An Experimental investigation on Fabrication of Artificial Teeth

Arun dev karan[1] and Alakesh Manna[2]
[1]Research Scholar, [2]Professor, Mechanical Engineering Department, Punjab Engineering College (Deemed to be University), Sector-12, Chandigarh-160012, India. Email:

Abstract

Paper presents the detail study and results of the experimental investigation during fabrication of artificial teeth. In present study, explained the fabrication processes of artificial teeth prosthesis which includes design to establish geometry in orthocad software, selection of material and machining of artificial teeth. The Poly Methyl Methacrylate (PMMA) material is selected for artificial teeth because of its good modulus of elasticity, corrosion resistance, hardness and biocompatibility. Machining is done on CNC milling machine with glass ceramic tools. The machining of artificial teeth is very challenging due to the complex shape of teeth and the associated restrictive geometrical and dimensional requirements. To achieve the required surface finish, the input cutting parameters is optimized based on Taguchi design of experiment. In this study various machining challenges are described during machining of PMMA. The SEM images of artificial teeth were taken and analysed the surface texture of the fabricated teeth. The surface roughness heights, R_a (µm) and R_t (µm) of fabricated artificial teeth were measured and analysed in the paper.

KEY WORDS : *Poly Methyl Methacrylate, Fabrication, Machining, Surface texture.*

1. Introduction

Human teeth's are not only an important masticatory organ but also closely associated with both pronunciation and the facial aesthetics of human beings. Beyond all doubt, teeth's play an extremely significant role in our daily life. With ageing, various pathological factors and traumas, tooth lesions such as caries, partial or overall tooth tissue loss will occur unavoidably. As a result, artificial dental materials have gradually been developed and used to restore and treat the lesions of human teeth. Now a days, metals and alloys, ceramics and composite materials are most widely used for dental restorations and implants.

Understanding of dental friction and wear behaviour would help the clinical management of tooth wear, which involves the replacement of missing tooth tissue with dental materials, together with an attempt to minimize the causal factors and develop new dental materials. In addition, tooth wear proceeds in a regular progressive manner, particularly in the molar teeth, endowing it with potential as a method of estimating the evolution, age, diet and health changes of ancient humans in archaeology. Fig.1 shows human teeth structure.

The tooth size is calculated using Bolton's method. Bolton selected 55 cases of excellent occlusion and measured the mesiodistal diameter of all teeth on the casts except for the permanent second and third molars. From the measurements obtained, Bolton determined that a certain ratio existed between the size of the upper and lower permanent teeth. A ratio could be determined for either the 6 anterior teeth or all 12 of the measured teeth in each arch by measuring the teeth manually.

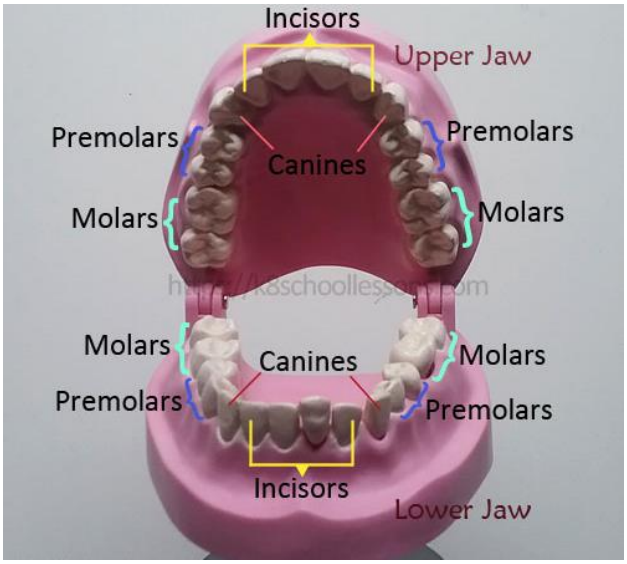

Fig 1. Human tooth structure (Source: https://www.pinterest.com/pin/781585710305959331/; https;//k8schoollesson.com)

The new material such as polystyrene and light activated methacrylate were introduced PMMA is the polymer of methyl methacrylate, chemical formula is $(C_5H_8O_2)n$, it is a clear and colourless polymer. PMMA is routinely produced by suspension or emulsion polymerization. PMMA used in dentistry is produced by suspension polymerization. In this investigation, focus given on the design and manufacturing of artificial teeth. Initially it is very difficult to get dimensions of teeth. Different steps were undertaken for fabrication of artificial teeth such as:

- Impression of artificial teeth to be manufactured was taken on functional silicone material.
- Designing the frame of the denture using CAD software.
- Execution of the denture frame using the CAM software and CNC milling of titanium.
- Installation of the frame of the prosthesis on the master cast.
- Carrying out of the re-scan of the master cast with the metal frame.
- Designing the outlines of the restoration based on the designed frame.
- Manufacturing of the denture on PMMA material by CNC milling.
- Connecting the frame with the denture.
- Performing the characterization of the restoration.

2. Design of Artificial Teeth and Selection of Material

Orthocad software is used to design the teeth. Artificial teeth has different geometries at its outer and inner surface. Hence, the detail design of artificial teeth is completed in two step. In first step, design the surface of enamel of the artificial teeth. In second step, design the surface of crown of the artificial teeth. Fig. 2 shows the views of artificial teeth drawn with Orthocad.

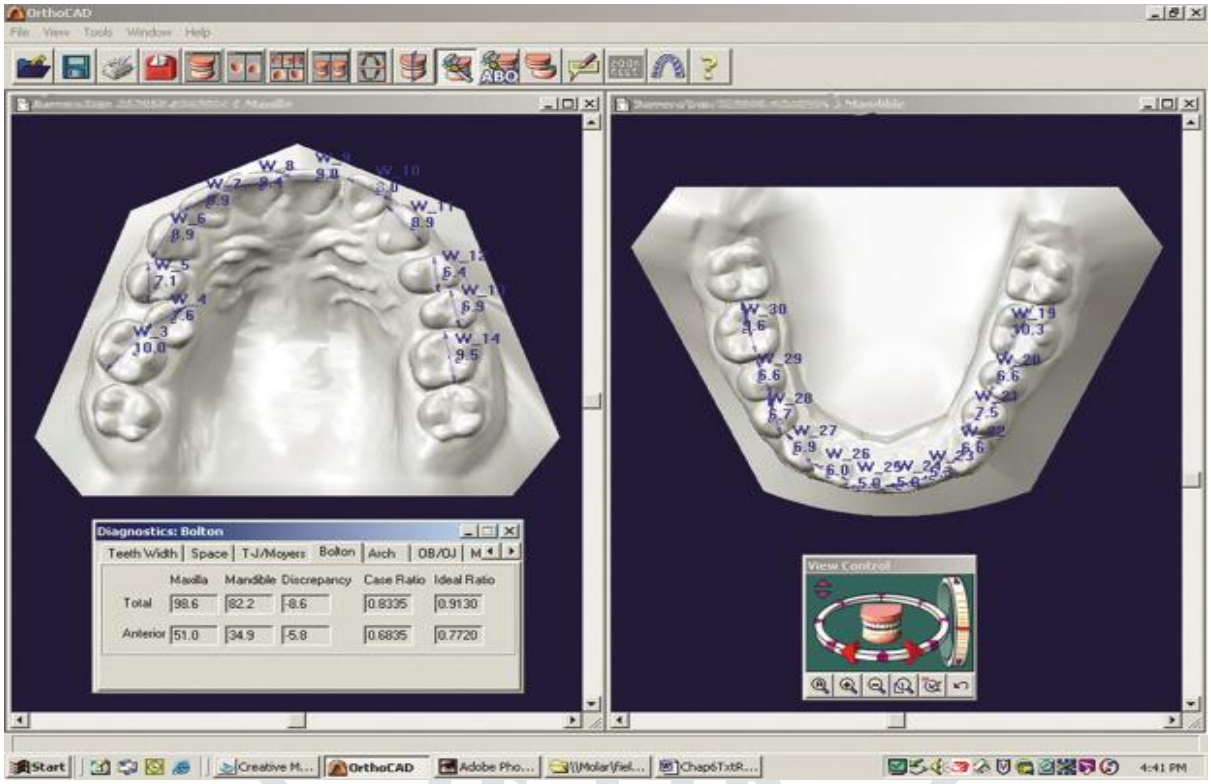

Fig. 2 Artificial teeth on orthocad software with showing dimension of each individual tooth

It is very important to select the appropriate material for artificial teeth. Material should be biocompatible for artificial teeth. PMMA (Poly methyl methacrylate) is selected because of its properties match with biocompatible material (Pietrokovski et al. 2010). The properties of PMMA material was explained by Kumar et al. 2011, which is considered for fabrication of artificial teeth.

3. Fabrication of Artificial Teeth

Based on review of literature and study on fabrication of artificial teeth, it is identified that the CNC Milling is one of the suitable processes for manufacturing of artificial teeth. The artificial teeth is manufactured by machining on CNC ARUN 5X-200 Milling machine. Fig.3 shows the CNC ARUM 5X-200 milling machine used for machining of artificial teeth. Fig.4 shows the machined artificial tooth.

The selection and setting of cutting parameters are of great important for machining of PMMA because of surface roughness. Keeping in view, few trail experiments were carried out to identify the setting level of the cutting parameters but not explained in the present paper. Utilized the identified setting level and employed Taguchi design of experiments detail experiments were carried out and measured the surface roughness heights, R_a (µm). Experiments were carried out with varying the machining parameters i.e. rotational speed of cutter 500 to 1500 rpm, feed rate from 0.3 to 0.5 mm/rev and depth of cut 0.2 to 0.4 mm.

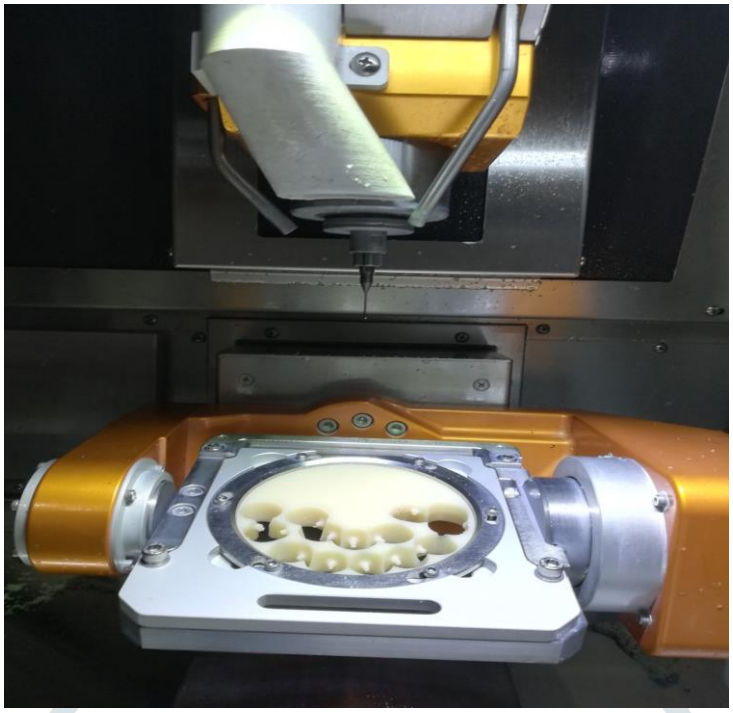

Fig.3 PMMA workpiece hold on CNC ARUN 5X-200 Milling machine

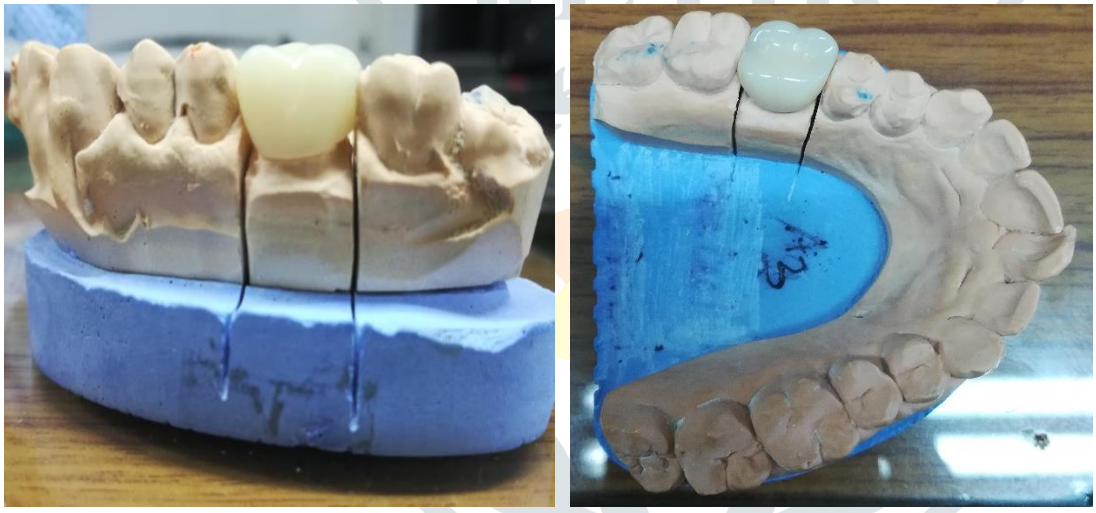

Fig.4 Fabricated artificial teeth

Utilized the mathematical relation equation 1, experimentally acquired results and MINITAB 19 software the S/N ratios (dB) were calculated and drawn the S/N ratio graphs for R_a (µm). The S/N Ratio (dB) for minimum surface roughness heights utilized 'Smaller-the-Better (LB)' criteria the relation is employed as

$$\text{S/N Ratio for (LB)} = \eta = -10\log_{10}[\frac{1}{n}\sum_{i=1}^{n} y_i^2], i = 1,2 \dots \dots n \quad \text{.....Eqn.1}$$

Fig. 5 shows the S/N ratio (dB) graphs for surface roughness heights R_a (µm).

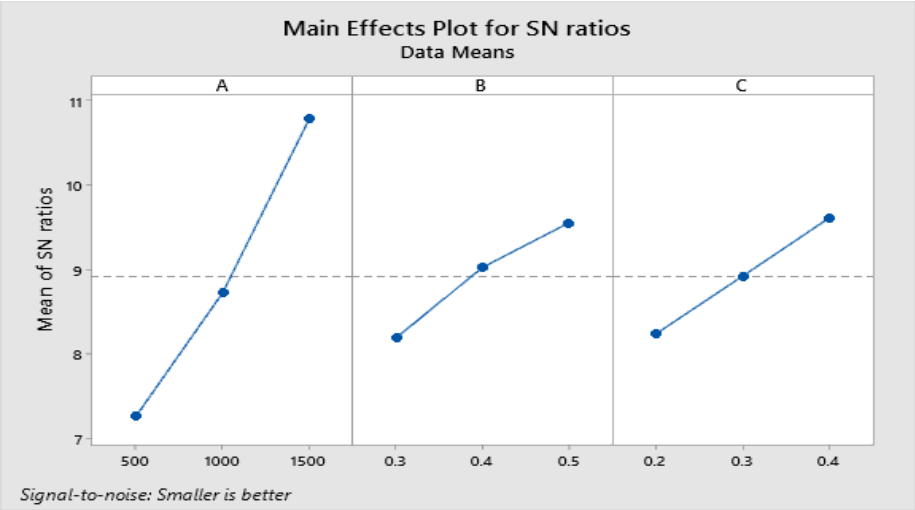

Fig.5 Variation of input parameters with S/N ratio for R_a (µm)

From Fig. 5, identified the optimum level of parameters for lowest surface roughness heights, Ra (µm) is 1500 rpm rotational speed of cutter, 0.5mm/rev feed rate and 0.4mm depth of cut. The experiments were carried out at optimal parameter setting i.e. 1500 rpm rotational speed of cutter, 0.5mm/rev feed rate and 0.4mm depth of cut and measured the surface roughness heights. The measured values of the machined surface roughness height, Ra (µm) was 0.370 µm. The machining of PMMA with glass ceramic tool on CNC ARUM 5X-200 milling machining at 1500 rpm rotational speed of cutter, 0.5mm/rev feed rate and 0.4mm depth of cut can be used for manufacturing of artificial teeth.

4. Analysis of Surface Texture

Scanning electron microscope is used to take the images of the fabricated teeth. The SEM images were taken to investigate the machined surface texture of the fabricated artificial teeth.

Fig.6 (a)

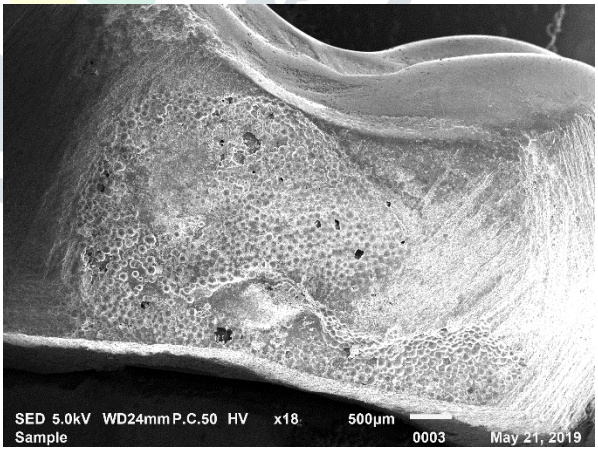

Fig.6(b)

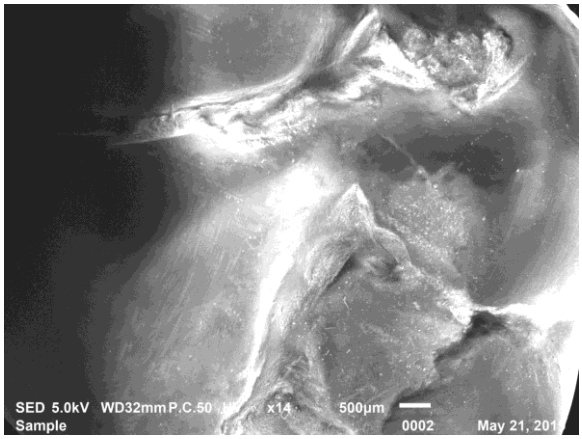

Fig.6(c)

Fig.6 SEM images of the fabricated teeth viewed from (a) right side of the tooth, (b) left side of the teeth (c) top side of the teeth where made a small cavity during machining

The SEM image Fig. 6(a), shows an actual surface viewed from the right side of the artificial teeth. It represents the outer surface texture of the artificial teeth after machining of poly methyl methacrylate (PMMA). From Fig. 6(a), it is clear that the machined surface of the fabricated artificial tooth was very good. In SEM image Fig. 6(b) shows the image viewed from the left side of the artificial teeth. It represents the outer surface texture of the machined i.e. fabricated artificial tooth. Whereas in SEM image Fig.6(c) shows the image viewed from the top side of another artificial tooth that shows the rough surface texture because of some zig-zag surface of the teeth. It is may be due to formation of very small cavity on top surface of fabricated artificial tooth during machining. Hence, machining of poly methyl methacrylate is a challenge which demands much care and setting parameters properly for achieving better surface texture during fabrication of artificial tooth by CNC ARUM 5X-200 milling.

5. Conclusions

In the present research investigation, investigated on different stages of manufacturing of artificial teeth prosthesis which includes design for tooth geometry via CAD, selection of material and machining of artificial teeth. Based on the experimental results during fabrication of artificial teeth during CNC milling, the following conclusions were made and listed below:

1. The PMMA (Poly methyl methacrylate) material may be selected for fabrication of artificial teeth prosthesis as this material has moderate elastic modulus, hardness and easily available with low cost.
2. The appropriate machining operation is found as CNC milling for fabrication of artificial teeth, because this machining operation can support to make complicated contour and generated good surface finish which is one of the important requirements of artificial teeth.
3. The surface roughness of fabricated teeth is measured. The measure value of the fabricated teeth surface roughness height, R_a is 0.370 µm.
4. The SEM images of artificial teeth were taken after milling. Investigate the surface texture of the fabricated teeth through SEM images and identified that the surface of the fabricated teeth was acceptable.

References

1. Dankwort CW, Weidlich R, Guenther B, Blaurock JE. Engineers(2004), 'CAx education-it's not only CAD. Computer-Aided Design'36,pp.1439-50.

2. Miyazaki T, Hotta Y, Kunii J, Kuriyama S, Tamaki Y(2009), 'A review of dental CAD/CAM: current status and future perspectives from 20 years of experience',28, pp.44-56.

3. Zhang YD, Jiang JG, Liang T, Hu WP (2011), 'Kinematics modeling and experimentation of the multi-manipulator tooth-arrangement robot for full denture manufacturing', 35, pp.1421-1429.

4. Kanazawa M, Inokoshi M, Minakuchi S, Ohbayashi N (2011), 'Trial of a CAD/CAM system for fabricating complete dentures',30,pp.93-6.

5. . J'Obrien W (2002), 'Dental Materials and their selection', 3rd edition, quintessence Publishing Co. Inc,pp.74-89

6. Goodacre CJ, Garbacea A, Naylor WP, Daher T, Marchack CB, Lowry J (2012) 'CAD/CAM fabricated complete dentures: concepts and clinical methods of obtaining required morphological data'107,pp.34-46.

7. Meng TR, Latta MA (2005), 'Physical Properties of Four Acrylic Denture Base Resins', 6(4),pp.93-100.

8. Khindria SK, Mittal S, Sukhija,(2009) 'Evolution of denture base materials. *Journal of Indian Prosthodontic Society*, 9(2),pp.64-69.

9. Vanscott De ER, Boucher LJ, (2006) 'The Nature of Supporting Tissues for Complete Dentures', *Applied Dental Materials, ~ 87 ~ International Journal of Applied Dental Sciences Blackwell Publishing, India 8th Edition,*pp.96-107.

10. Ferracane JL, (2001), 'Materials in dentistry: principles and applications', pp.262-280.