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Resiliency Of Temporomandibular Joint Disc-A Literature Review.

N Gupta, Manisha, N Kathuria, R Prasad

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Abstract

The TMJ disc consists mainly of collagen fibres and proteoglycans being constrained in the interstices of the collagen fibre mesh. This construction results in a viscoelastic response of the disc to loading and enable the disc to play an important role as a stress absorber during function. Clinically, it is impossible to understand fully the fine points of occlusion without an indepth awareness of anatomy, physiology, and biomechanics of temporomandibular joint. The most important requirement for successful occlusal treatment is stable and comfortable temporomandibular joints. It is only through thorough understanding of how the normal healthy TMJ functions that dentist can make out what is wrong when its functioning is not comfortable. The purpose of this article is to review, the biomechanical behaviour of the TMJ disc in response to different loading conditions because the knowledge about the viscoelastic behaviour of disc is required for its functioning to be understood.

INTRODUCTION

The TMJ comprises of the mandibular condyle fitting into the mandibuar fossa of the temporal bone (1). Articular disc separate these two bones from direct articulation. The articular surfaces of the TMJ are highly incongruent leading to smaller contact areas.[6] During joint loading, this incongruence may lead to large peak load causing damage to the cartilage layers of the articular surfaces. However, the articular disc in between is somewhat flexible and is capable of deforming and adapting its shape to that of articular surface during function. These changes in the shape of the disc reduces the stress concentration and probably the progression of injury.[1] Therefore, the presence of fibro cartilaginous disc in the joint is believed to prevent peak loads (Tonne et al, 1991; Scapino et al; 1996) and functions as a stress absorber and a stress distribution material.

ANATOMY (2)

TMJ is a compound craniomandibular joint in which the articular disc serves as a third non-ossified bone hat permits the complex movements of the joint. The articular disc is composed of dense fibrous connective tissue which is non-innervated and non-vascularized for the most of it.

ATTACHMENTS

Posteriorly – The disc is attached to the highly vascularized and innervated connective tissue called as retrodiscal tissues.

Posterosuperiorly: The retrodiscal lamina rich in elastic fibers attachs the disc to the tympanic plate.

Posteroinferiorly: The inferior retrodiscal lamina rich in collagenous fibers attaches the disc to the posterior margin of the articular disc of the condyle.

Anteriorly- The disc is attached to the capsular ligaments.

Antero-superiorly – Capsular ligaments attaches the disc to the anterior margin of the articular surface of the temporal bone.

Anteroinferiorly – Capsular ligament attaches the disc to the anterior margin of the articular surface of the condyle.

In between the capsular ligaments anteriorly the disc is also attached by the tendinous fibers to the superior lateral plerygoid muscle. The attachments of the capsular ligaments anteriorly, posteriorly and medially, laterally divides the joint into upper and lower cavities. The internal surfaces of the cavities are bound by the specialized endothelial cells that form synovial lining. These cells along with the synovial fringe located at the anterior border of the retrodiscal tissues, forms synovial fluid that fills the joint cavities.

Synovival fluid acts as

1. Medium for providing metabolic requirement to

the non-vascular tissues of the articular surface.

2. Lubricant in bringing about smooth frictionless movements between the articular surfaces of the disc, condyle and fossa.

COMPOSITION OF ARTICULAR DISC

The articular disc is composed of variable amount of cells and an extracellular matrix. The matrix consists of macromolecules (15-35%) and tissue fluid (65-85%). These macromolecules consist mainly of collagen (85-90%) and proteoglycans (10-15%) (3-5). Macromolecular composition is responsible for imparting the mechanical properties to the disc.

COLLAGEN

It gives the disc tensile strength and stiffness and maintain the shape. They can resist tension parallel to their orientation. The collagen fibers mainly run anteroposteriorly in the inter mediate zone. Thus presenting greater tensile modulus and strength anteroposteriorly than mediolateraly in the intermediate zone (6-8). In the anterior and posterior bands the collagen fibres run mainly mediolaterally thus presenting larger tensile modulus and strength in the mediolateral direction. Collagen fibers exhibit waviness. In tension there is first straightening of the waves without the lengthening of collagen fibers (9). On application of further load, the collagen fibers begin to extend and become load bearing. Also, the collagen network present slight permeability to interstitial fluid (10,11). On loading, the disc initially bears it by the pressurization of the incompressible fluid without much deformation of the collage network (12). However, on further load application, the permeable collagen network transmits the fluid. Thus, transferring the load the collagen fibers. These collagen fibers rearranges once the water is squeezed out (13,14).This squeezing out of water and deformation to collagen network is reversible if the disc is not deformed beyond the physicologic strain range (15). This pumping action and diffusion of synovial fluid through the disc into the joint cavity helps in nourishing the joint cartilage (weeping lubrication) (16). However, it has been reported that after unloading some of the energy used to deform the disc is not released immediately. According to Beek et al the return of tissue fluid from outside the disc and recovery of the disc to its original shape is relatively slow (17). This residual strain could be an important factor in the permanent deformation of the disc (Clenching).

PROTEOGLYCANS

These consists of a core of protein attached to glycosaminoglycans (GAG) sulphate side chains. These are hydrophillic, stiff viscoelastic material with a large molecular size that are intertwined through out the collagen network. As these are hydrophilic in nature, they tend to bind water, leading to expansion of the matrix. The tension in the collagen network counteracts the pressure caused by the expansion of the matrix, thus supporting the joint loading. Further loading leads to squeezing out of the fluid. New equilibrium is therefore achieved which is reversed on the release of load. Thus proteoglycans indirectly modulate the stiffness of the collagen network.

There are a group of

a) Small proteoglycans – Core proteins to which one/two side chains are attached (18,19).

b) Large proteoglycans – Aggrecan contains both chondroitin sulphate and keratan sulphate (20).

The large proleoglycans are present in greater concentration in the central part of the intermediate zone and the anterior, posterior bands of the disc that encounters heavy compressive joint loading, thus maintaining the resilience of the disc (21,22,23). During compression these larger molecules interfere with the flow of the fluid out of the disc resulting in increased compressive modulus compared to the medial and lateral regions of the intermediate zone, that contain greater concentration of smaller proteoglycan. When loading occurs in the jaw-closed position, the deformations in the disc are spread through out the entire intermediate zone, while translation of the condyle in the forward direction to obtain a protrusive or open jaw position leads to a concentration of the deformation in the lateral part of the disc.

Proteoglycans are largely responsible for the compressive modulus of the disc and collagen fibers for its tensile modulus. Compressive modulus is generally smaller (14-17 Mpa) than the tensile modulus (22-26 Mpa). Also, it has been seen that the static loading reduces proteoglycan synthesis and dynamic loading increase it. This is considered as an important factor in maintaining the homeostasis of the joint cartilage (Burger et al, 1992, Kukoskio et al, 1997; Quim et al 1998) (24-26).

Shear stresses may also occur in the disc in the range of (1.0Mpa -1.75Mpa) as the articular surfaces compressing the disc are not parallel. The shear stresses in the disc are sensitive to the frequency and direction of joint loading (Mowet at 1992).

AGE RELATED CHANGES

It was found that Ca^{2+} and phosphorus content of the articular disc increased progressively with aging where as the sulphus contents decreased lightly with aging.

Calcification of the disc of the TMJ were studied by Masato Jibiki et al in 1999 and stated that the calcifications were recognized more frequently posteriorly than anteriorly, and were related to disc perforations. They suggested that the disc degeneration which may occur as a result of aging or mechanical stress, causes calcifications.

The glycosaminoglycan content relative to the tissue fluid markedly increases with age. This increase in the content of sulphated glycosaminoglycan may elevate the osmotic pressure, thus increasing the compressive stiffness of the disc (Nakano & Scott 1996).

The collagen content of the disc increases with age relative to the water content which remains constant. This leads to increase in elasticity of the disc as the aging occurs (23).

SUMMARY

The temporomandibular joint behaves as a viscoelastic structure. The disc can behave as stress absorber and stress distributor because of its viscoelastic properties as a result of which it prevents stress concentration and excessive stress in the cartilage and bone components of the joint. These functions protect the joint from degeneration of disc and osteoarthrosis. The viscoelastic properties depends on the direction (tension, compression and shear) and the type of applied loading (static and dynamic). Several finite element analysis were done which have shown that stress in the joint components and size of the contact areas depend on the elastic modulus of the disc. Wear of the disc has been found primarily in its anterior band or intermediate region. According to Tanaka et al anterior band receives the largest loads resulting in the concentration of chondroitin sulfate in this region. Devocht et al, Nargahara et al, Beek et al conducted various studies and concluded that the disc is predominantly loaded in its intermediate zone resulting in wear of disc in this region. Stress distribution in disc is also affected by direction of loading. During opening or protrusive jaw movements, translation of condyle occurs leading to concentration of loading in lateral part of the disc. Furthermore, Gallo et al concluded that during mastication, fatigue failure of TMJ disc could result from shear stress produced by mediolateral translation of stress location.

CONCLUSION

A sound understanding of biomechanical behavior of TMJ disc is necessary for evaluation and treatment of various temporomandibular joint disorders.

References

1. Tanaka E, Tanaka M, Hattori Y, Aoyama J, Watanabe M, Sasaki A,et al. Biomechaical behaviour of bovine temporomandibulararticular discs with age. Arch Oral Biol 2001a; 46:997-1003.
2. Jefery PO. Management of temporomandibular disorders and occlusion. 5th edition.
3. Nakano T, Scott PG. A quantitative chemical study of glycosaminoglycans in the articular disc of the bovine temporomandibular joint. Arch Oral Biol 1989a; 34: 749-757.
4. Sindelar BJ, Evanko SP, Alonzo T, Herring SW, Wight T. Effects of intraoral splint wear on proteoglycans in the temporomandibular joint disc. Arch Biochem Biophys 2000; 379:64-70.
5. Beek M, Koolstra JH, van Ruijven LJ, van Eijden TMGJ. Threedimensional finite element analysis of the cartilaginous structuresin the human temporomandibular joint. J Dent Res 2001b; 80:1913-1918.
6. Tanaka E and Ejiden T. Biomechanical behavior of the temporomandibular joint disc. Crit Rev Oral Biol Med 2003,14:138
7. Tanne K, Tanaka E, Sakuda M. The elastic modulus of the temporomandibular joint disc from adult dogs. J Dent Res 1991; 70:1545-1548.
8. Teng SY, Xu YH, Cheng MH, Li Y. Biomechanical properties and collagen fiber orientation of TMJ discs in dogs: part 2. Tensile mechanical properties of the discs. J Craniomandib Disord Facial Oral Pain 1991; 5:107-114.
9. Gathercole LJ, Keller A. Crimp morphology in fibre-forming collagens. Matrix 1991; 11:214-234.
10. Mow VC, Holmes MH, Lai WM. Fluid transport and mechanical properties of articular cartilage: a review. J Biomech 1984; 17:377-394.
11. Mow VC, Ateshian GA, Spilker R..Biomechanics of diarthrodial joints: a review of twenty years of progress. J Biomech Eng 1993; 115:460-467.
12. Soltz MA, Ateshian GA. Experimental verification and theoretical prediction of cartilage interstitial fluid pressurization at an impermeable contact interface in confined compression. J Biomech 1998; 31:927-934.
13. Mow VC, Kwan MK, Lai WM, Holmes MH (1986). A finite deformation theory for nonlinearly permeable soft hydrated biological tissues. In: Frontiers in biomechanics. Schmid-Schonbein GW, Woo SL-Y, Zweifach BW, editors. New York: SpringerVerlag, Chapter 13, pp. 153-179.
14. Woo SL-Y (1986). Biomechanics of tendons and ligaments. In: Frontiers in biomechanics. Schmid-Schonbein GW, Woo SL-Y, Zweifach BW, editors. New York: Springer-Verlag, Chapter 14, pp. 180-195.
15. Scapino RP, Canham PB, Finlay HM, Mills DK. The behaviour of collagen fibres in stress relaxation and stress distribution in the jaw-joint of rabbits. Arch Oral Biol 1996; 41:1039-1052.
16. Shengyi T, Yinghua X. Biomechanical properties and collagen fibre orientation of TMJ discs in dogs: Part I. Gross anatomy and collagen fibre orientation of the disc. J

Craniomand Disorder 1991; 5:28-34.
17. Beek M, Aarnts MP, Koolstra JH, Feilzer AJ, van Eijden TMG. Dynamic properties of the human temporomandibulajoint disc. J Dent Res 2001a; 80:876-880.
18. Chopra RK, Pearson CH, Pringle GA, Fackre DS, Scott PG. Dermatan sulphate is located on serine-4 of bovine skin proteodermatansulphate. Biochem J 1985; 231:277-279.
19. Fisher LW, Termine JD, Young MF. Deduced protein sequence of bone small proteoglycan I (biglycan) shows homology with proteoglycan II (decorin) and several nonconnective tissue proteins in a variety of species. J Biol Chem 1989; 264:4571-4576.
20. Nakano T, Scott PG. Proteoglycans of the articular disc of the bovine temporomandibular joint. I. High molecular weight chondroitin sulphate proteoglycan. Matrix 1989; 9:277-283.
21. Mills DK, Daniel JC, Scapino RP. Histological features and invitro proteoglycan synthesis in the rabbit craniomandibular joint disc. Arch Oral Biol 1988; 33: 195-202.
22. Nakano T, Imai S, Koga T, Dodd CM, Scott PG. Monoclonal antibodies to the large chondroitin sulphate proteoglycan from bovine temporomandibular joint disc. Matrix 1993; 13:243-254.
23. Nakano T, Scott PG. Changes in the chemical composition o the bovine temporomandibular joint disc with age. Arch Oral Biol 1996; 41:845-853.
24. Burger EH, Klein-Nulend J, Veldhuijzen JP. Mechanical stress and osteogenesis in vitro. J Bone Miner Res 1992; 7: S397-S401.
25. Kuboki T, Shinoda M, Orsini MG, Yamashita A. Viscoelastic properties of the pig temporomandibular joint articular soft tissues of the condyle and disc. J Dent Res 1997; 76:1760-1769.
26. Jibiki M, Shimoda S, Nakagawa Y, Kawasaki K, Asada K, Ishibashi K. Calcifications of the disc of the temporomandibular joint. J Oral Pathol Med 1999; 28:413-419.

Author Information

Neelam Gupta, M.D.S
Reader, Dept. of Prosthodontics, P.D.M Dental College & Research Institute

Manisha, M.D.S
Senior Lecturer, P.D.M Dental College & Research Institute

NIDHI Kathuria, M.D.S
Senior Lecturer, Dept. of Prosthodontics, P.D.M Dental College & Research Institute

Rahul Prasad, M.D.S
Senior Lecturer, Dept. of Prosthodontics, Bharati Vidyapeeth Dental College