

Digital casting cone and sprue fabrication for 3D printed patterns designed for casting dental alloys

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Abstract

Background: In the contemporary prosthetics almost any restoration could be digitally designed, but the final process of materializing still encounters some serious obstacles. The conventional approach for pattern fabrication has many disadvantages and issues, that are overcome and solved by the integration of modern concepts, which utilize the CAD/CAM and 3D-printing processing.

Materials and Methods: For the purpose of the study STL-files of prior generated and morphologically different crown's patterns are used. The patterns are modified by non-medical software for 3D-editing by generating a custom-made, digitally-designed casting system and arranging its various components to the known casting cone dimensions. This allows all the components of the sprue system to be materialized as a single object.

Results. The designed sprue system is successfully materialized and prepared for investment.

Conclusion: The conventional approach by 3D printing of patterns is very convenient method, but there are some issues with the fabrication of the sprue system made of wax. These problems could be overcome by reduction of wax usage and digital designing of the whole sprue system and 3D-printing it as a single object.

Keywords: prosthetic dental medicine, 3D-printing, casting, casting system, digital design.

Background

In the contemporary prosthetics almost any restoration could be digitally designed, but the final process of materializing still encounters some serious obstacles. One of the most generally used approach is a fabrication of a pattern, that is later replaced by casting.[1] Modern concept usually utilizes materialized CAD models, that are milled by CAM or 3D printed and later those patterns are invested and casted.[2] And no matter that the accuracy of the patterns is acceptable, casting could not be considered to be an accurate method of conversion of objects due certain factors such as:

temperature changes, physical and mechanical interaction between the materials that are used, the residual ash remnants.[3,4,5,6,7] It is well-known that the wax, which is the most commonly used material for casting system fabrication, has the ability to flow and can be easily deformed by minimal temperature changes or even its weight.[8,9] The Castable Wax® (Formlabs™) is resin-based material, it contains at least 80% light-curing resin, which allows it to stay stiff when a higher temperature is reached and it doesn't flow.[10,11] Moreover, it is harder and more resistant to any mechanical forces than the wax, which is an important factor for result predictability as far as dental technician's work is concerned.[12] The major disadvantage of this approach is the wax that is used for fixation of the 3D-printed object to the casting cone. It can lead to dislocation of the casting system as a result of any forces that interact the sprue system or any temperature rises. Although the quantity of wax that is used during the presented approach is less than the conventional approach, proper orientation of the finished pattern into the casting mold could be challenged and any inaccurate position could result as a failure. Formation of the casting cone, casting sprues and the position of the compensatory chambers should be done according to the shape size and volume of the casting mold.[7] And as general all of them are made of wax patterns, which are known to be susceptible to thermal distortions that could alter the accuracy of position of the pattern during the stage of investing.

Aim

The purpose of the study is to demonstrate a digital method that utilizes post processing of the STL-file of the finished design and then a 3D creation, planning and proper distribution of the casting cones, sprues and chambers, according to the investment molds that are available in any lab.

Materials and Methods.

For the purpose of the study STL-files, containing digital full-contour crown's patterns of different types of teeth (in morphological aspect) are used. The patterns are modified by non-medical software for 3D-editioning - Autodesk Meshmixer® (Autodesk, Inc.). It allows 3D designing of different configurations of casting sprue system, as well as, the opportunity to arrange every single detail accurately at desired place to the walls of the casting ring and central thermal zone of the mold.

At the beginning STL-files of the CAD crowns are imported and aligned to each other and the known size of the desired casting ring. Then casting sprues and reservoirs should be designed and connected to the casting cone and crowns. Finally, the newly generated objects are ready for exportation to a new STL-file, in order to be prepared for materializing.

In our research a digital casting cone is created, which has the same diameter as the prefabricated one. Then six crowns (2 central maxillary incisors, 2 first maxillary premolars and 2 first maxillary molars) are imported into the 3D-editioning software and are prepared for vacuum-pressure casting. By using the Meshmix tool six direct sprues are generated. They are designed to be straight and 2,5 mm. in diameter, as

their length is set to be enough, in order to allow the distance between the most lateral points of the crowns and the prefabricated ring to be between 5 mm. and 8 mm. Fig.1.

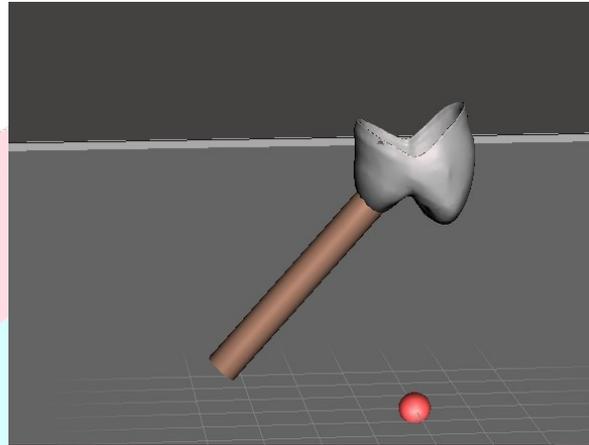


Fig.1. The digital projection of the sprue connected to the crown's pattern.

Afterwards, ball-shaped reservoirs are digitally made along the sprues by the Meshmix tool and are situated in a position to be within the thermal zone of the mold. Fig.2.

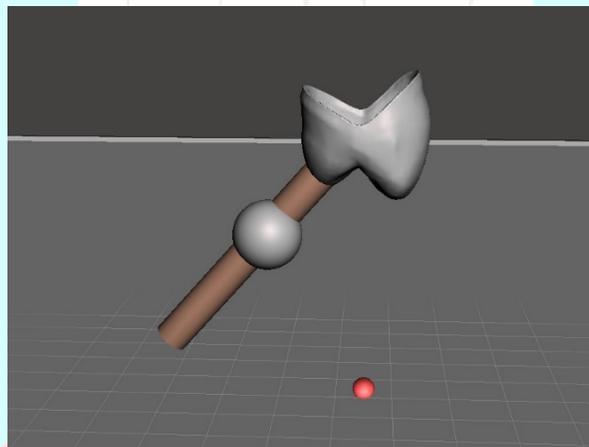


Fig.2. The crown's pattern with fixed casting sprue and a ball shaped reservoir created.

Once the desired object is generated the software activates the Transform tool that allows assignment of precise measurements of the different elements as it shown on the figure 3.

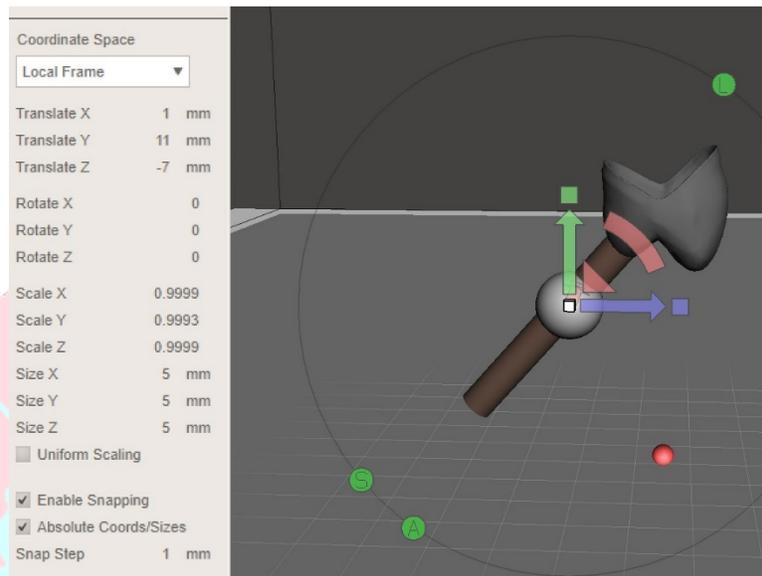


Fig.3. The size can be assigned at the three axes (x, y, z). The figure shows that the measurements of the ball-shaped reservoir are 5 mm. in diameter at x axis, 5 mm. in diameter at y axis, and 5 mm at z axis.

Then crown and the reservoir alignment check to the known size of the prefabricated casting ring can be performed. So, when the created sprue system is already connected to the casting cone, a grid integrated in the software or a special measuring tool that allows precise measurement of the desired dimensions can be used for alignment check. Fig.4

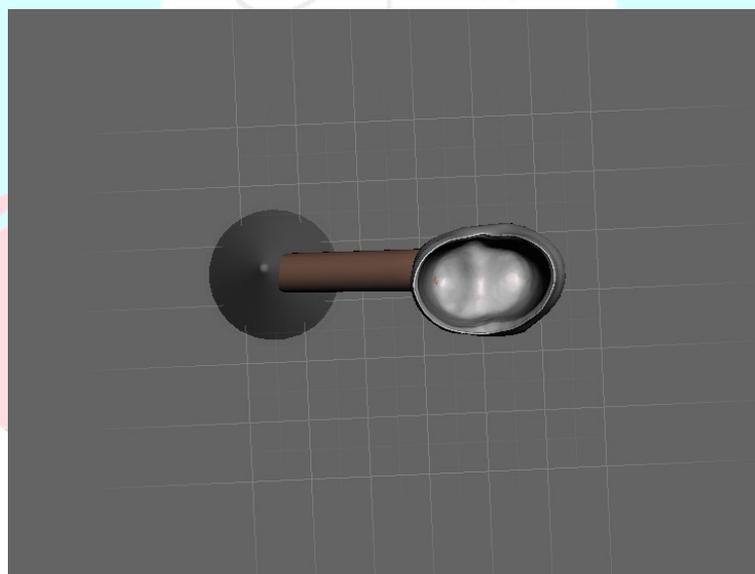


Fig.4 The crown is aligned to the known sizes of casting ring's walls. The available grid allows good accuracy in the crown placement.

If a better precision is needed, the software's Measure tool should be used. Fig.5.

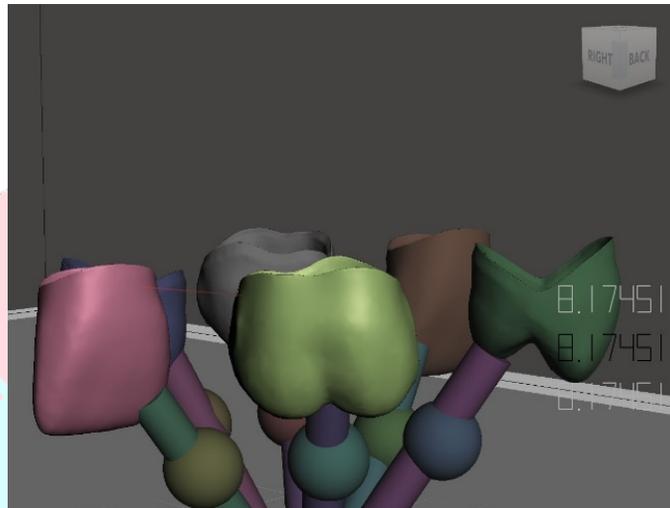


Fig.5. The space between the digital projection of the crowns is set to be 8,18 mm., measured by the a Measure tool.

As a result the casting system is designed to be in the best desired position in accordance to the dimensions of the pre-fabricated casting ring (Rapid-Ringless-System®, BEGO™). Fig.6.



Fig.6. Rapid-Ringless-System® (BEGO™) castable ring system - size 3, 55 mm. in diameter and 60 mm. height

The proper alignment of the first crown is followed by the same procedure done for the second and all of the rest crown's patterns, while a precise check of the position may be performed at any step if needed. All of casting system's details are generated and situated using the same method as described and the final result is shown on figure 7.

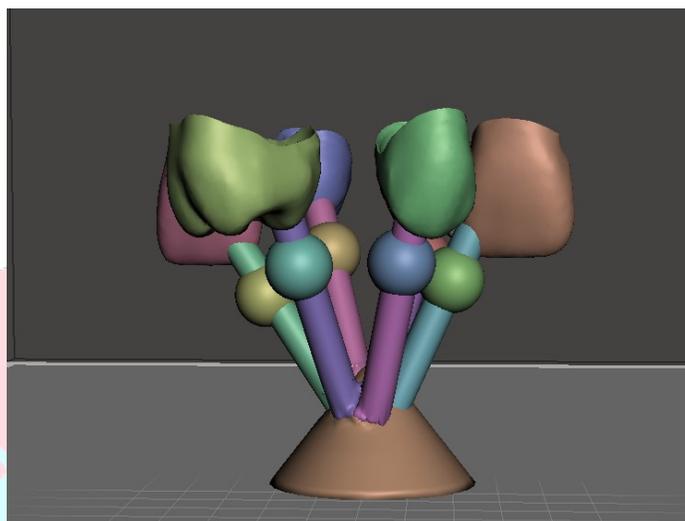


Fig.7. The figure illustrates a digitally designed casting system, which contains casting cone, sprues, ball-shaped reservoirs and described crowns.

Once the digital designing is done, a STL-file is generated and it is imported in the PreForm® software, where it is prepared for 3D-printing. The patterns are materialized by SLP technology, using 3D-printer Form 2® (Formlabs™), and the certificated resin for casting – Castable Wax® (Formlabs™).

Results

The sprue system is successfully materialized by using the described method. After cleaning the remnants of uncured resin by isopropyl alcohol the supporting structures are removed and the sprue system is prepared for investing. Fig.8.

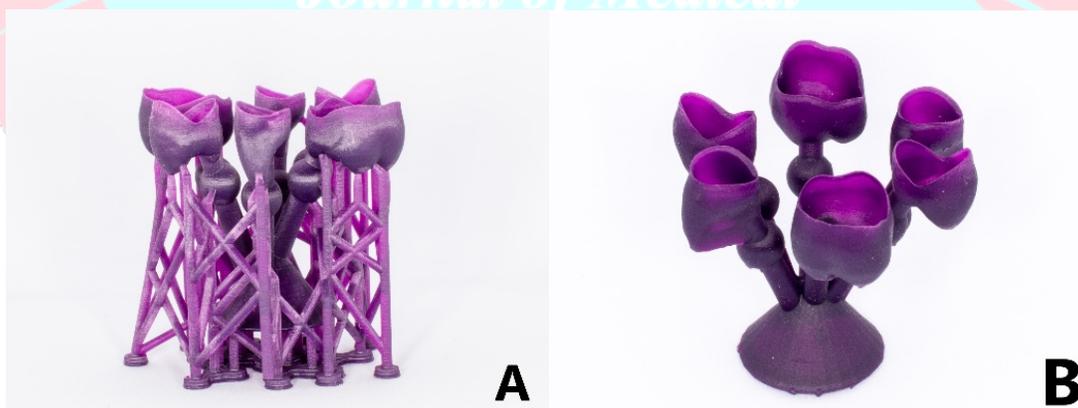


Fig.8. Illustrates the crown's patterns and casting system that are produced by SLP technology (A). After supporting structures removal, the digitally generated casting cone can be used as a base for mounting of the casting system to the prefabricated casting cone (B).

Then it is fixed to the prefabricated cone in proper position by wax. Fig.9.

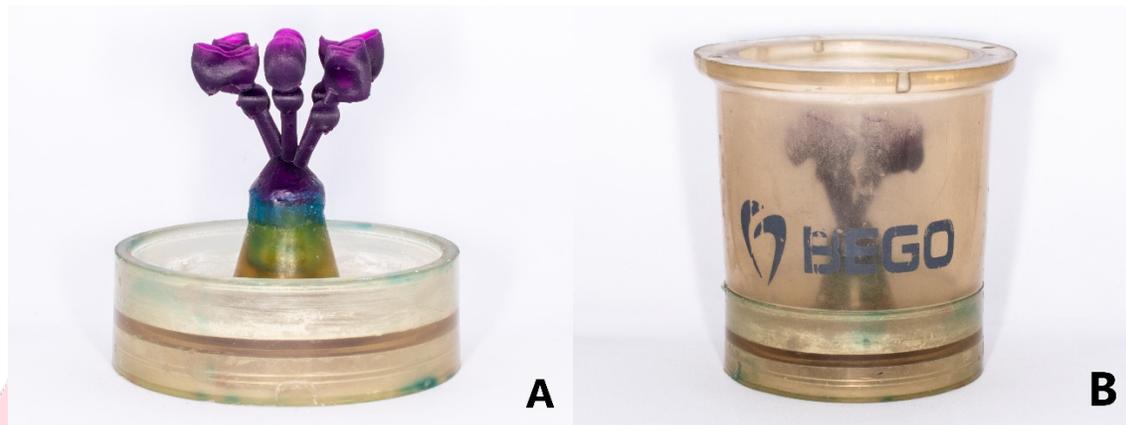


Fig.9. Casting system fixed to the prefabricated casting cone (A). Casting ring assembled to the casting cone (B). The thermal zone of the mold and ball-shaped reservoirs matching is visible when fig is observed.

Discussion

The digital casting system is designed in way that the parameters of the desired prefabricated casting ring are leading factor for detail arrangement. At the same time the software allows precisely measuring all of the parameters, which allows very accurate and objective arrangement of the different parts by the dental technician. Virtual designing also allows locating the central thermal zone of the mold, and the preferential zones for the patterns. When examining the casting system design, it is apparent that the feeder sprues are designed to be straight. Such a configuration is suitable because of that the vacuum pressure-casting machine is used. It is obvious that the software allows the casting sprue system configuration to be adapted to the casting technology in very accurate way, furthermore designing of more complex casting systems is also possible.

In addition, virtual designing of the sprue system prevents errors that are caused by the properties of the materials that are usually used for sprue system fabrication.

Conclusion

3D printing of patterns is very convenient method, but there are some issues like wax usage for casting system fabrication and it's feature to flow under any mechanical interaction or temperature rising that have to be considered, when this approach is chosen. Depending on poor mechanical properties of the wax, its use can be reduced, in order to achieve more secure approaches for 3D-printed patterns casting. Digital designing of the sprue system, is a reliable solution of this issue.

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