Feasible Study on Dental Restoration Using Time Compression Technologies

Nurul Hatiqah Harun
Mohd Shahir Kasim
Raja Izamshah Raja Abdullah
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia

Hambali Boejang
Hassan Attan
Faculty of Engineering Technology, Kampus Teknologi,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia

ABSTRACT

Time compression technologies (TCT) are concurrent engineering approaches employed during product and process development. TCT such as reverse engineering (RE) and rapid prototyping (RP) techniques are widely used in dentistry and medical sectors. Taking advantage of new technologies in computer-aided design (CAD) data, rapid mechanical prototyping makes it possible to fabricate complex shaped three-dimensional (3D) parts quickly using an RP machine. The current practice of dental restoration in dental laboratories is time consuming. Therefore, this paper presents the possibility of a TCT approach that can be applied to replace this conventional process in producing dental crowns. The TCT approach has been applied and compared to the conventional approach throughout this experiment. The TCT process is faster and simpler than the conventional process. The results show that the crowning process is difficult to be fabricated correctly. Problems arise due to the limitations of the Projet 3500 HD machine, which cannot build parts with a thickness of 300 µm or less.

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Introduction

Nowadays, the application of time compression technologies (TCT) in medical and dentistry is greatly expanding. Even though, the use of RP in the field of medical and dentistry has been slow arriving, the potential of the technique is seen to be widespread. TCT such as rapid prototyping (RP) refers to a class of technology that can automatically construct complex shaped three-dimensional (3D) parts from computer aided design (CAD) models [1]. The current manual process of dental restoration in dental laboratories is time consuming and required human skill. One complete dental crown might take several weeks before can be delivered to the patients.

The application of TCT in the field of dentistry is not a new thing. The technology has grown in dentistry since in the late 1980s due to the development of CAD systems accelerated by commercialization of portable computers [2]. Currently, there are two types of approaches that can be used to fabricate physical prototypes in dentistry which are subtractive and additive method. The used of additive method for dental modeling is more advantage compared than subtractive methods as it can produce more complex shapes within shorter time.

Therefore, this paper assesses the possibility that this modern TCT approach can be applied during dental crown fabrication. The main objective of this research is to produce dental crowns using an additive manufacturing machine (Projet 3500 HD) and to compare the conventional dental crown process against the modern approach.

Research Methodology

a) Pre-processing
   The impression sample is taken from the patient to be cast using dental stone, which is then mixed with water. The slurry of mixture is then slowly poured into the vibrating assisted impression mould to avoid any trapped bubbles. Next, the cast is left to cure for 30 min. Once hardened, the plasticine and impression trays are carefully removed. Figure 1 shows the plaster model of the teeth.

Figure 1: Plaster model

b) Reverse Engineering (RE)
The hardened plaster model of the teeth is then scanned using an RE brand Faro, model Faro Arm, serial number P08-05-08-41000. A non-contact digitizing method was selected because it is faster to digitize an image with 10000 point/sec than the contact approach method [3].

c) Data Manipulation
The digitized image data, in point cloud form, was then manipulated using Geomagic Studio, 2013. Geomagic Studio software was used to repair any defects in the point cloud data of the digitized image. Next, the data was exported to Magic RP software version 17.02 for the final design. The teeth were set with a hollow thickness of 300 µm to mimic the actual crown's dimensions. Figure 2 shows the point cloud data of the tooth.

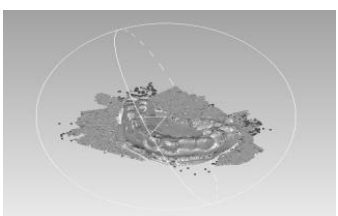

Figure 2: Point cloud data

d) Dental Crown Fabrication
A Projet 3500 HD RP machine was used to fabricate the dental crown. This machine produces a physical prototype using a layer-by-layer technique until the final prototype is completely built. This particular machine was selected due to its higher dimensional accuracy and good surface finish; compared to other RP machines available. It has an accuracy of up to 25 µm to 50 µm [4].

e) Post-Processing
Finally, the crown underwent a de-waxing process to remove the supporting wax around the crown. The process took 15 minutes with an average temperature of 70ºC inside the oven.

Result and Discussion

Figure 3 shows the crown after fabrication by the Projet 3500 HD. It was noticed that wax remained stuck to some parts of the surface. Figure 4 also shows the results of the crown after de-waxing.

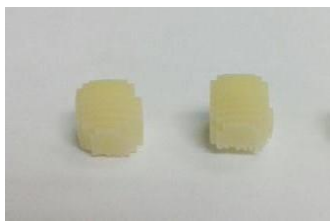

Figure 3: Fabricated dental crown

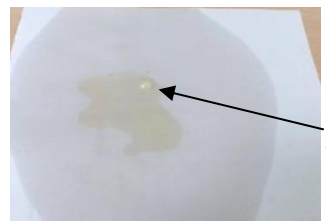

Figure 4: De-waxing of the dental crown

The results show that the crown completely melted after the de-waxing process, which changed the designed dimensions. There are three factors that might cause defects:

1. Machine limitations – The machine used to fabricate the crown had an accuracy of 25-50 µm; whereas, the thickness of the crown is 300 µm. This shows that the crown failed to be fabricated acceptably due to machine limitations. The functionality of RP parts is severely affected due to staircase effect resulting from layer-by-layer deposition [5]. Therefore, small features would usually have higher dimensional error in RP due to layer thickness and machine accuracy.
2. Thin wall issues – Based on a previous study by Bakar et al. [6], RP machine is said to be inaccurate and cause dimensional error of 127 µm when forming circular parts and dimensions of less than 2000 µm. Therefore, the wall is too thin to be fabricated using Projet 3500 HD. The recommendation by the FDM manufacturer also suggests that 400 µm minimum wall thicknesses should be fabricated [7].
3. Fabrication parameters – Part orientation is a one of important parameter that should be considered for fabrication [1]. To confirm the effect of this parameter, different part orientations were tested. A hollow

crown, with a minimal thickness of 300 µm, was fabricated with both up facing and horizontal orientations. The results show that part orientation does not affect the result.

Based on the results of the crown failure in the initial fabrication, the crown has been redesigned; whereby the hollow part was changed to solid. However, the bore of the crown needs to be ground manually. The problem that arose was difficulty to fit with the model during the fit and form test. The grinding process of the crowning is problematic due to the small part sizes involved. Figure 5 shows the re-designed crown. Meanwhile, Figure 6 shows the crowns undergoing the fit and form test. The image shows that the crowns do not match perfectly with the plaster model, as the thickness of the crown is not exactly 300 µm.

Figure 5: Re-designed crown

Figure 6: Fit and form test

Finally, the dental crowns of the conventional processes and the modern approach were compared in terms of process flow and build time. Table 1 shows the build time comparison between the conventional processes and the modern approach for hollow crown. In the conventional process, the total time taken to produce one complete crown was 40 hours. Meanwhile, the build time required by the modern approach to produce hollow crown was 18 hours and 50 minutes. This shows that the total time taken has been reduced by 54% using the modern approach.

Table 1: Build time for hollow crown

Conventional Process	**Modern Approach**
Crowning process : 40 hours	• Pre-Processing : 30 min • Reverse Engineering (RE) : 5 hours • Data Manipulation : 10 hours • Rapid Prototyping (RP) : 3 hours • Post-Processing : 20 min
Total: 40 hours	Total: 18 hours 50 min

Meanwhile, Table 2 shows the build time required by the modern approach to produce a solid crown. The total time taken was 21 hours and 10 minutes. This shows that the total time required for producing a solid crown has been reduced by 48% using the modern approach.

Table 2: Build time for solid crown

Modern Approach
• Pre-Processing : 30 min • Reverse Engineering (RE) : 5 hours • Data Manipulation : 10 hours • Rapid Prototyping (RP) : 5 hours • Post-Processing : 40 min
Total: 21 hours 10 min

Table 3 shows the process flow of the conventional processes against the modern approach. While there are 22 steps involved in the conventional process, there are only six steps involved in the modern approach. It can therefore be concluded that dental crown fabrication using the modern approach is much simpler and quicker than the conventional process; as it simplifies the process down to only six steps.

Table 3: Process flow

Conventional Process	**Modern Approach**
1. Impression cleaning 2. Position the impression 3. Preparing the mould 4. Base plate preparation 5. Drilling the plate 6. Add the metal pegs 7. Pour the dental stone 8. Make the opposing cast in the plaster model 9. Remove the plasticine and the impression 10. Top and bottom views of the upper model 11. Sanding the upper model 12. Separating the crown area 13. Make the wax post	1. Impression cleaning 2. Plaster model 3. Scan the plaster model 4. Data manipulation 5. Rapid prototyping 6. Post-processing

14. Shape the wax post 15. Sprue the wax post 16. Pour the investment material 17. Burnout and casting 18. Removing the metal casting 19. Sandblasting the metal casting 20. Excess metal removed from the casting 21. Crown manufacture 22. Wax metal cast	

Conclusion

In conclusion, it is possible to produce a dental crown using RP machine. However, there is a wall limitation to the crown as Projet 3500 HD is unable to produce dental crown thinner than 300 µm. Based on the study, it is observed that the build time required by the modern approach to produce one complete dental crown is faster and simpler than the conventional process. It is believed that in the near future, most of the dental restorative disciplines will be fully revised and the TCT method will be used optimally. Further investigation is needed, since this technology can be implemented in producing dental crowns faster and simpler than the conventional process.

Acknowledgements

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