

Three-dimensional finite element analysis of two kinds of extracoronal attachments in a new design to restore maxillary edentulous jaw

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Abstract. *Objective:* To choose a kind of more reasonable attachment by comparing three-dimensional finite element stresses of two kinds of attachments in anterior implant fixed bridge and posterior extracoronal attachment denture to restore maxillary edentulous jaw. *Materials and Methods:* The three-dimensional finite element model of extracoronal resilient attachment model (model I) was reconstructed which had a good similarity. By modifying part model, extracoronal rigid attachment model (model II) was established. Static loading direction was 30° diagonal and vertical to buccal inclined surface of lingual cusp of the first molar. The load force was 300N and load place was buccal inclined surface of lingual cusp of the first molar. The results of stresses were analysed by MSC software. *Results:* The stress of model II was significant higher than model I in four implants, anterior teeth and attachments. Otherwise, the stress of model II in palatal bars and posterior teeth was similar to model I. *Conclusion:* Choosing extracoronal resilient attachment is better in the design of anterior implant fixed bridge and posterior extracoronal attachment denture to restore maxillary edentulous jaw in oral biomechanics.

Keywords: implant, attachment, maxillary edentulous jaw, three dimensional finite element

1 Introduction

Many countries have been aged society, and there are about 12 million edentulous patients in China. During these patients, the restoration of maxillary edentulous jaw is very important and necessary because it has close correlation with pronunciation, esthetics, comfortability and mastication. Now there are three main methods to restore maxillary edentulous jaw including traditional maxillary complete denture, maxillary complete implant fixed bridge and maxillary complete implant overlay denture, which have not only advantages but also disadvantages^[1, 5]. So according to characters of attachment, implant and maxillary edentulous jaw, we design a new method to try to overcome three main methods' disadvantages which is anterior implant fixed bridge and posterior extracoronal attachment denture to restore maxillary edentulous jaw. Previous studies have demonstrated extracoronal resilient attachment is better than extracoronal rigid attachment in oral biomechanics in existed designs such as traditional complete denture, partial removable denture and fixed bridge etc^[2, 6-10]. But it is still unknown in this new design. Therefore the purpose of the study is to choose a kind of more reasonable attachment by comparing three-dimensional finite element stress of two kinds of extracoronal attachments in the new design.

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2 Materials and methods

2.1 The establish of entity denture model

A maxillary edentulous jaw of adult was choosed *ex vivo*. Its alveolar bone was midrange absorption and bilateral symmetry, and no obvious bone needle. Alginate impression of maxillary edentulous jaw was acquired and then affused to get plaster model. we made sure occlusal plane, did wax base and set teeth. According to setting up of teeth situation, we implanted four spiral cylinder implants (length 13mm, diameter 4.3mm) parallely in the places of maxillary lateral incisor teeth and canine teeth (#13, #12, #22, #23), and got silicon impression and plaster model. Fixed porcelain bridge was made between both canine teeth. Ceka extra-coronal resilient attachment denture was done in the place of posterior teeth (positive part was connected with posterior denture and negative part was connected with anterior fixed bridge). Stress relieving was realized by soft gasket between two parts of attachment.

2.2 The construct of three dimensional finite element model

Placing denture and implants model on Philip CT machine to helical scan that the space was 0.6mm and overlap was 0.3mm, we got 337 CT photos which were saved as DICOM format. In 3D-DOCTOR software, we got the data of three dimensional model and output the IGES format's data. Then we predigested data in Mechanical desktop power pack software to output IGES format also. In Unigraphics NX2 software, the model was transformed to parasolid(x.t) format. Dealing with a series of three dimensional and finite element softwares (MSC softwares) in a computer that EMS memory was 256M, we parted nodes and cells and established the three dimensional finite element model I having a good similarity to the morphology of the three dimensional images. By modifying part model that elastic modulus of the whole positive part of extracoronar resilient attachment including the soft gasket was changed into alloy's, extracoronar rigid attachment model (model II) was established.

2.3 The mechanics parameter, boundary condition and loading type

2.3.1 Mechanics parameters of materials were listed (table 1)

Table 1. Mechanics parameters of materials

Materials	Elastic modulus (MPa)	Poisson's ratio (u)
titanium	1.03×10^5	0.35
alloy	2.18×10^5	0.33
porcelain	7.0×10^4	0.19
artificial dentition	3.0×10^3	0.35
soft gasket	1.0×10^1	0.40

2.3.2 Boundary condition

Materials were assumed to be continuous, isotropic and line elastomeric. Surface of denture foundation and implant surrounding when models were loaded on were supposed to be rigid constraint. And loading did not slip relatively.

2.3.3 Loading type

Static loading direction on two models was 30° diagonal and vertical to buccal inclined surface of lingual cusp of the first molar. The load force was 300N and load place was buccal inclined surface of lingual cusp of the first molar. The stress of Maximum von mises was the index of observation.

3 Results

The disposition of stress were expressed by von mises stresses i.e. combination stress. The Maximum von mises stresses of implants and denture in two models were showed in Table 2. The stress of Model II was significant higher than model I in four implans, anterior teeth, and attachments. Otherwise, the stress of model II in palatal bars and posterior teeth was similar to model I. (Note: The study adopted the tooth position records of FDI. #12 was right upper lateral incisor; #13 was right upper canine tooth; #22 was left upper lateral incisor; #23 was left upper canine tooth.)

Table 2. Maximum von mises stresses of implants and denture in two models (mpa)

Parts	Model I	Model II
#23 implant	1.1710-2	8.1610-2
#22 implant	3.4710-2	2.3210-1
#12 implant	6.3210-2	3.2710-1
#13 implant	5.2810-2	2.4510-1
attachment	7.21	3.03101
anterior teeth	2.83102	1.02103
posterior teeth	3.07108	2.07108
palatal bar	1.95107	1.33107

Note: The study adopted the tooth position records of FDI. #12 was right upper lateral incisor; #13 was right upper canine tooth; #22 was left upper lateral incisor; #23 was left upper canine tooth.

To the whole Model II or model I, the positions of maximum von mises stresses of implants and denture are the same. In implants, the stress in #12 implant was the greatest and stress in #23 implant was the smallest. The positions of implants were the lingual sides of implant necks. The stress of anterior teeth was mainly centered on lingual side of #12 dental neck. In attachments, the main stress was localized on positive part's mesiocclusion of loading side. And the stresses of two models in palatal bars were mainly centered on the connection of bar and posterior basal plate and the stress in posterior teeth was mostly concentrated on the loading place (Fig. 1).

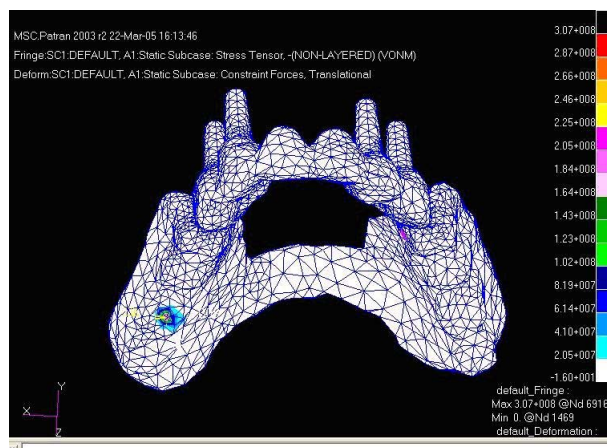


Fig. 1. The all stress of model i

4 Discussion

This study shows that extracoronal elastic attachment is a kind of more reasonable attachment in the new design because of its more evident stress buffering function which is realized by the soft gasket. It had

been demonstrated by comparing stresses of two kinds of extracoronal attachments. And that the stresses of attachment and anterior teeth of extracoronal elastic attachment model were comparative low was more protective to attachment structure and anterior part including implants. Further, in the new design, the results incorporate and confirm previous studies that extracoronal resilient attachment is more superior to extracoronal rigid attachment in oral biomechanics in existing designs.

The reason of the greatest stress in #12 implant is still unknown, but may be related with the long bridge pontic and hints that the implants in lateral incisors should be strong and long. In this study, we had found stresses in implants were mainly localized on the lingual side of neck, which confirmed other researcher's reports^[3, 4, 11, 12], so the neck of implants should have enough section area and avoid sharp. To attachments, the reason that the main stress was on positive part's mesiocclusion of loading side is uncertain, but one possibility is that the site is clearer to the loading place. Palatal bars' stress was centered on the connection of bar and posterior basal plate because of the comparatively large difference between two kinds of material elastic modulus, which may explain the impaired phenomenon, so the strengthen of this place should be emphasized in clinical design.

To our knowledge, this is the first report of the new design that maxillary edentulous jaw is restored by anterior implant fixed bridge and posterior extracoronal elastic attachment denture. First, anterior implants avoid the excessive low problem of maxillary sinus, and visual field is so clear that it is easy to implant surgery and implant attendance. Moreover, anterior fixed bridge benefits pronunciation, esthetics and comfortability. Second, the new design not only utilizes the favourable support function of implants but also cuts down the cost of implants by using the less implants^[13]. Third, this study shows extracoronal elastic attachment has evident stress buffering function to protect implants in this new design. On the whole, the new design may be a kind of perfect method to restore maxillary edentulous jaw.

5 Conclusion

In summary, this study shows that choosing extracoronal resilient attachment in the new design of anterior implant fixed bridge and posterior attachment denture to restore maxillary edentulous jaw is better than extracoronal rigid attachment in oral biomechanics, but further studies of the new design are still needed.

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