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STRESS ANALYSIS & REVERSE ENGINEERING ON ADAMS AND PUNCH CLASP: AN ORTHODONTIC APPLIANCE

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ABSTRACT

Orthodontic appliances are used for the treatment of malocclusions of a tooth or group of teeth. These appliances is retained in oral cavity with the help of its integral component known as *Clasp* which engages the undercuts of teeth for retention. There are generally two types of orthodontic appliances, Removal and Fixed type. Here we are dealing with "Removable" type of orthodontic appliance which can be removed for cleaning purpose by the patient or for re-adjustment by the orthodontist. In removal type of Orthodontic appliances stresses is induced in the Clasp either due to removal or insertion of appliance as well as during mastication, which may leads to deformation and fracture of the Clasp earlier. Therefore, achieving clasp designs producing less stress is very important. The present wok is focused on stress analysis of two types of Clasps 1) Adams and 2) Punch Clasp. Adams clasp is more commonly used for retention of these appliances. With some modification a new type of Clasp is made known as Punch Clasp. Comparative study of these clasps shows that under the similar loading condition stress induces in Punch Clasp is less than stress induces in Adams Clasp. We employed Reverse Engineering approach to develop the CAD models of the Clasp and Stress analysis is done using Finite Element analysis software ANSYS.

KEYWORDS: Adams Clasp, Punch Clasp, Reverse Engineering, Stress Analysis

INTRODUCTION

Clasps are retentive components of a removable appliance which "clasp" the teeth and prevent displacement of the appliance. Clasps engage the undercut areas of the tooth to obtain retention. The Adams clasp takes retention from the proximal undercut and Punch clasp takes retention from both undercuts.In clinical use the clasp can be chosen within the limits of the real conditions, but the most important parameter is a design producing less stress [1]. The choice and design depends on several factors: clasp material, clasp form, and the amount of undercut. Among this, only the clasp form is under the control of the dentist or dental technician.Proper material selection is crucial in determining whether wires maintain their adaptation, whether breakage will be a problem, and whether flexibility will be adequate. The gauge of wire used will depend on clasp arm length, undercut depth and amount of retention desired [2].Because Removable Orthodontics Appliances are not rigidly fixed, they are subject to movements in response to functional loads.These functional movements induce stresses and displacements in the metal framework of the denture. Direct retainers are designed and used to control these possible movements [3]. The choice of retention elements and their individual design require biomechanical considerations [4]-[6].

The literature reveals Finite Element analysis performed only on components such as major connectors [7], different cast clasps [8]-[10].The results obtained using an FE method depend on parameters that are introduced into a computer program, such as the coordinates of the points used for the generation of a geometric model, the generation of a geometric model, choice of FE type, material properties [11],[12], element properties, and conditions of restraining and loading. The skill, accuracy, and expertise of investigators performing the analyses also may influence the outcome.The FE analysis method also has some disadvantages. These arise from the use of a simplified geometry and a finite number of elements. Materials used for the manufacturing of prostheses are considered homogeneous, isotropic, and elastic, with known mechanical and elastic properties. It is important that the physical phenomenon be correctly represented, because the results depend on the size, placement, and type of external loads [13].

The complication and failure rates of Removal Orthodontic appliances were high for retainers, different studies have tried to clarify the component that had high rates of failure and complications [14]. Various retainer designs were compared by measuring the occlusal load [15], the stress distribution in the abutments and the abutment mobility [16], and the masticatory performance of the dentures [17].Comparative studies were performed for alternative materials for RPD applications for Co-Cr, like titanium and noble alloys [18]-[21]. Using finite element analysis, the clasp should be designed with consideration of the stress distributions within the clasps [22].It is evident from the literature review presented above that design of clasp producing less stress is very important. Clasp material and its form is main criteria in selecting a clasp producing less stress.In this study a comparative study of stresses induces during functional loading on two types of Clasps 1) Adams Clasp and 2) Punch Clasp were conducted. The Adams clasp which is commonly used in removable appliance fabrication has a disadvantage that the arrowheads are points of stress concentration [23]. The punch clasp has a vertical loop with helix and moreover it is embedded in acrylic so there are less chances of breakage [24]

MATERIAL AND METHODS

We used Reverse Engineering approach for obtaining a geometric CAD model of the product from 3-D points which is acquired by scanning/ digitizing existing parts or products. Reverse engineering provides a solution to this problem as the physical model is the source of information for the CAD model. This is also considered as the physical-to-digital process.

Using **Stienbichler**L3D scanner, we scan the Physical model to achieve 3D CAD model (.stl format) in order to design the Clasps. For most situations, a single scan will not produce a complete model of the object. Multiple scans, from many different directions were required in order to complete the 3D scanning process. For the scanning of our Model, we used Rotating table and calibrated its one complete rotation in 20 equal parts i.e. we take 20 images for each model and then aligned and merge all the 20 images to complete the scanning process and saved the resulting cloud data in .stl format.

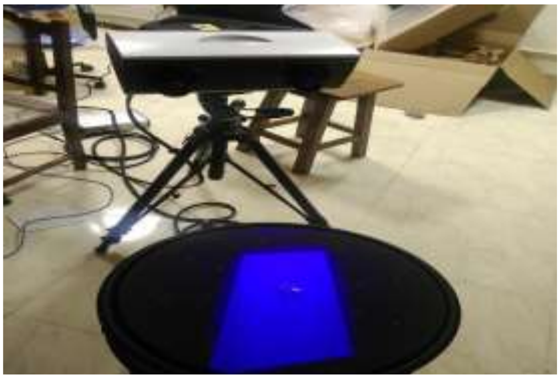

Fig. 1. Laboratory setup of 3D Scanner

STL files were imported into Solid Works, where the point clouds from the tooth surfaces were cleaned and assembled. After successfully developing the surface of the model, using the command Spline line, develop a path along the surface and a circular profile of 0.7 mm dia at the the end of the path. Now using the command Swept Boss/Base developed the solid CAD model of the object and saved in IGES format.IGES files of Clasps were imported into Finite Element analysis Software ANSYS Workbench-16 and following steps were used for stress Analysis.

1. Meshing: We have used fully automatic mesh generation module to mesh our model. The Fig. 2 shows the plot of meshed model of Adams Clasp. Total no of automatically created finite elements and nodes are 2985 and 6325 respectively. The Fig. 3 shows the plot of meshed model of Adams Clasp. Total no of automatically created finite elements and nodes are 1246 and 7506 respectively.

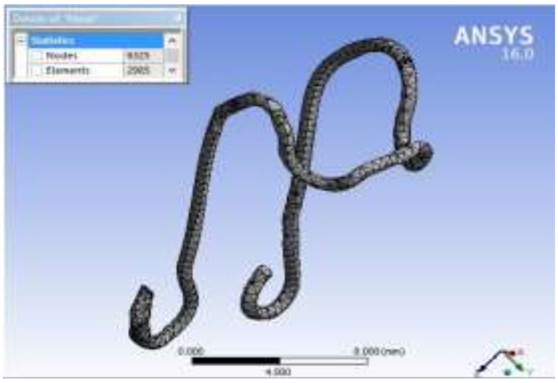

Fig. 2. Meshing of Adams Clasp Fig

Fig. 3. Meshing of Punch Clasp

2. Boundary Condition: Fig. 4 shows the boundary condition for Adams Clasp, Tags of Clasp and portions of the clasp which will touch the proximal undercuts were fixed. Fig. 5 shows the boundary condition for PunchClasp. Tags, Helix and portions of the clasp which will touch the proximal undercuts were fixed.

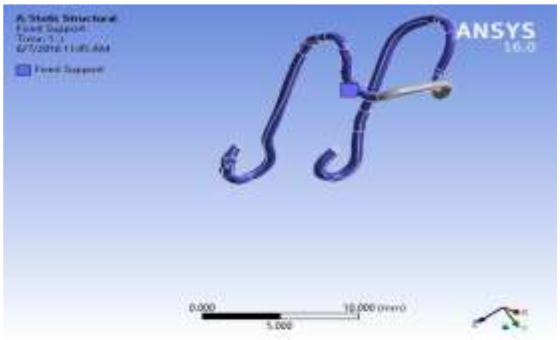

Fig. 4. Boundary condition for Adams Clasp.

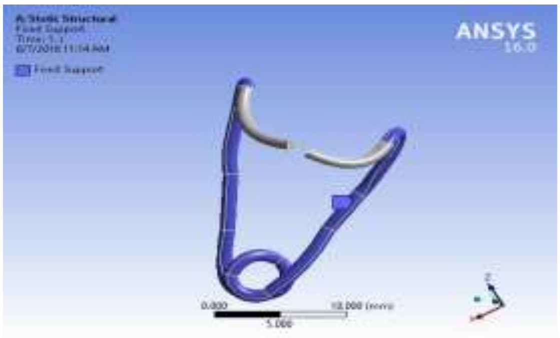

Fig. 5. Boundary Condition for Punch Clasp

3. Force: The force applied for simulation of removal of Adams clasp are shown in in the Fig. 6. A force of 5 N were uniformly distributed perpendicular to the occlusal surface on the Bridge. Also 5 N load is uniformly distributed perpendicular to the occlusal surface on the portion of Punch clasp touching the buccal surface, shown in Fig. 7.

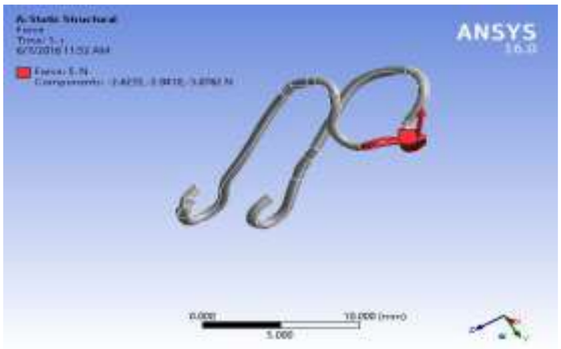

Fig. 6. Force on Adams clasp.

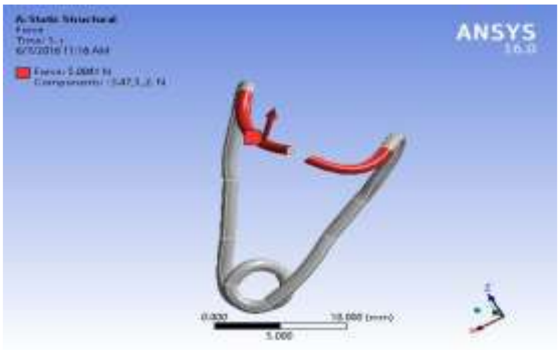

Fig. 7. Force on Punch clasp

For Finite Element analysis, the characteristics of 'stainless steel – 316' is used for the framework is entered into the computer Program. The characteristics, as purported by the manufacturer, included a tensile strength of 579 MPa, ductile yield of 290 MPa, elasticity modulus (E) of 1.93E+05 MPa, and Poisson's ratio (n) of 0.3.

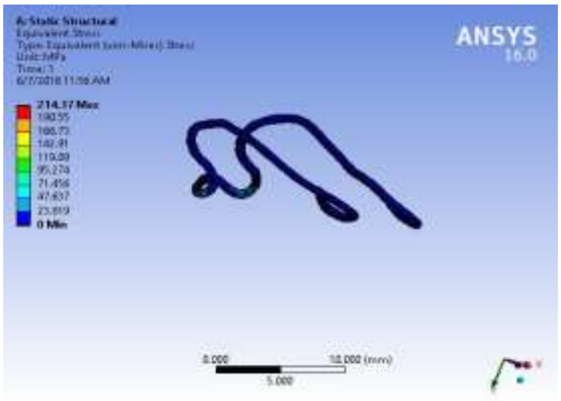

Fig. 8. Von Mises equivalent stress in Adams clasp resulting from removal simulation.

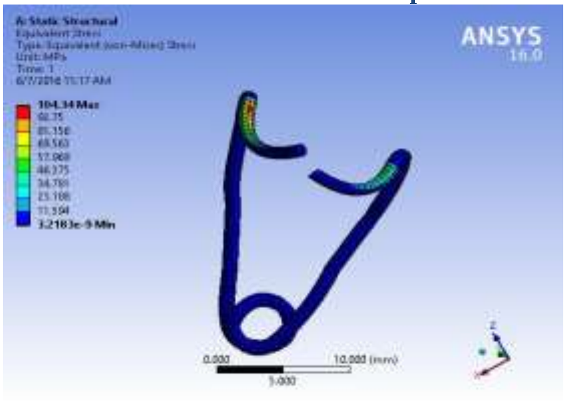

Fig. 9. Von Mises equivalent stress in Punch clasp resulting from removal simulation.

RESULTS

The reverse engineering approach was successfully employed to create the model of the Adams and Punch Clasp. This approach represents a useful tool in designing and simulation of Clasps.Generated Equivalent stresses and Total deformations were calculated using Finite element analysis software ANSYS, which have been shown Above. Results were displayed as coloured stress contour plots to identify regions of different stress concentrations. In both the Clasps high stress values were present on Arrow head of the Clasps, in the portion located between Tags and Bridge. The result obtained in Ansys are shown in following table:

Table 1. Result of Stress Analysis

Type of Clasp	Equivalent stress induced during Removal of Clasp in 'MPa'.	
	Minimum	Maximum
Adams	000.00	214.37
Punch	003.22	104.34

DISCUSSIONS

The permanent problem in practice is the choice of clasp geometry and dimensions, so that they satisfy functional needs, as well as less prone to failure. The tools of the reverse engineering approach may benefit us to create the 3D CAD model of the clasps. This tool gives us freedom to create CAD model of clasps so that their design analysis can be done through software like Ansys in very less time. That means alteration in the physical dimensions of the Clasp and their analysis become easier and comparatively less time consuming task by using reverse engineering approach.3D reconstructions after scanning, in order to obtain faithful models, can be used for numerical simulations of the teeth and prosthetic restorations. CAD is mainly used for detailed 3D models, but it is also used throughout the manufacturing process, from conceptual design, through strength and dynamic simulation analyses.Two types of the physical model of the clasp were assessed for stress analysis using Ansys and obtained the region high stress concentration. It was observed that in both type of clasp high stress concentration region is at arrow head, located between Tags and bridge. The result obtained from this investigation shows that stress concentration is very high in Adams clasp than in Punch Clasp. Such difference in stress concentration can be interpreted as Adams clasp have high sharp turn than Punch clasp, at arrow head which leads to high stress concentration. It means Adams clasp is more prone to failure under similar loading condition.

CONCLUSIONS

This study demonstrate that the tools of Reverse engineering were used effectively to create the solid CAD model from the available physical model of Clasp. Alteration in the physical dimensions of the Clasp and their analysis become easier and comparatively less time consuming task by using reverse engineering approach. After the simulation result it may be observed that higher fracture risk area for both the clasp is at arrow head. Under similar loading conditions maximum stress developed on Adams Clasp is 214.37 MPa, whereas on Punch

Clasp maximum stress value is 104.34 MPa. Punch Clasp is less prone to failure under similar loading condition.The reason of such difference in stresses value is more sharp turns of Adams Clasp. Therefore it is suggested to design a clasp which have less sharp turn as well as it should offer good patient compliance.

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