Aesthetic restorations using various all-ceramic-systems

There is More than one Way to Achieve Aesthetics

A contribution from Ralf Dahl, MDT, Duesseldorf / Germany

CAD / CAM and aesthetics do not contradict one another; they complement each other. Therefore it is possible to produce aesthetic work where the aesthetics shine through right from the start of the framework construction and throughout the ceramic build up procedure. It is important to have good knowledge of the physical properties and the different framework materials as well as the ceramic materials; it is an important precondition for the planning and manufacture of high quality restorations. It is possible to improve ones skill in using the ceramic materials and through individual ability to achieve impressive aesthetic results. Nowadays most ceramic materials offer many options for aesthetic individual solutions. Ralf Dahl, MDT finds the Initial-Ceramic-System offers the best possibility for producing aesthetic and natural ceramic restorations. By building up the ceramic material up logically, with respect to its individual properties this ceramic offers great creative potential and can be considered a very future orientated material.
But do we use the flexibility of this material to its full potential and more importantly – do we use it correctly? Ralf Dahl, MDT has studied the use of CAD / CAM with ceramic and would like to introduce his technical solutions with the following patient cases.

Key words: Aesthetics, CAD / CAM, natural analog build-up technique, all-ceramic, zirconia dioxide

The history of ceramic and all-ceramic materials

By the 7th Century, ceramic had already been discovered in China, however it was not until 1708 that "European Porcelain" was invented after *Friedrich Boettger* deciphered the composition of Chinese Porcelain more than 1,000 years later. It was another 100 years before Ash produced the first metal ceramics in England in 1838.
Afterwards the intervals between the developments of new and innovative ceramics in dentistry got shorter. The all-ceramic stage began with the development and production of the first ceramic inlays around 1857. Eventually, one by one the Dicor glass ceramic, Inceram, Empress 1 and 2, E-max, press over ceramics and many different ceramic layering materials were introduced.

Over the years the pure sintered ceramic has established its position in dental technology due to its excellent physical and aesthetic qualities. Added to which, we are able to construct very precise all-ceramic full and partial crowns, veneers and inlays, which can replicate the construction of a natural tooth, thanks to suitable duplicating systems and adaptable fire resistant investing materials. In 1965 *J.W.McLean* and *T.H.Hughes* developed an oxide-reinforced ceramic and after further development doubled its strength.
Then *Ron Garbie* in England had the idea to mix zirconia oxide and yttrium oxide thereby increasing structural strength due to the stabilisation of the conversion phase of the structure. The flexing strength and the fracture toughness have test figures that can be compared with steel. In dentistry these materials have been in use since the middle of the nineties.

Fig 1 to 3
In order to achieve the precise fit of zirconia frameworks, certain necessary conditions must be met. The prepared dies need to have an ideal and soft shape, with rounded edges, a sufficient hollow occlusal area and sufficient space.

Fig 4
Steep and parallel walls, guides or square reinforcements are not suitable.

Fig 5
If all the parameters are strictly followed a good milling centre can achieve fits like this.

The instigator in this area of the dense structure all-ceramic was without doubt In-Ceram. However this system is a glass infiltrated oxide ceramic. The strength is increased through infiltration with lanthanum glass.

The way to the future

The development, the introduction and the protocols of oxide ceramics have given us great challenges. By using this technology we can justify the ever-growing demand for metal free ceramic restorations in many of our cases.

New technology always comes with certain risks as well as technical fascination – particularly if we understand only a little about the material, the physical connections and the correct protocols of manufacture: zirconia oxide for example. I think through computer guided measuring and milling techniques we can achieve outstanding quality these days. The question of where have we arrived in the development of all ceramic systems remains unanswered, just as no one can judge realistically what the next generation of computers will look like.

One goal will be to analyse and interpret many different bite samples and correlate the appropriate condyle movements in order to put into functional action a computer guided and patient individual occlusal relief. This refers to an occlusal relief which merits the name according to the principles of recent functional studies.

Our biggest challenge in the future is to make certain we remain open to technical challenges and to make sure we use the opportunity to make individual, aesthetic, patient and functional use of our never-ending creativity.

CAD/CAM

There are some necessary conditions required for the manufacture of a precise zirconia dioxide framework. I am not claiming to know any rules for dentists on preparation, however technicians require some necessary basic shapes in order to be able to adapt the material and manufacturing procedure to the preparation.

The software is not always able to convert difficult geometrical shapes and this can cause delays in the refining process. Also the fitting procedures for the frameworks become more difficult and can result in unsatisfactory marginal fits.

The prepared dies must have an ideal shape for the scanning procedure to manufacture an exact milled framework (Fig 1). We need soft shapes, rounded edges, a sufficient hollow occlusal area and enough space (Figs 2 and 3). Steep and parallel walls, guides or square reinforcements in the area of the Isthmus are not very suitable (Fig 4). If all parameters are strictly followed a good milling centre can achieve an exact fit (Fig 5).

Fig 6
The same conditions apply when designing a zirconia oxide framework as for a metal ceramic one – the anatomical support is important.

In order to achieve precision, the quality and the manufacturing of the materials are crucial. Therefore the question arises to whether there are different qualities of blanks.
Amongst others Thailand and Australia are source countries for the raw material.
The material is refined in Japan. At the Swiss company Metoxid the zirconia oxide is made into blanks. The steps of refining are very demanding. The purity of the material, or rather of the raw material, is of utmost importance.

It is important that quality blanks start out with a good particle fineness ratio. This should be under 100 nm. Quality blanks give us a long-term security and reliability according to the figures gathered regarding the longevity of the physical properties. Therefore we must hope that even the cheaper zirconia oxide frameworks are manufactured of high quality materials!
The firing process plays a big part with regard to the correct temperature and the timing during the sintering of the material. The goal is to always achieve the best density of the zirconia dioxide, over $6.0 g/cm^3$. This final density is responsible not only for the final physical strength, but also for the "glassy" optical effect. A direct back tracking of the monocline in the quadrangular condition is rather unlikely. An improvement of the physical body through the closing or "healing" of micro cracks is still possible. However this effect has not been proven scientifically.

Through the thermal treatment of the existing additional constituents of the zirconia dioxide a certain "healing" process may occur. I think it would be sensible to do a relaxation firing at around 1050 degrees. What does one have to pay attention to when manufacturing a zirconia dioxide framework? The most important criteria is the anatomical design of the framework – something we already understand with metal ceramics (Fig 6). It is imperative that the correct adjoining section of the connectors is maintained!

Anterior tooth bridge 7 mm^2, posterior teeth bridge $9mm^2$, bridge with two links 12 mm^2
The vertical height of the connectors between crowns and bridge link must be at least 3 to 3.5 mm.

The zirconia dioxide layering material is not very forgiving if the design of the zirconia dioxide framework is not right. A wrong design can cause a so-called chipping or fracturing of the layering ceramic. There are two possible ways to manufacture anatomical frameworks – one is to use a digital wax knife. Using this technique the software takes control and extends the frameworks in the important areas and will place the pontics individually. The other option is to wax-up the zirconia dioxide framework with wax (Figs 7, 8a and b, as well as 9a and b). This is the most precise solution, but also the most demanding one.

First the data is read from the dies and the pontics, then the double scanning procedure is carried out using the data supplied from the wax-up. This is how a copy of the waxed up situation develops. Figure 10 shows a zirconia dioxide framework, which does not have a sufficiently good shape anatomically. The overhanging, unsupported area is too large to build up, making it very likely that the ceramic will chip.

How do I plan a prosthetic restoration?

This can only happen by working closely with the dentist and by considering the patient's requests. At the planning stage, it is important that the dental technician sees the patient for shade matching before starting the prosthetic restoration. During conversation with the patient the shape, length and the positioning of the teeth should also be discussed. Consequently, this helps determine the final outcome in achieving a realistic final goal. I would like to demonstrate, using some examples of patient cases, the methods and also the limits of the different techniques as I have found in my experience.

Fig 7
The starting situation. There are two possible ways to manufacture an anatomical framework. One is with a digital wax knife …

Figs 8a and b
… the other solution is to wax-up directly in wax.

9a and b
show the result in ZrO_2.

Fig 10
The zirconia dioxide framework has been poorly designed. Anatomically it is not shaped enough. It is almost certain the ceramic will chip.

Fig 11
The first patient case: upper and lower full / full restoration.
The vertical dimension has been lost through use over the years.

Fig 12
The starting model …

Fig 13
… has been duplicated and on it a diagnostic wax-up has been made.

The first patient case: Upper and lower full/ full restoration (Fig 11). The patient presents with a stable periodontal situation and with very good oral hygiene. The vertical dimension has been lost through use over the years. Through splint treatment a new physiological centric has been reconstructed. To aid the pre-treatment all insufficient fillings have been removed.

Planning

In order to better plan the final work the starting model (Fig 12) has been duplicated and a wax-up has been done (Fig 13). Functional and aesthetic demands are the main focus. An acrylic model has been produced in order for the patient to get a better and more understandable representation (Fig 14). For this, duplications are made of the waxed-up models. After removing the duplicate, the arch is filled with a lighter tooth shade of a K+B material. After setting and removing the arch of teeth we need to trim the areas underneath the gingival hem extremely conically and return to the mould. The missing parts of the model are filled with pink acrylic. After working on and polishing we have the model (Figs 15 and 16). The patient now has a much clearer idea of how the finished prosthetic result will appear than with a waxed-up plaster model. For this patient case we decided to use two ceramic systems. The planning stage in detail (Figs 17 to 20): In both the upper and lower anterior teeth, for 34 and 44 a sinter based all ceramic has been used and for the remaining posteriors we have used zirconia dioxide. Why? The answer lies in the strict indication of the different all-ceramic systems. Both systems have their own advantages and disadvantages, which I would like to explain in more detail.

Figs 14 to 16
The patient has difficulty envisaging the outcome from a wax-up – he is not a dental technician or a dentist – so we convert it to an acrylic model

Fig 17
The planning stage: All-ceramic crowns 13 to 23, 33 and 43 sinter based veneers

Fig 18
The vertical space relationship

Fig 19
For 44 an all-ceramic partial crown has been chosen, 46 will be a zirconia dioxide crown with 47 as a zirconia dioxide pontic, the width of a premolar tooth

Fig 20
Teeth 34 and 35 will be all-ceramic partial crowns, 36 to 38 will be zirconia dioxide crowns.

Fig 21 During the preparation the quadrants were dissolved one by one and the bite register secured over the existing splint. The exact position has been captured with Pattern resin and Impregum. Through this kind of procedure the carefully established centric has been fixed securely.

At the preparation the quadrants were dissolved one by one and the bite register secured over the existing splint (Figs 21 to 23). The exact position has been captured with Pattern resin and Impregum. Through this kind of procedure the carefully established centric has been secured. Figure 22 shows a flat impression and figure 23 the precision of the bite register on the models.

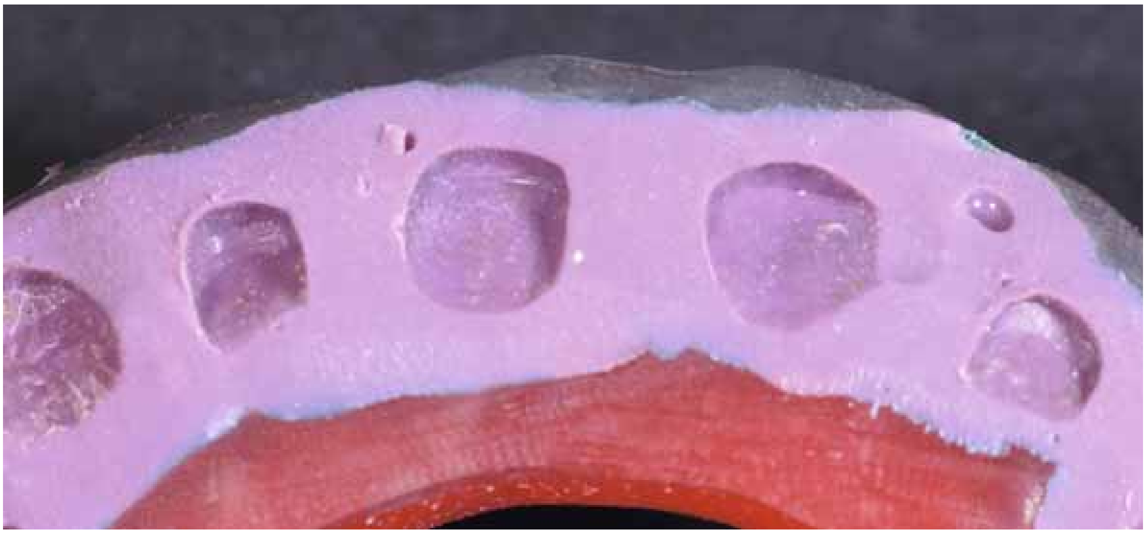


Fig 22
The impressions of the centric bite in detail

Fig 23
The precision of the bite registration on the model is clearly visible here.

	Sintered ceramic	Oxide ceramic, e.g. zirconia dioxide
Advantages	• The tooth colour can be reproduced in very thin and defined layers from the base. • The tooth shade of the base framework can be very individually manufactured. • The die can be coated in opaque, which is very important on a non-vital and darkly stained stump. • The fit can be produced very precisely. • Because of a several staged crystalline structure the ceramic is best etched and silanated. • Economically it is an attractive option for manufactured tooth restoration. • Aesthetic advantages when making veneers	• Extended indication through high flexibility strength up to 1300 MPa • Best physical figures regarding the resistance and the pressure resistance at the height of the bite of up to 1200 N • The possibility to conventionally cement the restoration • Manufacture of bridge construction without tension
Disadvantages	• Glass based ceramics can only work if they are fitted with “lege artis” made for purpose adhesive. • Restrict indication, because of their corresponding flexible strength	• The minimum thickness of the framework can not be breached, therefore there must be sufficient over all thickness. • Oxide ceramics are one stage, one component metal oxides > 90% • They have none or minimal glass, therefore they can not be etched, therefore it does not make sense to have an adhesive fit.

Figs 24 and 25 The master is sectioned and blocked out with wax and duplicated with Coppi Sil, a 1:1 addition cured silicone, then the fire resistant die is been made of Cosmotech Vest.

Fig 26 After sintering the die the coupling agent is applied to the dry die.

Fig 27 The fired die

Figs 28 and 29 The first relevant colour layer is built with internal material – high chromatic, fluorescent dentine – in the cervical area. Towards the middle third this layer flares out thinly. The light breaking edge needs to be covered with Flue Dentin. For lighter shades for example FD 91 is used.

Fig 30 The labial area is thinly layered with dentine.

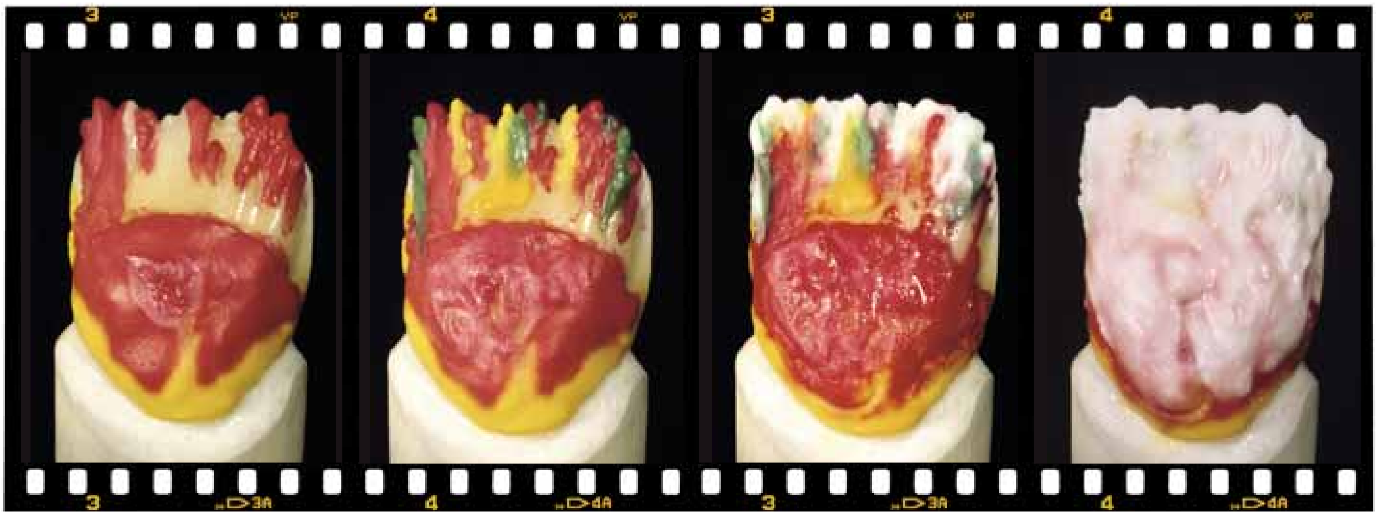
Fig 31 The result after the first firing

Layering scheme – Layering philosophy

I will explain the natural analog layering technique, which is used for all the ceramic materials in the GC range, by building up a veneer. This layering philosophy copies the natural build of a tooth. Tooth sections are ideal to demonstrate the exact structure build-up.

The master is sectioned and blocked out with wax and duplicated with a 1:1 addition cured silicone. After that the fire resistant die is made (Figs 24 and 25).

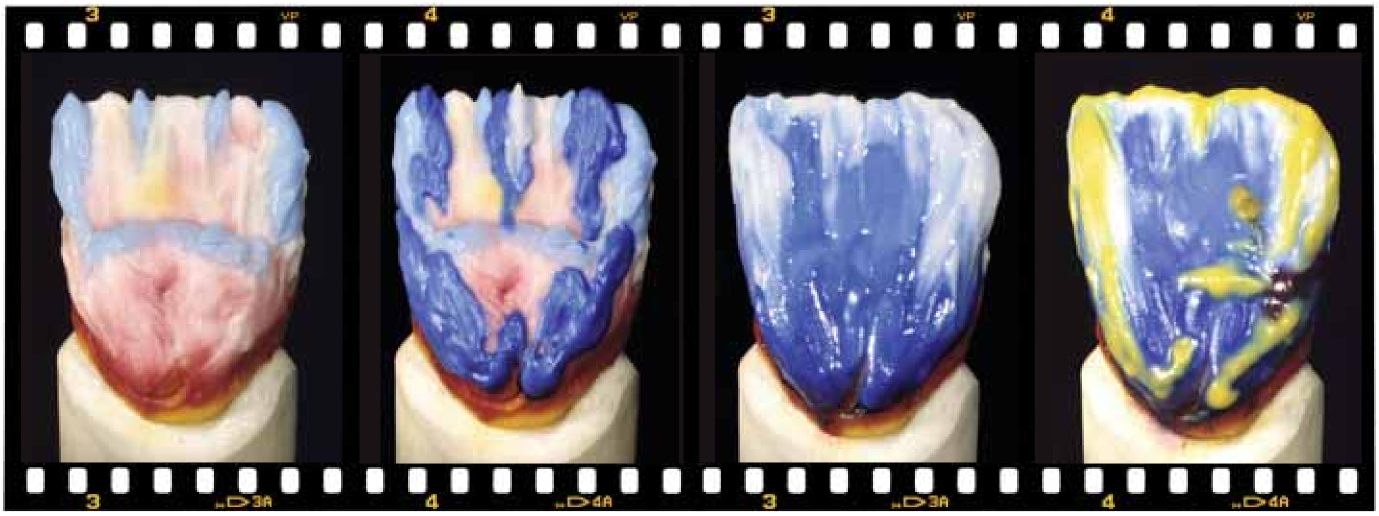
After sintering (Fig 26) the coupling agent is applied to the dry die (Fig 27). The first relevant colour layer is made with internal material (high chromatic, fluorescent dentines) in the cervical area. Towards the middle third this layer flares out thinly. The light breaking edge needs to be covered with Flue Dentin and the labial area thinly layered with dentine (Figs 28 to 30). Then we have the first firing (Fig 31).



Figs 32 and 33 Correction firing: the whole labial surface is built up with dentine. The restoration will appear colourless very quickly if there is too little deep chroma and dentine.
The incisal mamelon structures are applied (green, yellow).

Fig 34 In between the areas of the finger shaped structures is built up with EOP 3 for example. Within the primary dentine and the dentine structures you will always find alternating concave and convex areas, giving it its own light dynamic which develops through the "minimal layering"

Fig 35 The CLF Layering: a clear, fluorescent ceramic – the key for gathering light – is built up between Dentine and Enamel.
The same structure build-up is also found in a natural sectioned tooth and is referred to as "sclerosed dentine".



Figs 36 and 37 The exchange of enamels during the layering has the effect of making the incisal area more lively. The light dynamic develops through ceramic materials that have different reflection behaviours and also the individual colour that lie either in the convex or in concave areas.

Figs 38 and 39 The final layer using and opal material or a mixture of opal and enamel porcelain or cervical translucent in the cervical area.

For the correction firing the whole labial area is built up with dentine (Fig 32). The restoration will quickly appear lifeless if there is too little chroma and dentine from within. Of course it depends of how much dentine is used and on the expansion of the given decree of space. Mamelon structures are applied in the incisal area (Fig 33). The area in between the finger shaped structures is built up with EOP 3 for example (Fig 34). The structures within a build up layer should never be applied in straight lines. This means that within the primary dentine structure and the dentine structure there are always alternate convex and concave parts. In this way even when using "minimal layering" the reflection behaviour develops its own light dynamic in different areas. The most important layer between dentine and enamel is achieved with CLF – a clear, fluorescent ceramic (Fig 35). It is intended to mimic the "sclerosed dentine", which appears in natural teeth between the dentine and enamel. The exchange of enamels during the layering has the effect of making the incisal area more lively (Figs 36 and 37).

Fig 40
First main firing cycle

Fig 41
Second firing cycle: In order to prepare for the glaze firing the margins are finished precisely under magnification.

Fig 42
Finished veneer – fitted to the master die. The glaze is mechanically adjusted.

Fig 43
Patient case: prepared situation 11 and 21 for veneers

Fig 44
Finished fitted work

Fig 45
Back to our complex patient case from page 14 – the starting situation

Fig 46
The finished restoration on the model. There is no noticeable colour difference between the different systems.

The light dynamic develops through ceramic materials that have different reflection behaviours and individual colours that lie either in the convex or in the concave areas. The final layer is built with opal porcelain or a mixture of opal material and enamel with cervical translucent in the cervical area (Figs 38 and 39). Then the main firing cycle is done (Fig 40). The second firing cycle is the base for the glaze firing cycle. All margins are finished off precisely under magnification (Fig 41). After the glaze firing cycle the veneer is fitted down on the master die and adjustment is made to create the optimum grade of glaze (Fig 42). Fig 43 shows a prepared situation and Fig 44 proves how naturally the veneers fit in to their surroundings.

Here we have the starting situation of the very complex patient case described previously (Fig 45). Even here, despite the different ceramic systems used, there is no noticeable colour difference (Fig 46).

Fig 47 Tooth 44 has been restored with an all ceramic partial crown, 45 has been restored with a zirconia dioxide crown with a reduced cantilever (47).

Fig 48 Tooth 35 all ceramic partial crown, tooth 36 and 37 zirconia dioxide crowns

Fig 49 From 11 to 13 sinter based all ceramic, from 14 to 16 a zirconia dioxide bridge, 15 is a pontic and tooth 17 is a zirconia dioxide single crown.

Fig 50 The palatal shape of the anteriors corresponds with the function pattern of the patient.

Fig 51 The complete finished and fitted restoration – certainly much better aesthetics

Tooth 44 has been restored with an all ceramic partial crown, 46 and 47 have been restored with a zirconia dioxide bridge and 47 is a cantilever (Fig 47). In the third quadrant the second premolar has been restored with an all ceramic partial crown. From tooth 36 to 38 zirconia dioxide crowns have been placed (Fig 48). Teeth 11 to 13 have been restored with sinter based all ceramic, the posterior area in the first quadrant (14 to 16) has been resolved with a zirconia bridge. Tooth 17 is a single crown made of zirconia dioxide (Fig 49). The palatal shape of the anteriors corresponds with the patient's pattern of function (Fig 50). The finished restoration highlights the improvement made to the aesthetics (Figs 51 to 55).

Figs 52 and 53
For comparison: the situation before…

Figs 54 and 55
… and after the restoration

Fig 56 When is zirconia dioxide most appropriate? Here is a suitable starting situation.

Fig 57 The prepared teeth offer sufficient space.

Fig 58 The finished work: two linked zirconia dioxide crowns

Fig 59 When should I select sinter ceramic? Note the dies on a sectioned model: there was very little room for the labial build-up.

CAD / CAM or sintered ceramic?

Indication for zirconia dioxide crowns – a new case: This patient's central anteriors are not good (Fig 56). The female patient has had orthodontic treatment to move the laterals to take the place of the centrals. This is also clear to see in the picture with the incisal preparation of the teeth (Fig 57). To avoid a relapse the two zirconia dioxide crowns are linked and fitted (Fig 58). It was difficult to design the papilla in the 11 and 21.

Indication sinter ceramic – another case:
The teeth 12 and 22 needed to be replaced (Fig 59). For the restoration sinter ceramic was selected. The dies were slightly discoloured and therefore had to be lightly opaqued. The base colour had to be built up deliberately with high chromatic materials, due to there being very little space available in the labial area. Therefore, there should be a complete layering thickness of under 1mm. Figure 60 shows the crowns on the master model. Despite dark stumps, after the fit it is noticeable that a corresponding light and radiant colour has been achieved in accordance with the neighbouring teeth (Figs 61 and 62).

Fig 60 The crowns made with sinter ceramic on the master model

Fig 61 Detailed view of the tooth 22 in situ

Fig 62 Finished work after fitting. Despite dark stumps and insufficient space, a light and radiant tooth colour has been achieved in accordance with the neighbouring teeth.

Figs 63 and 64 Sinter ceramic or zirconia dioxide ceramic? When the patient presented she did not like the shape of the centrals. She considered the incisal "triangle" of tooth 12 too large and the mesial rim of 11 angled too heavily on the distal. Also tooth 21 was slightly darker than 11 and the incisal edge was built up with composite.

Figs 65 and 66 The prepared teeth: Best possible preparation shapes with clearly prepped borders

Indication sinter ceramic or zirconia dioxide ceramic:

The patient did not like the shape of the centrals because she considered the incisal "triangle" of tooth 12 too large. Added to this the mesial rim on 11 was angled too distally (Fig 63). Figure 64 not only shows that tooth 21 is slightly darker than tooth 11, but also that generally both teeth were made slightly too dark – plus the incisal edge was built up with composite. First the stumps were prepared to allow clear access to the preparation borders. There was nothing in the way to prevent achieving a perfect impression (Figs 65 and 66). In this case both types of restoration would certainly have been possible. The preparation suits sintered ceramic as well as zirconia dioxide crowns (Figs 67 and 68). There are certainly no problems for the clinician in fitting the sintered crowns "lege artis" in this kind of restoration. It is also possible to cement the zirconia dioxide crown. In respect of the aesthetics, either type of restoration would give a perfect final result. In the end we decided to go for sinter based crowns, adhesively fitted. During the aesthetic try in at the laboratory the patient was offered the opportunity to have the diamond removed (Fig 69).


Figs 67 and 68 The master models

Fig 69 The finished crowns after the final fit. In order to enhance the aesthetic result at the aesthetic try in I suggested to the patient that they remove the diamond. By the way these are adhesive fitted sinter based crowns.

Final remark

Our job offers us the possibility to use innovative techniques and to develop them further. The individual creativity of each person offers us a very varied and artistic field of activity. May be the work we are doing at the laboratory today will soon become obsolete, but there is one thing won't change in the future and that is the high expectations which are expected of us.
The demands of our dentists and patients for high quality, individual, functional, well fitting and aesthetic tooth restorations will always be there! These demands for high quality are the same for CAD/ CAM as for other techniques. Which ever way dental technology develops in the future it will be exciting and it will be exciting for us – but what a big challenge it offers!
Let's take it!

With gratitude

Many thanks for the great cooperation between our dentists' teams. Constructive and trustworthy cooperation encourages us always to manufacture high quality work for our patients.

About the author

Ralf Dahl, carried out his education to be a dental technician from 1981 until 1985. From1985 to 1988 he honed his knowledge in a commercial laboratory with the main focus on crown and bridge, ceramic and telescopic work. From 1988 until 1989 he worked as a dental technician in private practice until 1990 when he was a dental technician in a managerial position. One year later he successfully completed his masters exam at the Duesseldorf Master School. Since 1994 he is a part owner and manager of MB Dental Technik GmbH. He is a member of the “dental excellence- international Laboratory Group” as well as of the DGAZ. Ralf Dahl is a tutor of practical work shops nationally and abroad. He specialised in lectures on the topics of ceramic layering, all ceramic and composite. His specialities are: polychrome layering technique in the areas of ceramic and composite, functional and aesthetic manufacturing of all ceramic inlays, onlays, veneers and full crowns as well as the production of layering with oxide ceramics on crowns and bridges.

Product list

Indication	Name	Manufacturer
CAD/CAM-System	Everest	KaVo
Duplicating material	Coppie Sil	Dentona
Investment	Cosmotech Vest	GC Europe
Plaster	Fuji Rock	GC Europe
Ceramic materials	Initial	GC Europe

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