Application of Titanium for Implant-retained Suprastructures

Part 2: Aspects of Processing in the Dental Laboratory

Dr. Jürgen Lindigkeit

Introduction

Almost all dental implants are made from titanium or titanium based alloys. It is therefore also most convenient to use titanium for implant-retained suprastructures. Beside clinical aspects that have already been mentioned in part 1, it is of more interest for the dental technician, to deal with practical aspects of processing titanium in the dental lab.

It is well known in industry, that easy and precise machining of a material depends on the material itself and its properties. Hence, in industry, any working procedure is adapted to the material. Therefore, when processing titanium in the dental lab, we also have to consider the properties of titanium, since they influence the working procedure. This is an indispensable pre-requisite for easy processing with any material, and also of course, for titanium. Hence, requirements for dental laboratory operations can be derived from the physical properties of titanium.

Wax Modelling

Considering the modelling of a restoration in wax, we have to keep in mind, that the Young`s modulus of Titanium is nearly the same as of high gold precious alloys. Hence, to assure adequate stability of the titanium-casting, requirements for waxing are as for those alloys.

Recommended wall thickness for crowns and bridges should not be less than 0,4 mm in wax, ensuring a minimum thickness of 0,3 mm after finishing the metal.

Beside many other parameters, the quality of a casting also depends on the particular wax used for modelling. Shrinkage and surface-wetting of the wax influence the precision. Smoothness of the casting depends on the composition of the wax, since only a wax with constituents that burn off free of any residues will assure the best results. Hence, adequate and purely organic waxes should be used.

There are no special requirements, regarding the shape of wax copings. Therefore, for metal-ceramic restorations for example, usual criteria for shaping can be applied.

Spruing-System

Unlike an alloy, pure titanium doesn`t have a melting range, but a single melting point. Therefore, due to rapid solidification, there are no problems for titanium castings, regarding the formation of shrinkage holes and porosities, that often can be observed for alloys, having a more or less pronounced melting range. However, the mould has to be filled completely within a very short time. An appropriate spruing system is therefore required for the casting of titanium, depending on the individual casting device.

For single crowns, inlays and individual patterns the spruing system of the rematitan-system (Dentaurum) is T-shaped, comprising a main sprue and a runner bar, with a diameter of 4 mm each. The diameter of the leads are 3mm, with lengths of approximately 3 mm. The main sprue is fixed to the runner bar between the two leads.

The spruing system for larger bridges follows the same principles. Bridges exceeding more than 8 units , must have two 4mm-main sprues to the runner bar (Fig.1). Align the patterns in that way to allow the sprue cone to be located centrally in the mould.

Melting equipment

The Melting point of titanium is 1668°C. This is the highest of metallic casting materials used in dental casting technology. Titanium is also known to exhibit a high reactivity with commonly used crucibles. Thus, an appropriate melting equipment for titanium has to be taken into consideration.

Adoption of the main principles of proven industrial titanium casting technology is the best way to achieve a reliable titanium casting system for the dental lab.

This results in a dental casting system also using vacuum and argon protection gas to avoid entrapping of air to the titanium melt as in industry, thus maintaining the properties of titanium (Fig.2). The use of a copper crucible avoids reaction of the liquid titanium with the crucible. This melting technology is called scull melting in industrial foundries.

The procedure starts with a cleaning of both the melting and the casting chambers to remove any entrapped air. Melting is performed

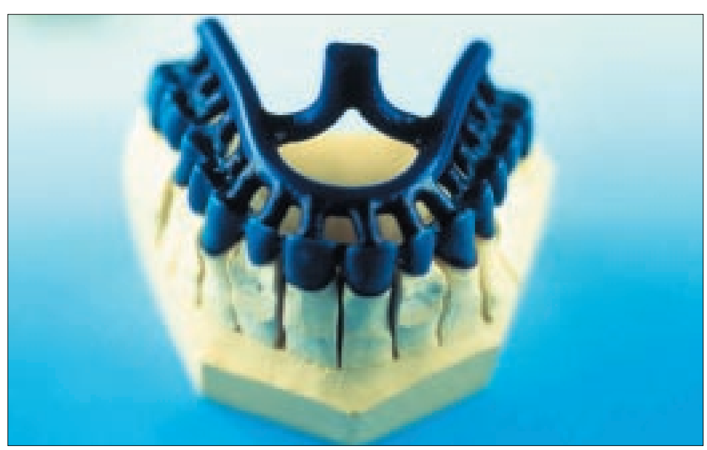

Fig. 1a,b: Spruing systems for titanium castings (Rematitan)

Fig.2: industrial and dental casting equipment (Dentaurum) for titanium

Suitability						
Titanium-Investments	Inlays	Crowns	Bridges	Attach-ments	Implant-super-structures	Frame-work casting
Rematitan Plus	++	++	++	++	++	+++
Rematitan Ultra	+++	+++	+++	+++	+++	–

Fig.3: Investments for casting titanium (Dentaurum)

by argon-arc-process, using a tungsten carbide electrode. Casting itself is a pressure casting, using the high pressure of argon in the melting chamber and the low presssure of vacuum in the casting chamber, thus enabling the melt to fill the mould.

Investments

Commonly used investments in the dental laboratory like gypsum-bonded or phosphate- bonded silica-investments cannot be used for casting titanium, since they have a high reactivity with liquid titanium. Therefore, appropriate investments for titanium have to be used.

Special titanium investments are available today, that cover a whole range of applications for cast titanium, including individually cast implant retained suprastructures (Fig.3).

The formation of the so-called alphacase-layer on the surface of titanium castings, known to be extremely hard and brittle, can nearly be suppressed by using an adequate investment for titanium.

For the Rematitan Plus investment, expansion for crown-and bridgework is controlled by modifying the dilution of the stirring liquid and by using a special liquid for framework-castings to ensure proper fit.

For the Rematitan Ultra investment expansion is not controlled by diluting the liquid, but by modifying soaking time and maximal temperature within a certain range.

Casting temperature for both investments is not the maximum temperature of the prehating cycle, but the mould is allowed to cool down in the preheating furnace to 430°C. This is sufficient to ensure complete filling of the mould and in addition, it provides good surface quality. Following the recommended procedures will result in very precise fitting.

Even large span bridges like this 14-unit brigde will exhibit this precision. So, fitting of titanium castings is no problem at all. In a recent study it was confirmed that there is no difference in accuracy of fitting between titanium and high gold alloys (1).

Trimming and Polishing

When using appropriate instruments, titanium can be trimmed and polished quite easily, since it is not a very hard metal, and has a Vickers hardness of only 200. Selected instruments like cutting disks, grinders, rubber polishers and tungsten carbide cutters have been tested to work effectively with titanium. Also a special finishing kit is available from Dentaurum, which comprise all tools for effective trimming and polishing of titanium.

For example, tungsten carbide cutters, designed to use with titanium, have a special cross shaped cutting edge and are recommended for use with low speed of max. 10,000 rpm. By applying only low working pressure, thus we take the hardness and the low thermoconductivity of titanium into consideration (Fig. 4).

Use of Prefabricated Parts
7.1 Parts for Implant Systems

Application of titanium for implant retained suprastructures covers the whole range of fixed and operator-removable restorations and removable prosthesis. Also, prefabricated titanium parts, precisely fitting the related implant-system, can be used. For the TIOLOX®-System, a variety of prefabricated parts are available like straight and angulated abutments, ball anchors, adjustment sleeves, bar attachments and joints and also special abutments for laserwelding.

Availability of special parts for laserwelding is of importance, since Laserwelding is the recommended technique for joining pure titanium.

Laserwelding

In contrast to soldering or plasma welding, only laserwelding provides a biocompatible joint. Laser joints exhibit only a small area affected by heat, thus retaining high precision due to low deformation. Beside biocompatibility and low deformation, laser-welding in dental technology also means: efficient working, considerable time savings, high mechanical strength, , reduced stress, working near acrylic and ceramic materials and easy realization of connections, extensions and repairs.

Similar to the casting process , entrapping of air has to be avoided for Laserwelding of titanium. However, since only small areas are molten by the laser-beam, applying argon gas by a nozzle is sufficient. Proper adjustment of argon gas nozzle is assured by checking and avoiding discoloration of the laser spot on a titanium test disk (Fig.5).

Even without any casting, a passively fitting bar restoration can be obtained by laserwelding, using only prefabricated titanium parts.

Before welding, a butt joint contact has to be prepared. To avoid reflexion of the laser-beam, the area has to be sandblasted. Fixation is done with 2 single spots.

The laser joint is build up by overlapping each spot to the former one by 70%, thus ensuring an even track. Welding one joint of the bar to an abutment has to be completed before starting the next joint. Build up of the welding with additional material is possible with titanium welding wire.

After fabricating the full denture, the titanium bar sleeves are laser welded to the titanium retainers, and can be modified individually.

Hence, using prefabricated titanium abutment components lead to a precise, cost-effective restoration being fabricated using the same material.

Combination of Casting and Laserwelding

Titanium abutments can also be used in screw-retained restorations in combination with casting and laser-welding. This will be shown for a molar crown (2):

The plaster model with the lab pin and gingival mask is articulated and the occlusal space is checked (Fig.6). The gingival level should also be determined to ensure optimal contouring of the crown.The acrylic extension is placed on the titanium abutment and secured on the lab-pin with a titanium screw, ensuring rotational security.

The acrylic extension is shortened according to occlusal space available. The acrylic extension is waxed up then. It can be removed from the titanium abutment for modelling, since the rotational security ensures precise reposition (Fig.7).

The wax pattern of the crown is then removed from the titanium abutment, invested and casted in titanium according to the procedure already shown. Then the coping is repositioned to the abutment.

Crown and abutment are laserwelded at the cervical junction, following the recommended procedure as described. After polishing the laser-joint, the crown is ready for veneering with titanium ceramics like Triceram.

The screw aperture is sealed with a composite filling, placed by the dentist. A porcelain-inlay, fabricated in the dental lab, can also be used (Fig.8).

Veneering with Ceramics

Considering the physical properties of pure titanium—low thermal expansion, high reactivity with oxygen and a structural change of titanium at 882°C—it is obvious why, for ceramic veneering of titanium, an appropriate ceramic has to be used.

Surface conditioning for fusing ceramics onto titanium is just the same as usual, this is: blasting with aluminumoxide of 125-250 µm with a pressure of 2-3 bar. Due to the low thermal expansion of titanium , thermal expansion coefficients of the ceramic materials are adopted.

During porcelain firing, the affinity of titanium to oxigen has to be supressed to avoid oxyde-layers that may influence bond strength and esthetic appearance. Therefore, the titanium surface is sealed with a special bonder in the first bake.

Firing temperatures are well below the structural change of titanium at 882°C for titanium ceramic. In addition there is only a short bake process for Triceram and no long cooling is required.

Summary

Dentists and scientists view titanium as the best suited material for implant retained suprastructures. Thus, it is up to the dental laboratory to realize such restorations.

A well adapted and safe casting technique for titanium, prefabricated parts, the use of laser welding technique and last, but not least, well adapted ceramics enable the dental laboratory and the dental technicians to fulfill this requirement and supply precise, cost effective titanium restorations for high aestetical demands.

About the author

The author of this article, Dr. Jürgen Lindigkeit studied mechanical engineering and materials science at the Ruhr University in Bochum, Germany, from 1971 to 1976. From 1976 to 1979 he was employed as Scientific Collaborator at the Institute for Materials Research, an area of the German Research and Test establishment for Aeronautic and Space Sciences (DLR) in Cologne. In 1979, he obtained his postgraduate degree in

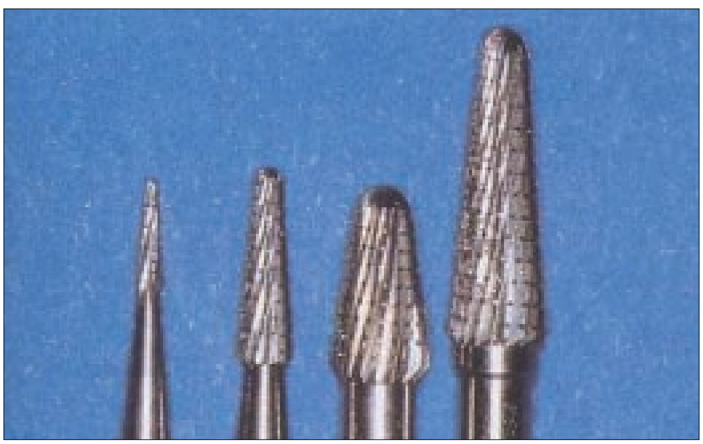

Fig.4a,b: Tungsten carbide cutters, cross shaped cutting edge (Dentaurum)

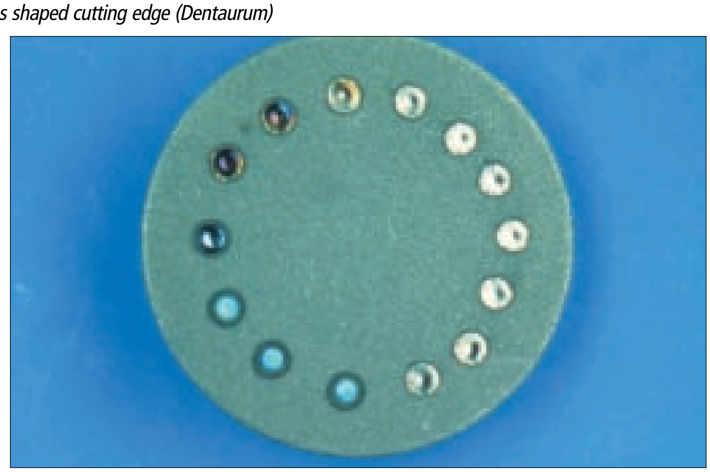

Fig.5a,b: Adjustment of argon gas, avoiding discoloration of laser spot

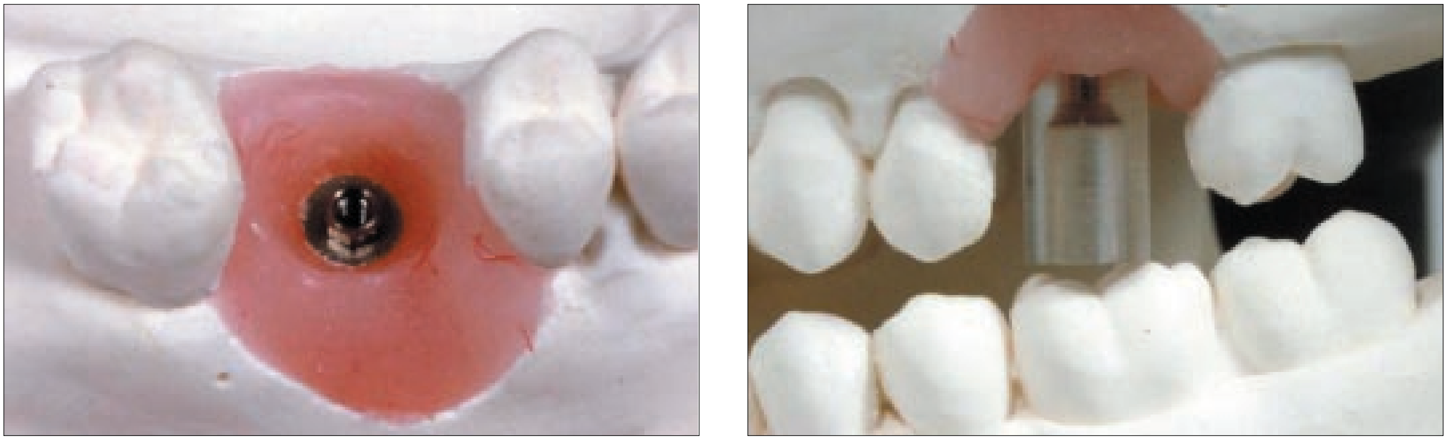

Fig 6a,b: Lab pin and gingival mask (a), acrylic extension witth titanium screw (b)

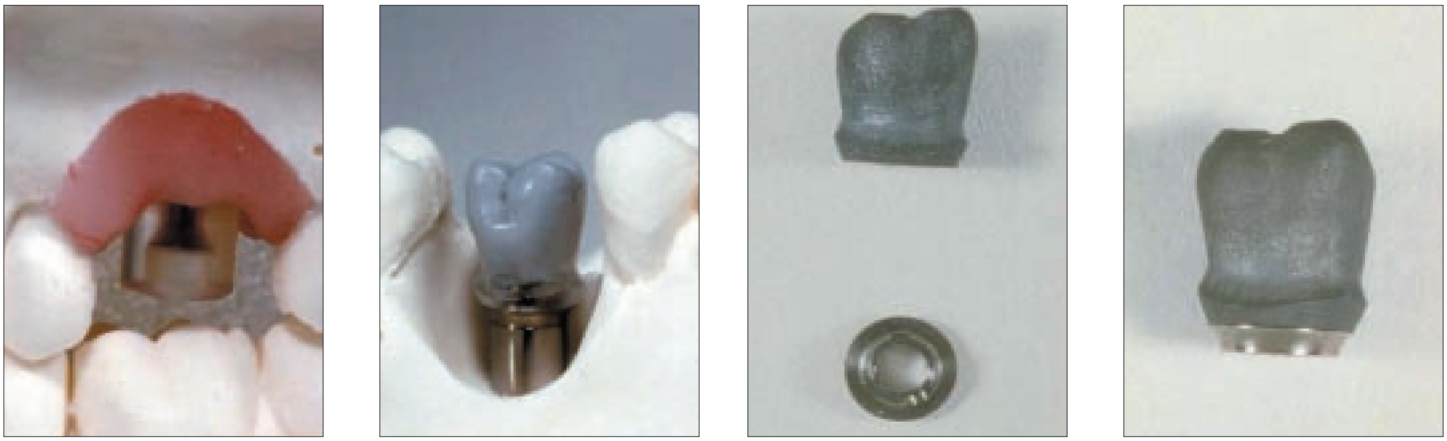

Fig.7a-d: Shortened acrylic extension (a), wax up (b), cast titanium coping with abutment (c), coping fitted to abutment (d)

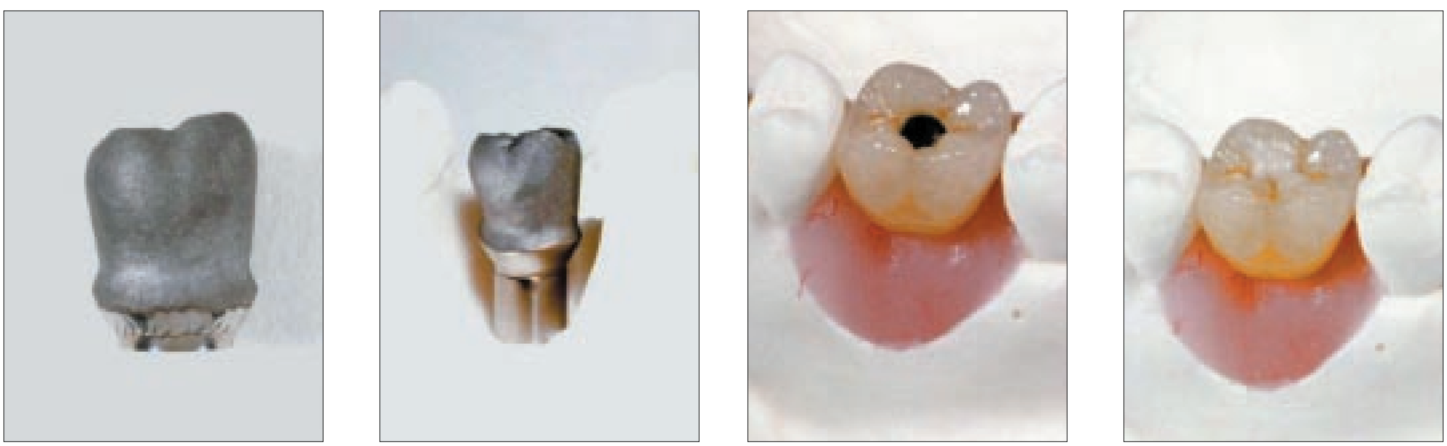

Fig.8a-d: Laserwelding at cervical junction (a), crown ready for veneering (b), veneered with titanium ceramics (c), sealed screw aperture (d)

engineering sciences and from 1979 to 1980 he acted as head of the working group on low-temperature materials, MAN-Neue Technologie, Munich.

From 1980 to 1995, he occupied a number of leading positions in development, production and product management in medical and dental technology. Since 1996, Dr. Lindigkeit has been head of Dental Technology and Development department at Dentaurum J.P. Winkelstroeter KG, Ispringen, Germany. Since 2000, he has also been head of Dentaurum`s metallurgical development department.

He is a member of a number of national and international associations (e.g. DGM, DGZMK, DGZPW and IADR), Chairman of the working group on dental base metal alloys at DIN-NA Dental (German Institute for Standardisation) and Convenor of the international ISO working group Base-Metal Alloys (ISO/TC 106 (dentistry)/SC2-WG2).

He also lectures widely and has published many articles on dental materials.

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