EFFECT OF BUCCAL SHELF ANCHOR AND CLASS II ELASTICS IN ANTERIOR DISPLACEMENT OF MANDIBULAR CONDYLE – A THREE DIMENSIONAL FINITE ELEMENT STUDY

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ABSTRACT:

Objectives:

Present FEM study evaluates the efficacy of various magnitude of force levels of intermaxillary elastics in anterior displacement of condyle and stress distribution values at the articular disc during protraction of mandible using buccal shelf screws as anchorage.

Materials and Methodology:

Design: Three dimensional finite element study

Study setting: Bangalore

Three replicas of pre-existing three dimensional finite element model of the craniofacial skeleton and articular disc from CBCT data and MRI data of a patient were used. Buccal shelf bone screws were inserted buccal to the mandibular second molar region, Intermaxillary forces of magnitudes 250gms, 350gms and 450gms were applied as class II elastics pattern with stainless steel archwires of sizes 0.019x0.025-inch as working wire in maxillary and mandibular arches.

Results:

On the articular disc the maximum stress was observed on the anterior and posterior zones at all different force levels. The stress on the articular disc and displacement of condyle increased with increase in force levels. The maximum stress and displacement of condyle was observed for 450gms and the least for 250gms force.

Conclusion:

The application of a low magnitude force (250g) produces acceptable stress levels and facilitates a relatively uniform anterior displacement of the mandibular condyle. In contrast, an increase in force magnitude appears to generate higher stress concentrations, which may predispose the condylar region to resorptive changes and potential wear of the articular disc.

Keywords:

Finite element method, Cone-beam computed tomography, Magnetic resonance imaging, Class II elastics, Buccal shelf bone screws.

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INTRODUCTION :

Class II malocclusions were frequently managed during this time period of growth by growth modification therapy using functional appliances as a phase I treatment and fixed mechanotherapy as a phase II treatment option. Both fixed functional appliances and Class II elastics were employed as orthodontic treatment modalities to correct Class II malocclusion. Fixed functional appliances aid in forward displacement of mandibular condyles and remodels the glenoid fossa into new position, similarly class II elastics also aid in correcting the malocclusion but the extent of skeletal corrections achieved are comparatively less. Long-term follow-up studies have demonstrated that although there were significant initial differences between the two treatment modalities, these differences were not maintained over the long term[1]. Finite Element Analysis (FEA) method was an in vitro, non-invasive and highly sophisticated method which explains qualitative and quantitative nature of tensile and compressive forces of complex structures like TMJ and osseous structures[2]. Temporary anchorage devices (TADs) were temporarily placed into the bone to serve as an anchor unit for orthodontic appliances which has around 91.3% of success rate which aids in class II correction[3]. Hence present study was done to check the effect of various force levels of class II elastics in forward displacement of mandibular condyle which aid in correcting the skeletal malocclusion[4].

MATERIALS:

- CBCT data of the craniofacial skeleton and the Temporomandibular joint of a patient of class 2 Div 1 malocclusion and MRI of Lateral pterygoid muscle
- 3D slicer and GOM software - to convert scan to STL format. • SOLIDWORKS software (Dessault systems, Waltham, Mass, USA) modeling software.
- ALTAIR HYPERWORKS software version 13 (Troy, Michigan, USA) meshing software.
- ANSYS software version 15 (Canonsberg, Pennsylvania, USA)-analysis software

METHODOLOGY:

Replication of 3D FEM of the craniofacial skeleton was made of conebeam computed tomography data and the temporomandibular joint and lateral pterygoid muscle was made from the MRI scan of a patient with skeletal class 2 div 1 malocclusion.

Using 3D slicer, images of the scan were selected and converted into a stereolithographic (STL) format. The buccal shelf screws (iNewton), class II elastics(AO), brackets (3M), archwires (ORMCO) was converted into STL format using GOM software. Furthermore, it was transformed into a geometric model using the Solidworks software. Meshing was done through ALTAIR HYPERWORKS and the analysis was carried out using ANSYS software.

The material properties of the teeth, alveolar bone, articular disc, periodontal ligament, stainless steel wires and stainless steel brackets were allocated. Individually it was assumed that the muscle, temporomandibular joint, bone, teeth are all isotropic, homogenous components[5].

MATERIAL	YOUNGS MODULUS(Mpa)	POISSON'S RATIO
Articular disc[6]	44.1	0.4
Bracket[7]	2×10^5	0.3
Periodontal ligament[7]	5×10^2	0.3
Alveolar bone[7]	2×10^3	0.3
Stainless steel wire[7]	2×10^5	0.3
Teeth[7]	2×10^4	0.3

Table 1: Mechanical properties of each material used in this study has been mentioned in this table.

0.022 x 0.028 slot stainless steel MBT brackets and molar tubes were modeled with specific tip and torque values for all maxillary and mandibular teeth and were placed in accordance with standard bracket positioning chart of MBT in such a way that the archwire sat passively through the bracket slots. Buccal shelf bone screws of length 10mm and 2mm diameter was simulated on the area buccal to the mandibular second molar region. Hooks were placed between the upper canines on both sides. Class II elastics were simulated and three different forces were applied. The three different force modules simulated were 250gms, 350gms and 450gms in order to produce forward displacement of mandibular condyle and the amount of forward displacement were measured with each force.

Figure 1 : simulation of intermaxillary class II elastics mechanism in FEM model with attached components.

The finite element analysis(FEA) was carried out using ANSYS software. The results were visualized as von mises stress maps. The amount of forward displacement of mandibular condyle was calculated and represented with different colors.

RESULTS :

The amount of maximum displacement and von mises stress generated in different parts of articular disc were calculated and represented with different colours. The displacement of condyle was represented with different colour. On the articular disc the maximum stress was observed on the anterior and posterior zones at all different force levels. The stress on the articular disc and displacement of condyle increased with increase in force levels. The maximum stress and displacement of condyle was observed for 450gms and the least for 250gms force.

force:250gms **force:350gms** **force:450gms**

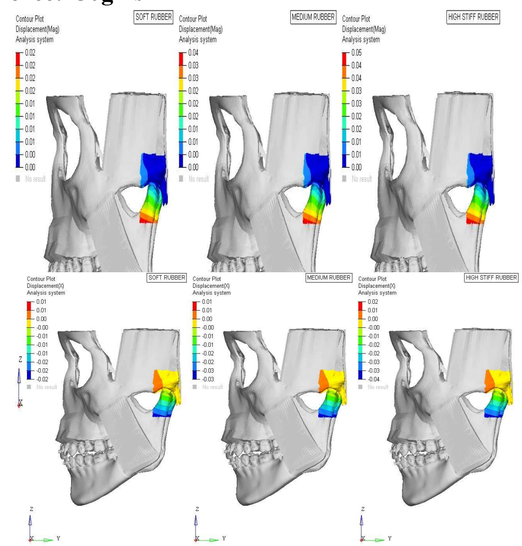

Figure 2 : displacement of condyle produced using buccal shelf screws and class II elastics with increasing levels of forces using 0.019 x 0.025-in wire.

force:250gms **force: 250gms** **force:350gms**

Figure 3 : stresses at the articular disc produced using buccal shelf screws and class II elastics with increasing levels of forces using 0.019 x 0.025-in wire.

FORCE	250 GMS	350 GMS	450 GMS
DISPLACEMENT (in MM)	0.02	0.04	0.05

Table 2 : The forward displacement of condyle using buccal shelf screws and class II elastics with increasing level of force along with 0.019 x0.025 rectangular stainless steel archwire has been tabulated.

FORCE	250 GMS	350 GMS	450 GMS
VON-MISES STRESS (in Mpa)	1.52	2.11	2.71

Table 3 : The von mises stress produced at the articular disc while using buccal shelf screws with class II elastics with increasing levels of force along with 0.019 x 0.025 rectangular stainless steel wire has been tabulated.

DISCUSSION :

Finite element investigations by El Helou (2017) into inter-arch elastics have revealed that different elastic configurations markedly affect stress generation within the TMJ complex and mandibular dentition. Inter-arch elastics applied from maxillary canines to mandibular molars produced varying stress potentials in TMJ regions and different displacement potentials along mandibular structures. These findings were significant because changes in force vectors imposed by Class II elastics can alter not only dental movements but potentially induce anterior displacement stresses at condylar regions through transmitted mandibular forces[8].

Evaluating the stress diffusion at the TMJ during complete recantation with buccal shelf screws in study done by Priya et al (2024) have shown that forces applied through skeletal anchorage can influence TMJ stress values, which may relate to condylar displacement trends in sagittal and rotational dimensions. This suggests that employing buccal shelf anchorage may modify the vector of distalizing forces away from purely dentoalveolar structures and could potentially affect condylar biomechanics when combined with another traction system like Class II elastics which is well in coordination with results obtained in present study. Present study also demonstrates the FEM analysis of stress distribution, forward movement of the condyle using a skeletal anchorage (buccal shelf screws) and class II elastics which shows improvement in forward direction which is directly proportional to the increasing force of elastics[9].

Direct finite element studies by Vas NVV et al(2025) on interconnected implants to anchor elastics (functionally similar to TAD anchorage) showed anterior movement of the mandible and posterior movement of the maxilla, with stress concentrations in the posterior ramus region and minimal dental stress, indicating more skeletal effect of elastics. These findings suggest a possible anterior displacement of the condylar region when elastics are used in conjunction with rigid skeletal anchorage. This displacement may be more pronounced when buccal shelf TADs are incorporated, as demonstrated in the present study[10].

The studies by Kumar D et al(2022) investigating the inclusion of skeletal anchorage with functional appliances (miniplate anchored functional appliances) demonstrated increased antero-inferior displacement of the mandible and differences in stress distribution compared to conventional approaches, emphasizing the role of skeletal anchorage in modifying overall mandibular biomechanics, including potential condylar changes. The entire mandible exhibited an anteroinferior displacement, and the present study demonstrated that the use of a skeletally anchored fixed unit (buccal shelf screw) generates greater stresses and displacements in the skeletal structures compared to the dentition[11].

The findings of the current study demonstrated the developing appreciable von Mises stresses in the condylar region following the application of forces through skeletal anchorage. The stress distribution pattern suggests a tendency for anterior displacement of the mandible, indicating a forward-directed biomechanical response. Furthermore, the adjunctive use of intermaxillary elastics resulted in a more uniform and consistent alteration in stress distribution, thereby enhancing the magnitude and homogeneity of the forward displacement effect. These observations highlight the combined biomechanical influence of skeletal anchorage and intermaxillary elastics on mandibular positional dynamics.

Studies done by Priyankar and Varadarajan(2009) shows more of dental changes compared to skeletal changes in forward movement of mandible. The movement of varied skeletal structures particularly in condylar head of mandible shows a mean of 0.000779 mm forwardly and the von mises stresses shows a mean of 4.438 Mpa using a force of 150-200gms by the help of fixed functional appliances. Whereas the present study shows a displacement of 0.02mm and von mises stress of 1.52 Mpa in the condylar region using a force of 250gms by the help of intermaxillary elastics which create a more forward displacement than the previous study[12].

Studies by Patil HA et al(2017) evaluating FEM evaluation of stress pattern in the mandible with a miniplate-anchored Forsus appliance revealed that the highest stress values occurred in the bony area of the cuspid region, particularly at the bone–screw region. Additionally, increased stress concentration was observed in the mandibular cortical bone at the condylar region. In the previous study, under a force of 150–200 g, the von Mises stress at the condyle was approximately 0.397 MPa and stress were 0.436 mpa. With contrast, present study demonstrated a von Mises stress of about 1.52 MPa under a force of 250 g, which is considerably higher than the values reported earlier[13].

Hence, within the limitations of current study, it is finalised that the incorporation of skeletal anchorage in conjunction with intermaxillary elastics facilitates enhanced anterior displacement of the condylar head. This biomechanical effect may contribute to the improvement of mandibular deficiency and could serve as a potential alternative to conventional removable and fixed functional appliances for the management pertaining to skeletal Class 2 malocclusion. Further investigations are warranted to validate and correlate the finite element method (FEM) findings with in vivo assessments through well-designed and adequately controlled clinical trials.

CONCLUSION :

With the present FEM study, It can be concluded that the application of a low magnitude force (250g) produces acceptable stress levels and facilitates a relatively uniform anterior displacement of the mandibular condyle for correction of skeletal malocclusion. In contrast, an increase in force magnitude appears to generate higher stress concentrations, which may predispose the condylar region to resorptive changes and potential wear of the articular disc. However, considering the inherent limitations associated with finite element modeling, a well-designed, controlled randomized clinical trial is recommended to validate these results and to obtain more comprehensive clinical evidence.

CONFLICT OF INTEREST : Nil

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