# Double crowns made of a new high performance polymer

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**_Double crowns** in form of telescopic or conical crowns have been used for many decades in dental prosthetics. In the beginning of dental implantology prosthetics, there were still droughts about the transfer of these constructions on the implant-supported dentures. However, in the practical application more and more telescopic or conical prosthetics recently prevail.

## _Introduction

In the 70s and 80s, the bar restoration on implants was the first choice e.g. by Ledermann (1979). Over the years, more and more telescope or conical crown applications have been described for implant-supported dentures. From the experience of the author it is clearly determinable that a double crown restoration in the mandible with four implants and secondary crowns is indicated. For example, they would provide very good and stable long-term results in electroplating technique (Figs. 1a & b).

The alternatives offered in form of attachments of various kinds stabilise the prosthesis more or less depending on the condition of the jaw. However, these attachments are usually inferior in fixation compared to a double crown restoration. Especially, one-piece implant systems—possibly with implants reduced in diameter and length—with simple ball retaining elements, such as rubber rings, are absolutely inappropriate in terms of a later change of the superstructures. A restoration with double crowns is more complex for both the dentist and the technician with regards to efforts and costs. In the following, a new technique is described using prefabricated parts and a new material combining the advantages of telescopic or conical crown technology with the ease of processing and manufacturing. The application should possibly be done as chair side alternative, which is reasonably priced in the dental laboratory. For fixed detachable prostheses, new possibilities for avoiding screw retention are also described.

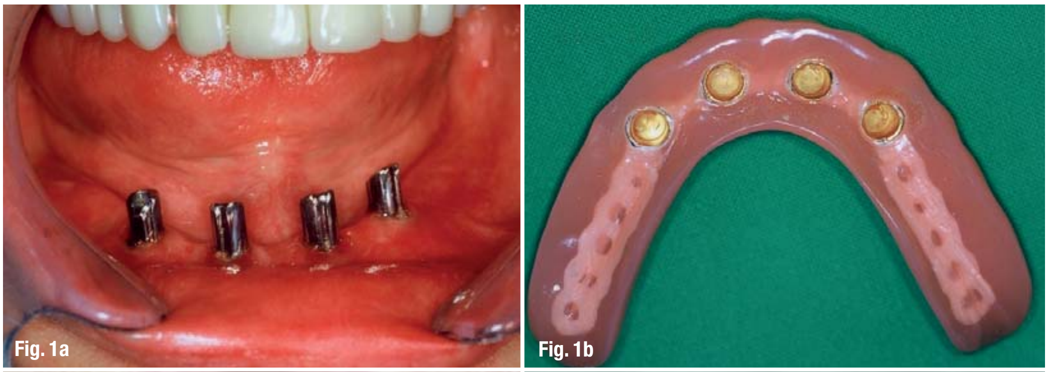


Fig. 1a Fig. 1b

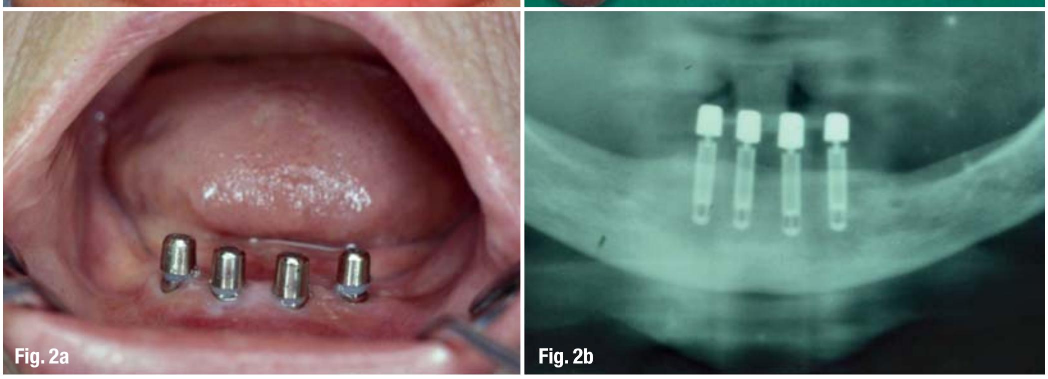


Fig. 2a Fig. 2b

**Figs. 1a & b**_Individually made telescopic crowns with secondary parts electroplated in "passive fit" technology glued to a metal frame.
**Figs. 2a & b**_Telescopic crowns on IMC cylinder implants (Dr. Nikola Laux 1984).

## _Historical development of double crown systems

From literature it is known that Starr was probably the first who reported, in 1886, about a removable bridge made of double crowns. In English literature Peeso (1924) reported about possible applications of the double crown systems. In Germany it was Häupl in 1929 and Böttger in 1961. The breakthrough of double crown systems took place in Germany in 1969 with Körber (1988) who advocated the use of conical crowns with a defined angle of convergence. Over the decades the conical crown has become known as "German crown" which refers to the frequent use in the German-speaking area until today. According to Körber (1988) double crown systems should include, among other things, exactly fitting pillar integration, secondary splinting with an axial directed periodontal load and firm support during function which is easily removable for hygienic reasons. Furthermore, the production should be as efficient as possible and a high economic effect should arise by a very long survival rate, which can be expected.

Körber (1988) distinguishes telescopes according to their form:
*Cylindrical telescope:* It hardly tolerates technical inaccuracies and is therefore, according to Körber, classified as problematic in manufacturing.
*Cone-shaped telescope:* With regard to the fit there is a high tolerance, it allows production with a low error rate.
*Resilience telescope:* Primary and secondary parts should have some backlash in the occlusal region in order to have some space on top of each other under load. The telescope should only undertake the functions of friction and indirect connection of the retaining teeth (bracing).

## _Definition of the cone angle for double crown systems

The three systems—the telescope crown, the conical crown and the resilience telescope—are double crown systems, which differ by the type of fit and adhesion. The determining factor for the strength of adhesion is according to Heners (1990), the convergence angle.

In the early days of implant dentistry one was still sceptically about the use of double crown systems on implants. At this time, as one of the first colleagues the dentist Dr Nikola Laux from Hamburg, Germany, introduced the use of telescopic crowns on implants (IMC cylinder implants) in 1984 (Figs. 2a & b). In 1996, two of the authors (Vollmer, R. and Vollmer, M.) provided a mandibular removable prosthesis with six implants and telescope crowns with secondary parts made of Teflon already (Figs. 3a & b).

**Convergence angle & value at various double crowns:**

Telescopic crown: $\alpha = 0°$ (clearance only)
Conical crown: $0° < \alpha < 8°$
Resilience telescope: $\alpha$ may only be so large that just an adherence occurs

Largest recommended convergence angle: $\alpha < 10°$
(with double crown systems according to Muhs, 2006)

**Advantages of the double crown technique**

1. Straightforward extensibility after losing a primary crown.
2. Possibility of extra-oral repairing.
3. Better and easier periodontal hygiene compared to fixed prostheses.
4. Parallelisation of abutment teeth in the case of divergences.

**Disadvantages of the double crown technique**

1. Complicated, precise and technical manufacturing, high demands on the technician.
2. High costs for the work of the technician and for the material (e.g. use of precious metal, electroplating).
3. In order to achieve aesthetic results, an intensive substance reduction of the abutment teeth must take place. If this is not possible, the result in the anterior areas of the jaws is aesthetically often unsatisfactory.
4. The use of ceramic veneers fusing to the secondary parts in the front area is risky (chipping).
5. Loss of adhesion and pull-off force after a certain time.
6. Missing or difficult possibilities of activation (post electroplating, fabrication of additional attachments).
7. When using an inexpensive base metal (non-precious metal) / Eco-gold combination, corrosion can occur leading to excessive friction.

## _The material PEEK—A historical review

For a long time, plastics were frequently used in the dental field. Light weight, an easy processing ability compared to metals and ceramics, are some of the benefits. The most known plastics are Polyoxymethylene (POM) and Polymethylmethacrylate (PMMA).

PEEK (Polyetheretherketone) is a newer polymer which is also used for medical products since the mid-90s (Fig. 5). The material was developed in 1978 and mainly used for mechanical engineering and in the automobile industry initially. Meanwhile, PEEK is used for the production of biomaterials in medicine, e.g. for artificial vertebral bodies, anchoring screws, artificial

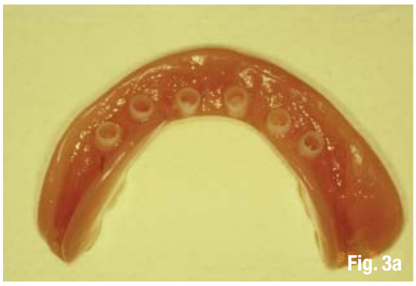


Fig. 3a

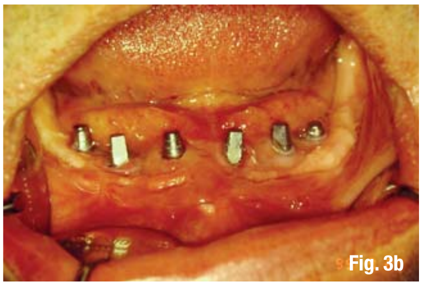


Fig. 3b


Fig. 4

joints etc. Since the original material has a dark colour, it initially appeared to be not suitable for dental applications. However, one succeeded to vary the colour of the material so that it could also be used for temporary restorations and abutments (Kirsch, 2002).

Today the following indications are cited: full crown caps for single crown copings, full anatomical bridges, scaffolds for veneer bridges, primary crowns, inlays, inlay bridges and Maryland bridges. So far, the approval of the material was limited to removable or conditionally removable (screwed) dentures. This means that with the described material metal-free dentures, secondary parts, over structures with combined dentures, implant-supported full crowns in the posterior region and conditionally removable, screw-retained bridges can be realised.

A distinction has to be made between pure PEEK and PEEK with additives. Recently, industrially manufactured blanks (Fig. 4) are available with an authorization for definitive and removable dentures (e.g. dental discs "Tizian PEEK Blanks" Schütz Dental Ltd., Germany). The material has no additives and is used in medicine for many years now. Since the highly pure PEEK material contains no additives—such as barium sulfate—it is not visible on X-ray control images (Fig. 6). Other manufacturers, however, use additives such as barium sulfate deliberately for a radiographic display.


Fig. 5

Also, a so-called white-PEEK is offered in the field of dental prosthetics from different companies. This material is mixed with up to 20 per cent titanium dioxide which makes the colour lighter or whitish. In this method, the hardness (flexural strength) of the material is raised, but at the same time the sliding property is deteriorated. Another disadvantage is that from the material titanium dioxide ions go in solution and work like a ventilation element after a certain period of wear. This can lead to discolouration of the gingiva. Therefore, pure, medical PEEK for prosthetic parts processing is rather recommended.

**Figs. 3a & b**_Full denture with Teflon secondary crowns (Vollmer, R. & Vollmer, M. 1996).
**Fig. 4**_PEEK prosthetic parts milled from so-called blanks (dental discs Tizian PEEK Blank, Schütz Dental Ltd., Germany).
**Fig. 5**_Applications of PEEK in the human body (Source: elements 39, issue 2/2012).

**Figs. 6a–c**_CNC machined PEEK abutment (Dental lab/milling center Anger, Remagen, Germany).
No radiological visibility of the PEEK secondary part.
**Fig. 7**_Prefabricated primary parts of different angulations (Schütz Dental Company Ltd., Rosbach, Germany).
**Figs. 8a–c**_Clinical situation with more severe atrophy of the mandible in the posterior region (a); production of total mandibular denture before implant exposure (b); marking the implant positions (c).

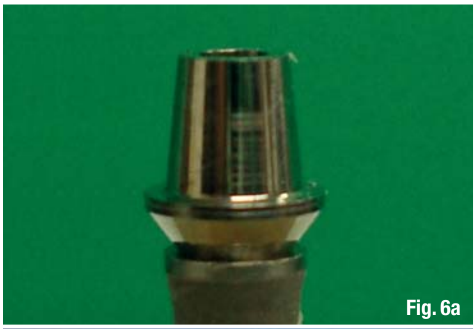


Fig. 6a


Fig. 6b


Fig. 6c


Fig. 7


Fig. 8a


Fig. 8b

## _The properties of PEEK

PEEK is dimensionally stable up to a temperature of about 152 degree Celsius, the material is high melting, about 334 degree Celsius. PEEK is resistant to water and ionising radiation. Therefore, the physical properties do not change even during sterilisation at 170 to 180 degree moist/heat sterilization at 200 degree Celsius/one bar or during sterilisation using gamma radiation. The chemical consistency is very good. It only reacts with concentrated sulfuric acid ($H_2SO_4$). Therefore, the use in the oral cavity is safe and the material has the CE mark for medical devices. The low specific mass, the elasticity similar to the one of bone, the absence of metals and the toughness, combined with an almost non-existent material fatigue makes the material an ideal partner in prosthetic dentistry and implantology.

## _Processing PEEK

To process PEEK the so-called "semi-finished" base material is needed which is produced in several ways of powders or pellets for later processing. These are:
- Extrusion
- Injection molding
- Selective laser sintering (SLS technology)
- CAD / CAM.

*CAD/CAM technology*

Since the material allows processing using CNC mills very well, the CAD/CAM technology is used to produce the finished parts. Elaborate individual work assignments of the dental technician in the form of scaffold modelling with subsequent individual polymerization can be avoided.

*Tasks and objectives*

The application of the double crown technique on implants will be described in the following. The prior mentioned advantages of the new material PEEK for dentistry should be used for dental implant superstructures by prefabricating standardised parts. The mentioned advantages of the double crown technique should remain and the disadvantages should be largely avoided or allow a reconstruction in a cost effective way.

A system is described to combine the advantages of the already known traditional custom-made double crowns with individually milled primary parts with the advantages of double crowns with industrial prefabrication.

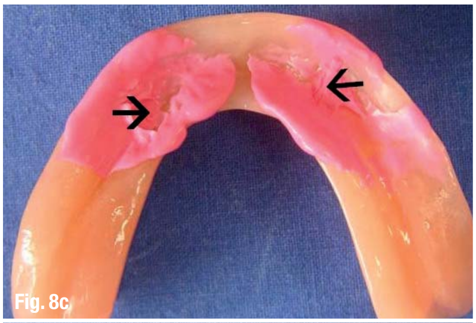
Prefabricated cone parts are used with different angular deviations of the implant abutment (Fig. 7). For these abutments perfectly fitting PEEK caps are manufactured using CAD/CAM technology.

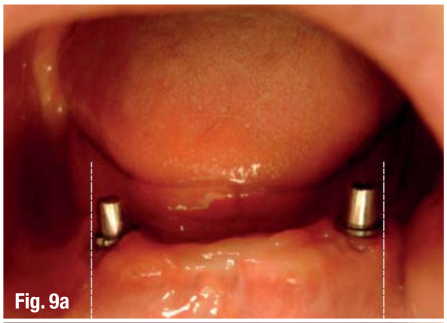
## _Different indications and case documentations

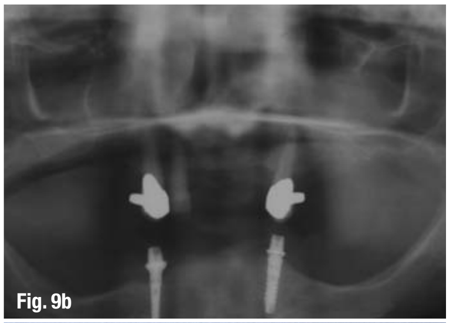
*Case 1: Removable prosthesis on two implants—direct procedure*

The cone primaries can be parallelized in the patient's mouth without time consuming impression taking and transfer to a model. Only an X-ray control recording to verify the abutment seating is useful. The previously made full mandibular denture (Figs. 8a–c) is marked with silicone at the implant exit points after tissue exposure. Then, the prosthesis is milled (Figs. 9a–c) and adjusted in the patient's mouth to the implant abutments covered with the PEEK caps (Fig. 10). In doing so, no later tension can arise. Using an acrylic resin,

**Figs. 9a–c**_Parallelisation of the primary parts in the mouth (a); X-ray control (b); grinding out the prosthesis for gluing the secondary parts (c).
**Fig. 10**_PEEK secondary parts in site.
**Fig. 11**_PEEK abutments polymerised in the prosthesis.







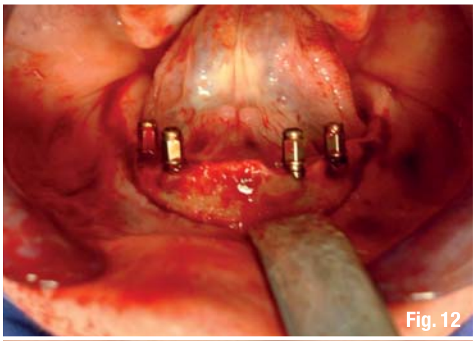


Fig. 12


Fig. 13


Fig. 14


Fig. 15a

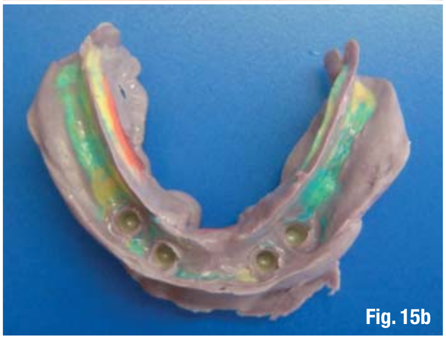


Fig. 15b

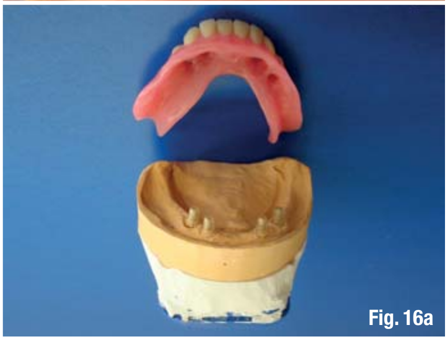


Fig. 16a

the PEEK caps are then glued in the patient's denture directly (Fig. 11). This method enables a so-called "passive fit" of the removable prosthesis. Due to the good adaptation of the PEEK material to the primaries a suction effect develops in addition to the friction of the parts. The primary parts can—if necessary—be sandblasted and thus roughened to increase the friction effect. Nevertheless, this is not required in most cases if there are sufficient parallel surfaces. In the present case, in spite of an in the posterior area severely atrophic mandible, one has been able to achieve a very good stabilisation of the removable prosthesis without having the effect of a rotation around the linking axis of the implants.

*Case 2: Removable prosthesis on four implants—half-direct procedure*

The female 79-year-old edentulous patient had received a new lower denture about one year ago. She was very unhappy all the time, until she had been informed by an acquaintance about the possibility of dental implantation. After appropriate education and measurement of the bone volume, four implants were inserted in the anterior mandible (Fig. 12) to provide a supply with prefabricated titanium primary telescopic crowns and PEEK secondary crowns.

After three months of healing, the titanium copings were then parallelised in the patient's mouth (Fig. 13). The PEEK caps were adjusted to the primary crowns (Fig. 14) and both bite registration and functional impression were made in one step procedure (Fig. 15). In the meantime, the existing prosthesis of the patient was already supplied with two PEEK caps and a soft relining, so that the primary abutments no longer had to be removed.

In the next session, the wax try (Figs. 16a & b) and the tertiary framework try-in was done. After the wax try-in, the secondary PEEK crowns were placed back in the mouth again and the premade model casting reinforcement was tried in. Since the fit was very good, according to the passive-fit method, the gluing of the PEEK abutments with the tertiary structure in the patient's mouth was made with a dual curing material (Fig. 17).

**Fig. 12**_Implants after insertion.
**Fig. 13**_Secondary conical parts parallelised and fixed.
**Fig. 14**_Try-in of the PEEK secondary parts.
**Figs. 15a & b**_Impression fixing the PEEK parts and bite registration in one step.

**Figs. 16a & b**_Wax up of the teeth and try-in of the full denture.
**Fig. 17**_Tertiary framework try-in and glueing in the patients mouth for passive fit.
**Figs. 18a–c**_Repositioning of the metal frame and check of the passive fit.


Fig. 16b


Fig. 17


Fig. 18a

Figs. 19 a & b_Prosthesis finished and final incorporation.

Fig. 18b

Fig. 18c

Fig. 19a

Fig. 19b

After the removal of the bonded parts, the complete part was reset to the working model (Figs. 18 a & b). There were no deviations or tensions detected. In the dental laboratory, the total work now could be completed so that the integration of the prosthesis was already at the next meeting (Figs. 19 a & b).

The PEEK abutments "run" or glide on the primaries very good. The prosthesis has a very solid tension-free fit and can still be easily removed by the patient. Prostheses pressure points have not occurred.

*Case 3: Fixed or removable prosthesis on nine implants—screwing or cementing or none of both?*

The female patient's age was 51 when about 14 years ago, in the year 2000 she received maxillary and mandibular implants. The wish of the patient at that time was not wearing removable parts in her mouth. Later in the maxilla, a fixed ceramic fused to metal bridge restoration was incorporated. In the lower jaw, a 14 unit acrylic bridge metal enforced from one piece was integrated. A retrievability was provided as in the anterior region a larger defect was already present. This region was used to stabilise the interim prosthesis with so-called bicortical screws.

However, since it turned out that after the healing the bicortical screws were absolutely stable and firmly healed, they were left in the jaw and incorporated into the prosthetic construction.

After about ten years, the patient started having problems at the distal right implant which turned out to be loose and had to be removed (Fig. 20). After a small makeover, the existing bridge was then reintegrated.

The implant failure had likely been caused by the so-called medial shift (Fig. 21) of the mandible and the cantilever construction. Sometimes, this effect is also observed in bridges in the mandible, ranging from the anterior region to the wisdom tooth. Especially when the patient is older and the lower jaw shows a decrease of density, it comes to this release or decementing effect. For this reason, appropriate separation points should also be included in the mandibular

Fig. 20_Situation ten years after full implantation. Loss of one implant in the lower right mandible.
Fig. 21_Medial shift by the masticatory muscles.
Figs. 22a & b_Original bridge designed for cementation. Signs of wear, discolouration, abrasions and cracks.

Fig. 20

Fig. 21

Fig. 22a

**Fig. 23**_Clinical situation after removing the bridge.


Fig. 22b


Fig. 23

bridge restorations. Cantilever constructions should be avoided whenever possible.

Over the years, the gingiva of the patient was for whatever reasons much more sensitive and the patient had great fear to lose more implants in the lower jaw. She wore the existing bridge structure only as a kind of a loose removable bridge. Since the design was intended for at least a temporary cementation, it always came to a wear and chipping of the plastic veneers, which could no longer be repaired (Figs. 22a & b). Now, in 2014, the patient is 65 years old and a new treatment-plan with three divided bridges for cementation was suggested. However, she refused and insisted to get a part that is removable or to have the old one repaired, which for technical reasons was not possible. There were different solutions discussed including new primary telescope parts and electroplating technique for the secondary parts. A decision was not made by the patient especially because of cost reasons. The only statement was that she wanted to have something like a removable bridge.

After assessments and parallelism measurements of the existing models in the dental laboratory, it turned out that there was also the opportunity to design a new restoration with the help of PEEK secondary crowns and a tertiary cast framework for acrylic pontics without removing the original abutments (Fig. 23). The patient agreed on this proposal.

First, the PEEK secondary parts, some of which were splinted, were tried in (Figs. 24a–c). The fitting was very good. The model casting reinforcement for the tertiary structure also fitted perfectly (Fig. 25). So the bonding of both (PEEK and metal frame) similar to the previous case was done directly into the patient's mouth (Figs. 26a & b). In this case, a pick-up impression in the double mixing method was manufactured (Fig. 27). The bite was registered over the tertiary structure. The result was a very good matching, stress-free, removable bridge with a pleasant chewing comfort that meets the needs and expectations of the patient (Figs. 28 & 29).

**Figs. 24a–c**_New designed secondary parts made of PEEK; Tertiary structure.
**Fig. 25**_Try-in of the tertiary structure.
**Figs. 26a & b**_Glueing the tertiary structure to the PEEK secondary crowns.


Fig. 24a


Fig. 24b

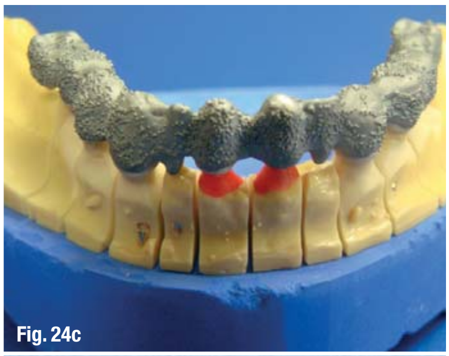


Fig. 24c


Fig. 25

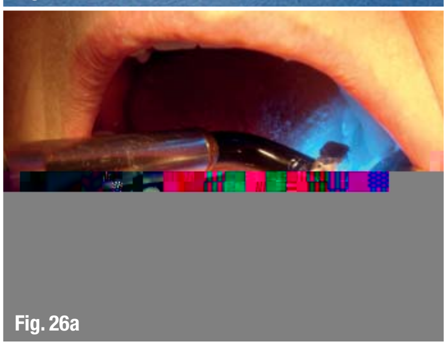


Fig. 26a


Fig. 26b

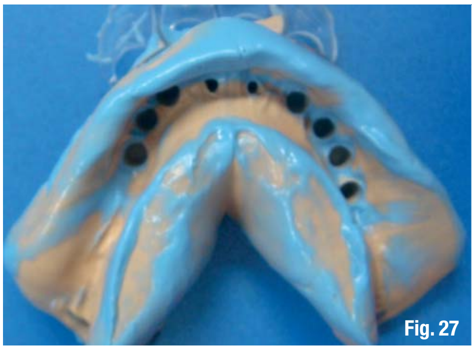


Fig. 27

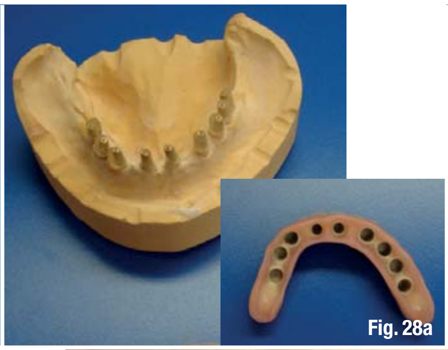


Fig. 28a


Fig. 28b

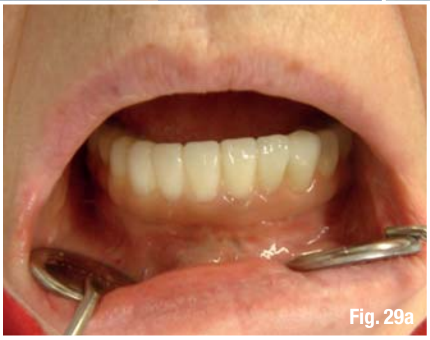


Fig. 29a


Fig. 29b

*Case 4: Fixed prosthesis on two implants and three unit bridges—screwing or cementing or none of both?*

This 77-year-old patient was already supplied with multiple implants and wanted the gap 23 to 25 to be filled with a fixed bridge (Fig. 30). Since it was a FP 3 option or indication according to C.E. Misch and hygiene deficits of patients had to be corrected with the help of a professional dental cleaning, in this case we decided to manufacture, similar to the previous case, a removable bridge which was neither cemented nor bolted.

The process was corresponding to the case before. The difference was that we were using porcelain fused to metal. The bridge was glued in the mouth to the two PEEK caps (Figs. 31, 32a & b). Now, the patient has a very good chewing comfort. The prosthesis can be removed from the prophylaxis assistant very well. The problem of a cemented bridge with the appropriate cement residues, a possibly too strong adhesion and a difficult retrieve possibility was avoided as well as the disadvantages of screwing. The use of ceramic veneers fused to the secondary parts is possible and chipping avoided (Fig. 33).

*Case 5: Removable prosthesis on four implants and Locator® attachments – unsatisfied patient*

The patient, aged 81 years, had significant problems with the adhesion and fit of his lower jaw full prosthesis for years. Because of cost concerns a bar or telescoping construction using electroplating was omitted. Although the initially applied two anterior implants with a simple ball connection device ensured a stabilization of the prosthesis, there were always returning pressure sores and points in the posterior region of the mandible

**Fig. 27**_Impression to fix the superstructure.
**Figs. 28a & b**_Final prosthesis.
**Figs. 29a & b**_Clinical situation.


Fig. 30


Fig. 31


Fig. 32a


Fig. 32b


Fig. 33

**Fig. 30**_Clinical situation, FP 3 /4 acc. to C.E. Misch.
**Fig. 31**_Peek parts on the stumps.
**Figs. 32a & b**_Porcellain fused to metal bridge with PEEK secondaries before glueing together.
**Fig. 33**_Finalised bridgework.



**Fig. 34**_Combination of Locator® abutments and prefabricated conical crowns for better stabilisation.
**Fig. 35**_Remanufactured mandibular denture.

causing pain. Later, two more implants were placed anterior because of the patient's request for a better stabilization of his prosthesis. However, the construction on four implants with Locator® attachments brought only a little improvement. Still, the patient was not 100 per cent satisfied, even though the prosthesis was underlined and perfectly fitting the jaw. Later, to eliminate the tilting movements in the distal jaw area during mastication, two Locators® were replaced by a prefabricated cone crown system with PEEK secondary parts (Fig. 34).

The immediate stable position and the perfect fit of the mandibular denture were amazing. Finally, the patient got the desired result, which was within his personal budget (Fig. 35).

## _Discussion

In recent years, a variety of proposals for affordable dental implant solutions for the patient are made according to Held. If one earlier estimated that four implants are necessary for a stable construction in the mandible, we are confronted with concepts varying from All-on-4 ® (Paolo Malo) to "All-on-One" ("Better one than none") e.g. a multicentre study by the University of Kiel, Prof. Dr Matthias Kern. The aim of the study is to provide more and more patients with a cheap and simple reconstruction in limited indications such as a very strong distal atrophy of the mandible. In general, money-saving reduced implant solutions have the disadvantage that the loss of a single implant already leads to a complete redesign and start from the beginning. This has to be considered during the complete planning process. A construction of two implants only with the use of pre-fabricated parts is—at least in the lower jaw —a good compromise between a minimal solution (one implant) with a very restricted indication and an only moderate stabilisation and prosthetic cost effective solutions that are based on at least four implants. The new high-performance polymer PEEK offers in combination with prefabricated conical crowns many ways especially with the use of CAD/CAM technology to expand the prosthetic range on a low-cost basis. The corrosion phenomena when using non precious metals/Eco gold can be avoided.

## _Conclusion

The bar prosthetic construction in the mandible propagated by Ledermann (1979) is currently the only scientifically validated indication. Every other described technique still requires further clinical testing and scientific evidence of their suitability.

The here described treatment option should combine the advantages of a high-quality implant restoration with the advantages of low-cost simple fabrication. The use of prefabricated components and the use of a new cost economical material enable well-fitting stable constructions, especially in cases of advanced mandibular atrophy. New indications like cement and screw less fixed solutions are of special interest and very challenging. Ceramic veneers can be fused to the secondary parts also in cases of removable bridges and avoid chipping.

New materials in the implant prosthetics will continue to offer new additional possibilities. Here, the imagination of colleagues for further development is almost not limited. The use of ceramic veneers fusing to the secondary parts in the front area is risky (chipping). There is still much to do. Let's do it!_

*Editorial note: A list of references is available from the publisher.*

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