Success factors in perfect ceramic firing

Keywords
Metal ceramics, veneering ceramics, ceramic firing, test of the degree of firing

Over the course of time, there are certain tasks that we carry out automatically, without being aware of it. We develop routines to keep our minds clear during our daily activities so that we do not need to think about every single step. As long as the correct result is achieved, there is no reason for us to make any changes. However, if there are problems, we should take a closer look at our processes and investigate why problems have occurred.

The aim of this article is to support dental technicians involved in the fabrication of ceramic veneer restorations in evaluating and mastering important parameters in ceramic firing. Beginning with the firing process, the goal is to raise awareness of the individual steps and success factors that influence a successful outcome in ceramic restoration work, and to provide criteria that allow users to analyze their own approach[1].

The firing process – what actually happens inside the furnace?

The firing process is comprised of four steps, which are summarized and illustrated using a heating microscope in Fig. 1:

1. The test sample made of veneering ceramic (picture A) is initially cylindrical. It then begins to shrink, at a temperature that varies depending on the ceramic.
2. The actual sintering process begins (picture B). As the temperature rises, the initially square, sharp-edged contours shown in the silhouette become more and more rounded.
3. Bridges then develop that link to adjacent particles of the powder, and the ceramic particles "bake" more closely together. During this preliminary phase prior to complete fusing, the volume of the ceramic shrinks by approx. 10 % to 12 % (picture C).
4. As the temperature rises, the contours increasingly blend together, and the sintering process slowly develops into a melting process until the silhouette of the test sample takes on the shape of a hemisphere (picture D); the melting point is reached.

The specified maximum firing temperature is, however, considerably lower than this melting point. Accordingly, the fully-fired dentin material also contains areas that are not completely fused. Transparency and shade intensity depend on the proportion of glass-phase matter within the structure. Both become more intensive as the proportion of glass-phase matter increases.

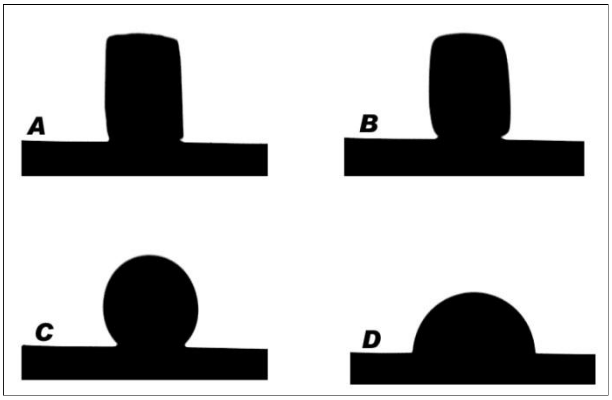

Fig. 1 Heating microscope images for the determination of temperature-related deformation behavior during the individual sintering steps for veneering ceramics: (A) Initial shape of the cylindrical test sample comprised of veneering ceramic; (B) The sintering process begins, contours that are initially sharp-edged become round; (C) The contours increasingly blend together; (D) The sintering process slowly develops into a melting process until the silhouette of the test sample takes on the shape of a hemisphere.

Our eyes only notice the transparency and shade intensity. These differences are often only attributed to the final firing temperature. However, other factors have an impact on the ceramic. The degree of firing of a dental ceramic depends, in addition to this final firing temperature, on other parameters that are described below.

Exact adherence to the pre-drying time

Urgent deadlines are a common occurrence in dental laboratories. However, those who take shortcuts when it comes to the pre-drying time are automatically accepting flaws in the final outcome, as this approach has a crucial impact on the resulting ceramic (Fig. 2). This is because the surface of the ceramic is already fused, and liquid and air within can no longer escape. Air bubbles as well as

[1] Further details are available in: Michael J. Tholey, Norbert Thiel: Firing dental veneering ceramics. Quintessenz Zahntech 2009;35(8):1018-1029.

modeling liquid residue remain within the material as a result. Longer pre-drying is a very simple way of solving this problem.

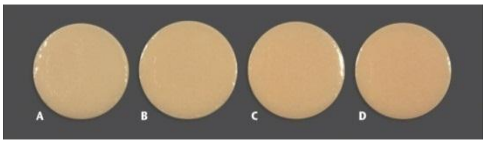

Fig. 2 Clear differences in terms of shade due to different pre-drying times with the same ceramic material: A: Without pre-drying, B: 2 minutes, C: 4 minutes, D: 6 minutes.

The correct lift position

If a restoration is not exposed to sufficient heat during pre-drying, so that the air and modeling liquid between the powder particles can escape, the ceramic will be too damp when the heating process begins in the firing chamber. Very small air bubbles and residual modeling liquid remain inside the ceramic. Due to the increased refraction of light near the air bubbles, this can cause the veneer to become cloudy (Fig. 3). This is why it is important to adhere exactly to the specified lift positions.

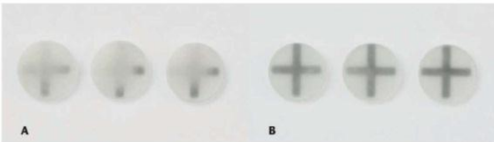

Fig. 3 Effect on transparency and shade effect when a crystal-clear material is not fully fired as a result of different lift positions (A: Furnace 25 % closed, B: Furnace 75 % closed)

Heating time and firing temperature

The degree of firing depends on the temperature and heating time. When heated slowly, the air in the ceramic escapes more easily. When heated too quickly, it is more difficult for the air present between the particles to escape, and the ceramic becomes cloudy (Fig. 4).

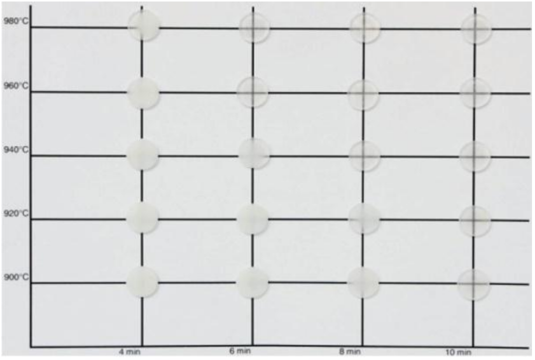

Fig. 4 Ceramic samples (Window material) with different degrees of firing depending on the heating time (x-axis) and temperature (y-axis)

The optimum hold time

Depending on the ceramic material, the optimum hold time is between one and two minutes; afterwards, the ceramic can become excessively sintered and may even fuse despite the relatively low temperature (Fig. 5). A restoration is perfectly fired when it has a slight shine and edges are visible. If the ceramic has been over-fired, then the edges are clearly rounded. An excess of glass-phase matter also has a negative impact on a number of physical properties.

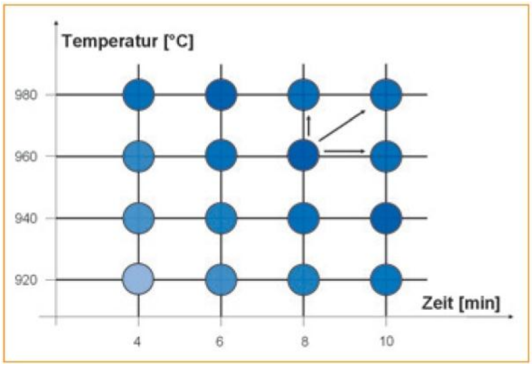

Fig. 5 Schematic view of the fired firing plates

Allowing the ceramic to cool slowly

The cooling time affects the coefficient of thermal expansion (CTE) as well as the thermal stress remaining within the ceramic. With dental ceramic samples that have been cooled quickly, a slightly lower CTE is measured than in those that have been cooled slowly. Slow cooling after firing relieves high levels of thermal stress within the veneering ceramic.

The view without a vacuum is clouded

Even if the firing parameters are otherwise identical, ceramic veneers that have been fired without a vacuum are considerably less transparent than those fired under vacuum conditions (Fig. 6). Without a vacuum, the ceramic remains milky and cloudy in appearance, as the air is no longer drawn out of the structure as is the case under vacuum. The reason for the cloudy appearance is the same as described earlier.

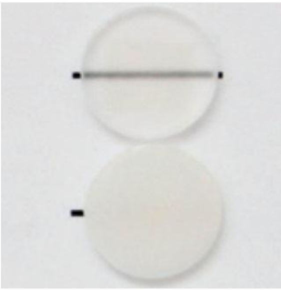

Fig. 6 Influence of the vacuum on the restoration; with a vacuum (see above), without a vacuum (see below).

Additives in the modeling liquid

All modern modeling liquids contain additives that improve the modeling properties, but which can significantly change the shade and transparency of the ceramic if the pre-drying interval is too short or if it is heated too quickly, or if the final temperature is too low (Fig. 7). It is therefore important that the liquid can escape completely. This allows the pre-drying time to be modified if a different modeling liquid is used.

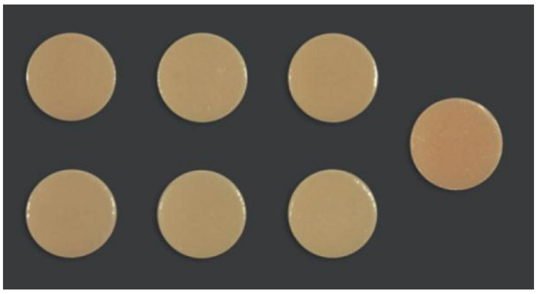

Fig. 7 Influence of different modeling liquids.

The framework – a smaller tooth shape for a defined layer thickness

The importance of the framework in a durable ceramic restoration where the shade does not fade is often underestimated. Only the ceramic-supporting design of the crown or bridge framework as a miniature version of the final restoration ensures an even ceramic layer thickness of no more than 1.5 – 2 mm

The size, dimensions and type of framework material are also factors in a good firing result. Accordingly, a larger 5-unit framework, for example, takes longer than a single crown to achieve the same level of heat penetration. In this case, extending the rate of climb somewhat during heating is recommended.

Testing the degree of firing provides for peace of mind

A particular phenomenon is regularly of concern to users: despite identical firing parameters, the firing results differ in terms of shade. With different types of furnace, this might be as a result of differences in design. In furnaces of the same model, this might be due to firing elements that differ in terms of age, for example, or as a result of different production lots.

The most effective way for the user to get to the bottom of observations of this kind is by testing the degree of firing[2,3]. This helps dental technicians to determine the optimum degree of firing in each of their ovens by themselves. An evaluation based on surface shine alone is not sufficient as it does not provide any indication of the degree of firing within the ceramic. The type of test described here is simple and can be easily reproduced in any dental laboratory.

Step 1: Cleaning firing in accordance with the specifications of the furnace manufacturer in order to reduce contamination as a result of different alloy components or the unwanted effects of contamination on the veneered restoration.

---

[2] Claus H. Ceramic dental materials prior to, during and following the firing process. ZWR 1985;94:612-616.
[3] Claus H. A simple test for verification of the grade of firing of the dental ceramic. Dent Lab 1997;45:245-248.

Step 2: A small amount of crystal-clear or transparent material is applied to a crown. In order to evaluate rounding, edges should also be modeled.

The temperature and heating rate of the furnace are correct when the firing sample is transparent, shiny and has sharp edges when it is removed from the furnace. If the final temperature is too high, the sample will have an "oily" shine, and the edges will be rounded (Fig. 8).

Fig. 8 Comparison of an incorrectly fired (left: underfired, poor vacuum) and a perfectly fired crown (right) with VITA VM 13 Window material.

If the final temperature is too low, or if the sample is heated too quickly, it will have a milky and cloudy appearance. The best way to approach a perfect result is to use 5 to 10°C increments. A new test sample must be modeled and fired each time firing is carried out, as once air is trapped inside the veneering ceramic, it can no longer be burnt out.

Summary

The relationship between firing ceramic dental veneers and the influence of the various firing parameters on the firing result is complex. The quality of the firing results can be influenced by changes in the parameters described, as long as the user follows a systematic and targeted approach when it comes to identifying and regulating these variables. If the firing result is still not as expected, despite following the processing instructions provided by the furnace and ceramic manufacturer, testing the degree of firing is the right starting point for identifying the reason.

First published: ZTM 18, 5, 260-263 (2014), Spitta Verlag GmbH & Co. KG, Balingen, Germany.

Author

Dr. Michael J. Tholey

VITA Zahnfabrik H. Rauter GmbH & Co. KG

Spitalgasse 3, 79713 Bad Säckingen, Germany