of the cutter, measured in revolutions per minute (rpm) and indicated as S, and the feed rate, measured in mm/min and indicated as F.
Cutter manufacturers do not provide these parameters but instead specify other characteristics of their cutters, so it is necessary to calculate the required parameters using formulas.
Typically, tool manufacturers specify the cutting speed (usually called Vc and measured in m/min) and the feed per tooth (usually called fz and measured in mm/tooth) for each cutter/material combination.
Vc represents the speed at which the cutter's cutting edge meets the material.
Fz indicates how many millimeters the cutter advances per revolution, divided by the number of teeth.
To calculate the spindle speed of a cutter with a diameter d, we can use the formula:

$$S(rpm) = \frac{Vc\left(\frac{m}{min}\right) * 1000}{3.14 * d\ (mm)}$$

To calculate the feed rate of a milling cutter with a number of teeth equal to Z, we can use the formula:

$$F\left(\frac{mm}{min}\right) = S(rpm) * Z * fz\left(\frac{mm}{dente}\right)$$

In the following table, you will find the recommended cutting speeds for each MESA milling alloy when using coated carbide cutters.
However, we still recommend using the parameters provided by the cutter manufacturer whenever available.

Alloy	Vc (m/min)
MAGNUM HYPERONE	55 -70
MAGNUM SOLARE	55 - 70
MAGNUM SPLENDIDUM	45 - 55

In milling, we always recommend abundant cooling with a lubricant-refrigerant consisting of a water-oil emulsion, with an oil content of more than 10% by volume. An oil percentage lower than this significantly reduces the lifespan of the cutters.
If the high oil percentage causes foaming issues, anti-foaming agents can be used.
Additionally, we recommend selecting the shortest cutter among those compatible with the task. A shorter cutter is more rigid, which makes it less affected by loss of sharpness and therefore extends its lifespan.

3.4 MESA CAD/CAM DISCS

Mesa produces discs for CAD/CAM machining in Cobalt-Chrome and Titanium, available in the following heights:

DIAMETER
98,5 mm

HEIGHT
8 mm
10 mm
12 mm
13,5 mm
14 mm
15 mm
16 mm
18 mm
20 mm
22 mm
24,5 mm
25 mm

Mesa Cobalt-Chrome discs, present on the market for almost 20 years, are produced with the **Magnum Splendidum and Magnum Solare alloys**.
They are characterized by easy milling, which results in greater consistency in the precision of the prototyped piece.
The physical, mechanical, and chemical characteristics of these alloys are illustrated in the tables below:

MAGNUM SPLENDIDUM
TYPE 3

COMPOSITION	
Cobalt (Co)	61%
Chromium (Cr)	28%
Silicon (Si)	1.5%
Tungsten (W)	8,5%
Others	Mn, Fe

PHYSICAL AND MECHANICAL PROPERTIES	
Solidus-liquidus temperature	1308 ÷ 1384 °C
Coefficient of thermal expansion	(25 ÷ 500 °C) 14,2 x 10^{-6} K^{-1} (25 ÷ 600 °C) 14,4 x 10^{-6} K^{-1}
Melting point	1440 °C
Density	8,5 g/cmc
Vickers hardness	273 HV10
Percentage elongation at fracture	16 %
Yield load strength (Rp0.2)	360 MPa
Modulus of elasticity	183 GPa
Release of ions in 7 days	1.75 µg/cm^2
Maximum firing temperature	980 °C
Colour	White

MAGNUM SOLARE
TYPE 4

COMPOSITION

Cobalt (Co)	66%
Chromium (Cr)	27%
Molybdenum (Mo)	6%
Others	Si, Mn

PHYSICAL AND MECHANICAL PROPERTIES

Solidus-liquidus temperature	1307 ÷ 1417 °C
Coefficient of thermal expansion	(25 ÷ 500 °C) 14,3 x 10^{-6} K^{-1} (25 ÷ 600 °C) 14,5 x 10^{-6} K^{-1}
Melting point	1470 °C
Density	8,4 g/cmc
Vickers hardness	255 HV10
Percentage elongation at fracture	11 %
Yield load strength (Rp0.2)	395 MPa
Modulus of elasticity	233 GPa
Maximum firing temperature	980 °C
Colour	White

Mesa Titanium discs are produced with the **Magnum Hyperone alloy** in Grade 23 titanium, whose physical, mechanical, and chemical characteristics are illustrated below.

MAGNUM HYPERONE
TYPE 4

COMPOSITION

Titanium (Ti)	90%
Aluminium (Al)	6%
Vanadium (V)	4%
Others	Fe

PHYSICAL AND MECHANICAL PROPERTIES

Solidus-liquidus temperature	1605 ÷ 1660 °C
Melting point	1710 °C
Density	4,426 g/cmc
Vickers hardness	312 HV10
Percentage elongation at fracture	14 %
Yield load strength (Rp0.2)	880 MPa
Modulus of elasticity	114 GPa
Colour	White

Titanium discs are characterized by being:

- Highly biocompatible
- Corrosion-resistant
- Lightweight
- Easy to mill
- Very tough

3.5 PROTOCOL FOR THE PREPARATION AND USE OF MAGNUM SOLARE

1st STAGE: THERMAL RELAXATION

Treatment Parameters

• 1030°C for 7 minutes (from 1 to 3 elements)

• 1030°C for 12 minutes (more than 3 elements)

What is thermal relaxation and what is its purpose?

The heat treatment of Cobalt-Chrome is aimed at relaxation, an essential process for eliminating residual tensile and compressive forces within the metal structure after processing. The treatment is carried out by bringing the workpieces to a temperature at which the material exhibits a very low yield strength.

At this temperature, residual stresses are reduced due to micro-viscous flow of the material until they become negligible. This process is essential to ensure the following benefits:

• **Maintenance of geometric stability** during subsequent processing

• In**creased fatigue resistance of the material**, reducing the risk of crack propagation

Considerations on welding**:** In cases where heterogeneous material welding is performed on the same workpiece (e.g., Nickel-Chrome welding), it is important to consider the different coefficients of thermal expansion. Different thermal expansions can lead to local distortions, localized residual stresses, geometric deformations, and, in the worst cases, the onset of cracks.

2nd STAGE: OXIDATION

Treatment Parameters

• 980°C for 2 minutes

What is oxidation and what is its purpose?

Oxidation is a natural phenomenon that occurs when a metal combines with oxygen, forming a surface oxide.

This process is essential in the dental field because:

• **It improves the adhesion** between the ceramic and the metal alloy

• **It optimizes the application** phase of the wash opaque and the opaque layer

3rd STAGE: CERAMIC LAYERING

Dental ceramics are divided into two main categories:

1. **Feldspathic ceramics** (feldspar-based mixtures)
2. **Synthetic ceramics**

Synthetic ceramics do not present particular issues during layering, whereas feldspathic ceramics require a simple protocol to follow.

Layering protocol for feldspathic ceramics

To ensure optimal adhesion between the alloy and the feldspathic ceramic, the following guidelines are recommended for selecting and applying the ceramic:

• **It must have a Thermal Expansion Coefficient compatible with the metal** (CET: $14.3 \times 10^{-6}\ K^{-1}$);

• **Do not use bonding**;

• **Mix the opaque paste with a drop of distilled water** to dilute and improve its consistency, as well as to accelerate drying (the use of powder opaque is recommended).

Important:
This protocol is specific to Mesa **Magnum Solare discs** (CET: 14,3 10^{-6} K^{-1}).
For the processing of other Mesa alloys, it is necessary to follow the protocols specified by the manufacturer of the ceramic being used.

4th STAGE: COOLING

Treatment Parameters

• 450°C: Open the furnace and allow gradual cooling

What is cooling and what is its purpose?

After ceramic firing, the workpiece must undergo slow and gradual cooling to room temperature to ensure the maintenance of structural stability and the metal's properties (hardness, strength, etc.), as well as to prevent defects.

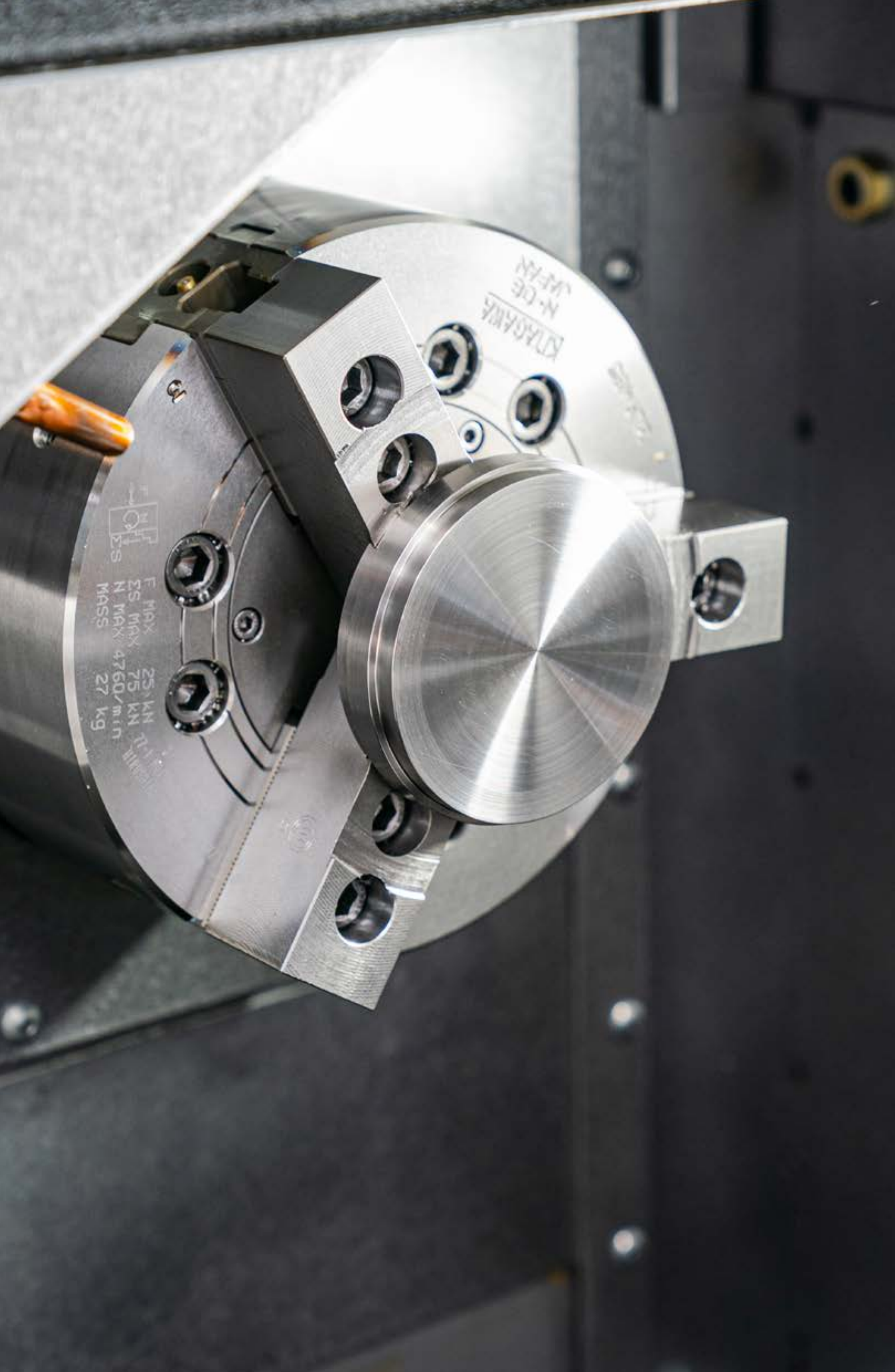
Gradual cooling allows for:

- **Avoiding internal stresses in the alloy**
- **Reducing the risk of ceramic fractures**
- **Stabilizing the mechanical properties** of the workpiece

A sudden cooling process could also cause unwanted movements in the alloy, leading to delaminations or fractures in the ceramic layering.

CONCLUSIONS

Strictly following this protocol ensures an optimal outcome in the processing of Magnum Solare Cobalt-Chrome, maintaining dimensional precision, mechanical strength, and excellent ceramic-to-metal adhesion.
Magnum Solare is a Medical Device manufactured by Mesa Italia S.r.l.
For any questions or needs, always refer to the Instructions for Use (IFU) of the Medical Device or contact the qualified personnel at Mesa Italia S.r.l.


F MAX 25 kN
ES MAX 75 kN
N MAX 4760/min
MASS 27 kg

4

THE ADHESION OF AESTHETIC MATERIALS

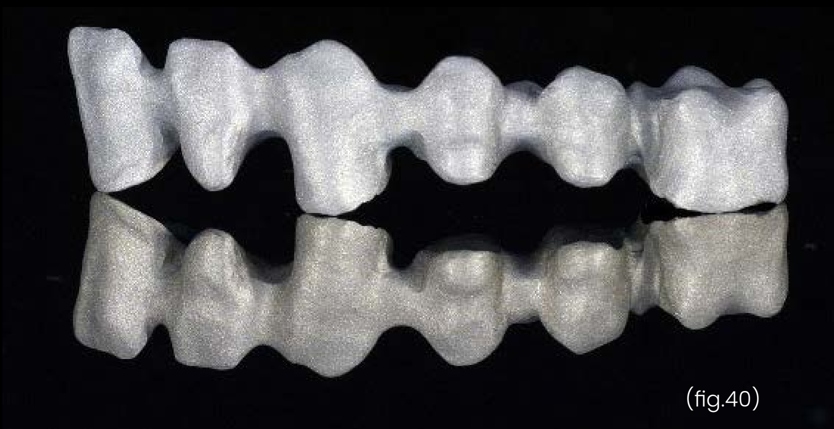
The framework is the skeletal part of the prosthetic rehabilitation, providing support and rigidity to the restoration, whether the prosthesis rests on natural teeth or implants. The prosthetic framework serves as a support for the covering materials, which adhere to and coat the framework itself, thus enabling the fulfillment of the following functions:

- Aesthetics
- Mechanics
- Durability
- Biocompatibility

Adhesion (the connection between two surfaces) refers to the force that opposes the separation of two bodies in contact.
The interfacial forces maintaining this bond can be chemical, mechanical, or a combination of both.

4.1 MECHANICAL ADHESION

Mechanical adhesion can be achieved by modeling small undercuts on the surface, such as hemispheres or inverted cones.
By sandblasting the metal surface—a process in which the outermost layer of a material is abraded using a jet of air and sand—microscopic irregularities and undercuts are formed. These create spaces where the aesthetic material can anchor, resulting in mechanical adhesion.
The type of sand used varies depending on the type of aesthetic material to be applied and the purpose of the procedure.
There are synthetic glass microspheres designed for polishing surfaces, ideal for attachments and counter-milling.
These are commercially available in grain sizes ranging from 55 to 100 microns.
Aluminum oxide, on the other hand, is used for cleaning metal surfaces from residual coatings and preparing them for mechanical adhesion.
Aluminum oxide must always be used in its pure form to avoid contaminating the metal. Its grain size ranges from 90 to 150 microns, with 110 microns being the size recommended by many composite manufacturers. (fig. 40)



(fig.40)

4.2 **CHEMICAL ADHESION**

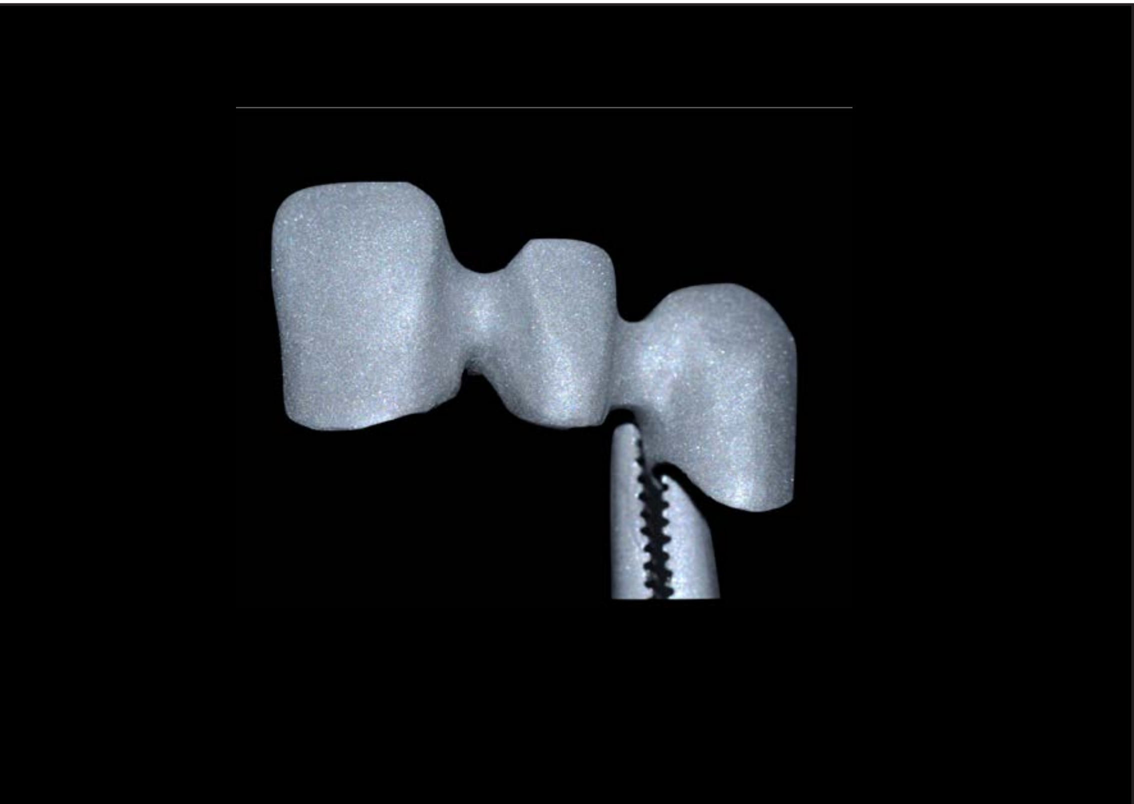
Composite manufacturers provide a metal primer in their sets, usually in liquid form, primarily composed of hydrophobic phosphate monomers or sulfur derivatives. These components create a direct chemical bond between the metal and the composite opaque layer.
Adhesion occurs through molecular attraction and is classified into two main types of bonds ionic bonding which holds atoms together to form molecules or crystals.
Physical bonding, which occurs through intermolecular forces.
Regarding the adhesion between metal and ceramic, mechanical retention is not required, as adhesion primarily occurs through compression between the two materials. (fig. 41)

(fig.41)

4.3 NON-THERMAL TREATMENTS

It is recommended to finish the structures using tungsten and silicon carbide milling cutters (fig. 42).

Pre-oxidation cleaning is performed through sandblasting with aluminum oxide with a grain size between 90 and 110 microns, followed by cleaning through vaporization.



20

Dentatura incrociata fina
Dentado cruzado fino
Corte cruzado fino

1

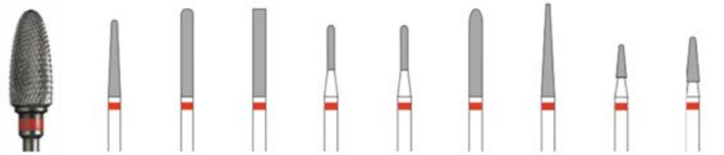


	Fig. No	261	364R	364	295	295	295	257	138	138
	L mm	14,0	16,0	16,0	8,0	8,0	16,0	17,0	6,0	8,0
	Size ⌀ 1/10 mm	023	023	023	010	012	023	023	018	023
Shank	Order No.	**0120.023HP**	**0220.023HP**	**0320.023HP**	**0420.010HP**	**0420.012HP**	**0420.023HP**	**0620.023HP**	**0720.018HP**	**0720.023HP**
HP	ISO 500 **104**...	194 140 023	137 140 023	116 140 023	292 140 010	292 140 012	292 140 023	187 140 023	198 140 018	198 140 023

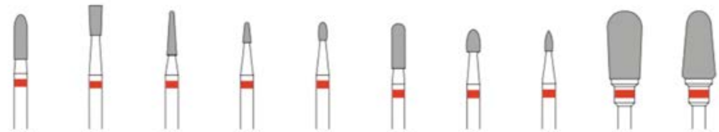


Fig. No	139	137	138	390	73	129	73	78	77	351
L mm	8,0	5,5	8,0	3,5	3,0	8,0	4,0	3,5	12,0	12,0
⌀ 1/10 mm	023	023	016	014	014	023	023	012	060	060
Order No.	**0820.023HP**	**0920.023HP**	**1220.016HP**	**1520.014HP**	**1620.014HP**	**1720.023HP**	**1820.023HP**	**3520.012HP**	**5120.060HP**	**5220.060HP**
ISO 500 104...	289 140 023	225 140 023	198 140 016	274 140 014	277 140 014	141 140 023	277 140 023	257 140 012	237 140 060	263 140 060

Fig.	601	602	603	609	613	622	624	632	633	638	639	640	649	650
Page	83	83	83	83	83	83	84	84	84	84	84	84	84	84

Fig.	651	652	652R	653	661	662	665	666	667	671	702	703	712	716
Page	84	84	84	84	84	84	84	85	85	85	85	85	85	85

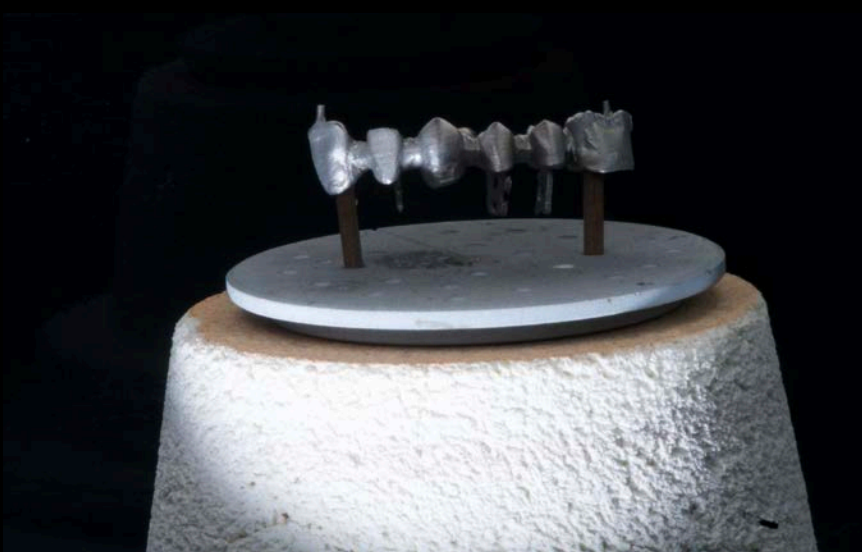
Fig.	721	727	728
Page	85	85	85

(fig.42)

4.4 THERMAL TREATMENTS

It is extremely important to thermally treat metals, whether cast or milled, before proceeding with the aesthetic finalization of the restoration, though for different reasons.
For cast metals, thermal treatment is necessary to homogenize the crystalline structure of the material, which has undergone a solid/liquid/solid state change.
This process ensures chemical and microstructural balance, eliminating harmful phases in freshly cooled alloys, including gases trapped during casting, and reducing stresses created by cooling. (fig. 43)
For milled materials, thermal treatment helps eliminate internal stresses in the alloy induced by the milling process.
To achieve effective treatment, it is recommended to reach a temperature between 50 and 80 degrees above the oxidation temperature and maintain it for 7–12 minutes in an atmospheric environment.
Oxidation is a thermal treatment performed after finishing, on the structure repared to receive the aesthetic coating.
Metal oxidation allows for a chemical bond between the alloy and the ceramic, enabling control and evaluation of the quality of the oxidized surface to ensure proper metal treatment during finishing.
This process helps both the clinician and the dental technician avoid potential complications during ceramic firing.

(fig.44)



4.5 **AESTHETIC FINALIZATION**

When it comes to the aesthetic coating, a fundamental parameter to consider is the compatibility between the Thermal Expansion Coefficient (CET) of the metal and that of the ceramic.

The CET of the ceramic must be lower than that of the metal, within a range of 5 to 10%. Any ceramic that falls within this range is suitable for use with these alloys.

Bonding acts as a mediator between the CETs of the two materials (metal and ceramic) and prevents Cr-Co oxides from rising to the surface during firing.

Its use is at the operator's discretion.

For composite materials, we recommend strictly following the manufacturer's instructions.

5

PROBLEMS AND SOLUTIONS


SOLUTION

5.1 **POROSITY**

- With torch casting, an incorrect propane/oxygen ratio adjustment can lead to the formation of circular porosity on the surface of the castings due to gas intrusion into the alloy in its liquid state.

✓ Adjust the propane pressure to 1 bar and oxygen pressure to 2-3 bars.

- If the alloy solidifies in the sprue channel before the anatomical part, porosity may form.

✓ Increase the diameter of the sprue channel.

✓ Add a small amount of extra alloy to create a proper reservoir that maintains a high temperature in the sprue channel, preventing premature solidification. (fig. 44)

✓ Use a reservoir with a diameter about 25% larger than the entry point.

- An incorrect ratio between the wax-up and the reservoirs or misplacement of the sprue channel can also contribute to porosity in the casting.

✓ Position the sprue channel at the thickest part of the restoration.


(fig.44)

5.2 SURFACE ROUGHNESS

- Excessive total mixing liquid used can result in a rough casting surface, as it may make the coating more porous and fragile.
- Excessive force or pressure during alloy casting.
- As well as an excessively high casting temperature, can also cause surface roughness. (fig. 45)

✓ Strictly follow the manufacturer's instructions for the coating material.

5.3 MISSING PARTS

- To prevent factors that may cause reduced casting pressure, insufficient machine pressure, or inadequate alloy heating, it is recommended to:

✓ Carefully adjust the pressure or thrust of the casting machine.

✓ Check the flame position and ensure the correct casting temperature.

- Avoid short or insufficient preheating of the cylinder.

✓ Adjust the preheating time of the cylinders according to their size.

- To avoid incomplete burnout of the wax pattern (fig. 46):

✓ Use materials that do not leave residues.

✓ Weigh the complete wax pattern, including sprues, and multiply the value by the specific weight of the metal.

(fig.45)

(fig.46)

5.4 **RESIDUAL COATING ON THE ALLOY**

- Presence of sharp edges in the wax-up.
- Incorrect junction between the wax-up and the sprues.
- Impurities in reused alloy.

✓ Carefully refine the junction between the sprues and the wax-up, avoiding sharp edges and constrictions.

✓ If reusing previously cast alloy, thoroughly clean the piece before casting.

5.5 **DIFFICULT METAL POLISHING**

- Porous metal
- Incorrect polishing protocol

✓ Follow appropriate polishing protocols.

5.6 **STAINED OXIDATION**

- Possible contamination during finishing. (fig. 47)

✓ Use burs exclusively dedicated to each type of metal.

5.7 **INCOMPLETE ADHESION OF OVERCAST METAL**

- The overcast metal does not fully flow to the defined margin of the overcast pattern.

✓ Check the temperature and preheating time of the cylinder.
Verify the thickness of the overcast section.

(fig.47)

5.8 FRACTURES

Vertical Fractures:

These can be caused by incompatibility between the CET of the metal and the ceramic or by improper cooling relative to the amount of metal.

✓ Perform extremely slow cooling, if the furnace allows, with a closed chamber.

Horizontal Fractures:

- Often caused by a lack of support from the substructure. (See substructure modeling 1.3 on page 16)

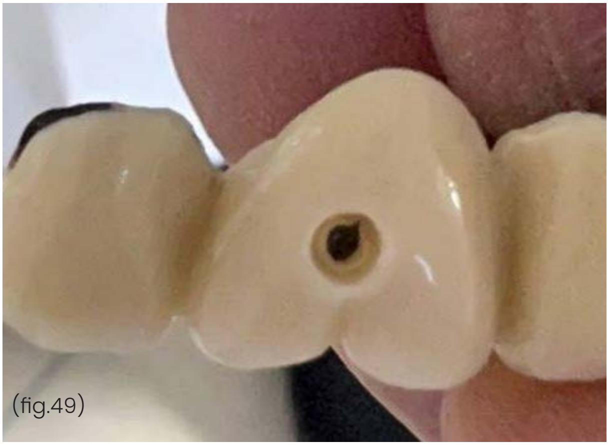
Chipping:

- Incorrect CET
- Sharp-edged substructure
- Patient parafunctions
- Incorrect wax-up anatomy
- Flexion of the structure due to failure to maintain minimum thickness requirements

5.9 CERAMIC DETACHMENT, BUBBLES

- Use of inadequate crucibles (graphite or contaminated).
- First opaque layer too dense.
- Excessive use of opaque liquid.

✓ Apply opaque layers that are not too dense, reactivating the material with distilled water.
✓ Use dedicated crucibles and replace them as needed.
✓ Ensure the alloy is not overheated by monitoring temperatures.
✓ Follow the manufacturer's recommended oxidation parameters. (fig. 48-49)


(fig.49)


(fig.50)

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