The Structure of the Human Temporomandibular Joint Disc: A Scanning Electron Microscopy Study

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The articular disc of the temporomandibular joint was studied in fetuses (16 to 39 weeks of intrauterine life), infants (up to 4 months of age), dentulous adults (aged 30 to 39 years), and completely edentulous adults (aged 60 to 69 years) by scanning electron microscopy. The constituent bundles of collagen fibers were stratified and were oriented anteroposteriorly, laterolaterally, and obliquely in the middle portion of the disc. A ring of laterolateral bundles constituted the main feature of the thick posterior portion. In the anterior portion of the disc, the fibers were anteroposteriorly and obliquely oriented. On the superior and inferior surfaces of the disc, a thin layer of perpendicularly arranged collagen fibers covered the underlying, thick, laterolateral oriented collagen fibers.

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The structure of the temporomandibular joint (TMJ), particularly of the articular disc, has been described in humans and in many animals to reveal its morphologic characteristics. Through light microscopy, the disc has been found to consist of dense bundles of collagen fibers of predominantly anteroposterior orientation in the anterior and middle portions[1–13] and other directions in the posterior portion.[7,14,15] However, few studies using scanning electron microscopy (SEM) have described the structure of the disc.

Taguchi et al[10] reported by SEM that the surface of the disc in monkeys consists of a close network of delicate collagen fibrils both vertically and horizontally arranged. In the middle portion, the matrix structure showed the collagen fibers running in a sagittal direction. These fibers, seen in their entirety, appeared as wavy, winding structures. In dogs,[12] the surface of the disc had an undulating configuration: the fine fibrils in the middle portion were twisted together tightly, presenting a wavy, winding, laminar structure anteroposteriorly arranged.

De Bont et al[11] observed in adults, particularly in humans (ages ranging from 58 to 73 years), that the articular surface of the disc was composed of closely packed collagen fibrils running predominantly anteroposteriorly. They still related small coiled fibrils and saw that within the articular disc, the collagen fibrils were arranged in bundles and sheets in frontal and sagittal planes. In addition, Jagger[16] demonstrated in adults aged 52 to 83 years the central portion of the discs, consisting of tightly bound collagen bundles and the bundles of the anterior and posterior portions more loosely bound and irregularly orientated. In human fetuses,[13] the major part of the posterior portion was composed of undulating fibrils passing antero-

posteriorly. In the surface of the disc, there were some spiral collagen fibers; in the middle portion, a stratum composed of anteroposterior and mediolateral collagen fibers was described by age 4 months.

Because of the relationship of the disc with dental occlusion and functional and pathologic changes of the stomatognathic system, the aim of the present study was to detect the structural arrangement of this important part of the TMJ through an SEM study on human fetuses, infants, dentulous adults, and completely edentulous adults.

Materials and Methods

Fifteen fetuses (16 to 39 weeks of intrauterine life; group 1a), 15 infants (aged up to 4 months; group 1b), 20 dentulous adults (aged 30 to 39 years; group 2), and 20 completely edentulous adults (aged 60 to 69 years; group 3) of both sexes were obtained at necropsy, 6 to 12 hours after death (stored at 0°C to 4°C). None had any known systemic diseases or lesioned discs.

The right TMJs were carefully dissected and fixed for 72 hours in a modified Karnovsky solution of 2.5% glutaraldehyde and 2% paraformaldehyde in 0.1 mol/L phosphate buffer (pH 7.4) at 4°C. Six discs from each of the four groups were washed in phosphate buffer for 30 minutes and treated for 8 days at room temperature with a series of sodium hypochlorite solutions in decreasing concentration (5% to 0.2%).[17] Two discs from each group were placed in phosphate buffer solution for 24 hours, immersed in liquid nitrogen, and broken, and some fragments were selected. An additional two discs from each group were washed in phosphate buffer solution and treated with 4 N hydrochloric acid for 10 minutes at 60°C,[18] immersed for 15 minutes (three 5-minute periods) in phosphate buffer, and placed for 20 hours in a type III collagenase solution (Sigma Chemical, St Louis, MO) at room temperature. All specimens were dehydrated in a series of alcohols of increasing concentrations and were critical point–dried with liquid carbon dioxide in Balzers CPD-010 and SCD-040 apparatus (Balzers Union,

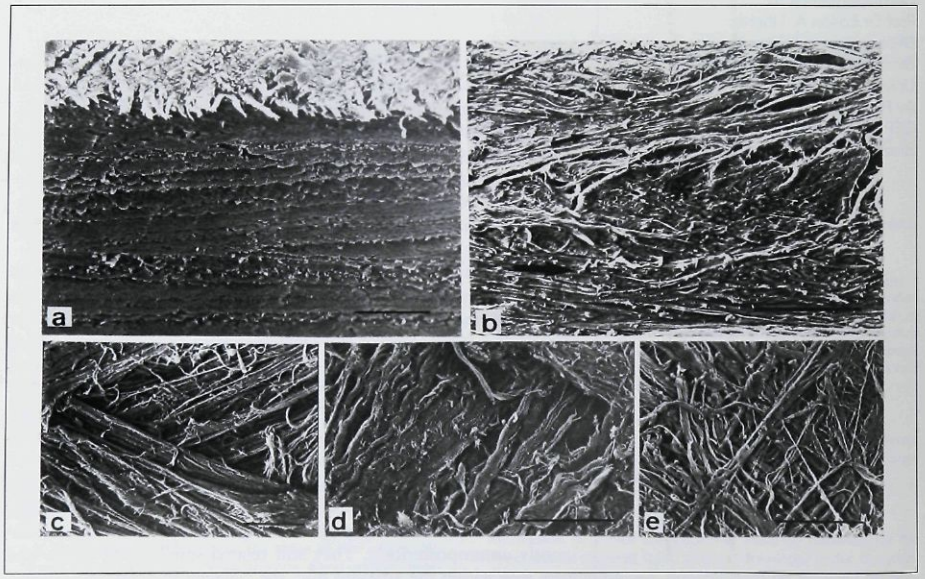

Fig 1 Central part of the middle portion of the TMJ disc. *(a)* Stratified nature of bundles of collagen fibers (sagittal plane, group 2, aged 30 years) (bar = 50 μm). *(b)* Collagen fibers in laterolateral (*), anteroposterior *(large arrow)*, and oblique *(small arrow)* directions are present (sodium hypochlorite solution, sagittal plane, group 3, aged 64 years) (bar = 100 μm). *(c)* Upper view of collagen fibers with rectilinear direction; these form diverse layers (group 1, 32 weeks of intrauterine life) (bar = 50 μm). *(d)* Deep layer with compact bundles of collagen fibers of an undulant nature (group 3, aged 68 years) (bar = 100 μm). *(e)* Upper view of the peripheral area. The collagen fibers are arranged as a network system (group 2, aged 36 years) (bar = 100 μm).

Liechtenstein, Germany). The remaining discs, 10 from each group, were critical point–dried and torn apart under a stereomicroscope with a small pincer, or they were sagittally sectioned using a razor blade.

The specimens were then gold coated in a Balzers SCD-040 ion sputterer and were examined in a Cambridge Stereoscan-240 scanning electron microscope.

Results

Observations concerning groups 1a and 1b are together described as group 1 because there were no significant differences between them. The middle portion of the disc had a central region of a stratified nature, with compact bundles of collagen fibers oriented anteroposteriorly, laterolaterally, and obliquely in groups 1, 2, and 3 (Fig 1[a to c]). Undulating and compact bundles of collagen fibers were present in the deep layers of the thick middle portion of the discs in groups 2 and 3 (Fig 1[d]). Although the stratified structure appeared in the peripheral areas, the loosely disposed fibers formed a network with narrow meshes (Fig 1[e]).

Thick, dense laterolaterally oriented bundles of collagen fibers, intermingled with others in diverse directions, constituted the main characteristics of the posterior portion of the disc in all groups analyzed (Fig 2[a and b]). These fibers formed a thick ring that circled the disc (Fig 2[c and d]).

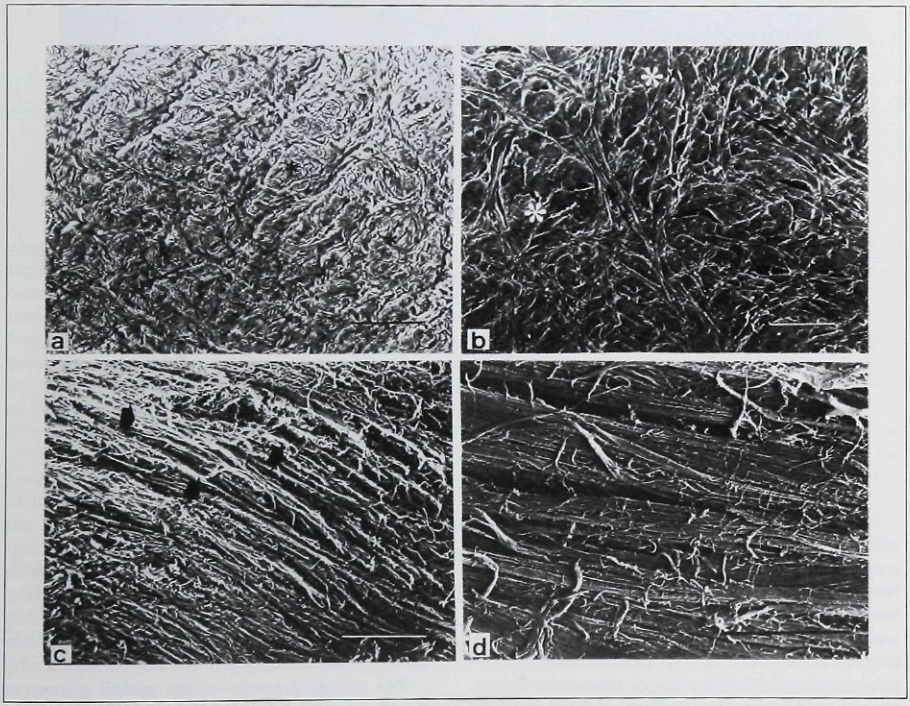

Fig 2 Posterior portion of the TMJ disc. *(a)* Bundles of collagen fibers in laterolateral direction (*) (sodium hypochlorite solution, sagittal plane, group 1, 28 weeks of intrauterine life) (bar = 100 μm). *(b)* Thick and compact bundles of collagen fibers in a laterolateral direction (*) and intermingled with others in diverse directions *(arrows)* (sodium hypochlorite solution, sagittal plane, group 2, aged 39 years) (bar = 100 μm). *(c)* Parallel arched fibers running in direction to anterior portion *(arrows)* (upper view, group 1, aged 1 month) (bar = 250 μm). *(d)* Thick ring that circles the disc (upper view, group 2, aged 34 years) (bar = 50 μm).

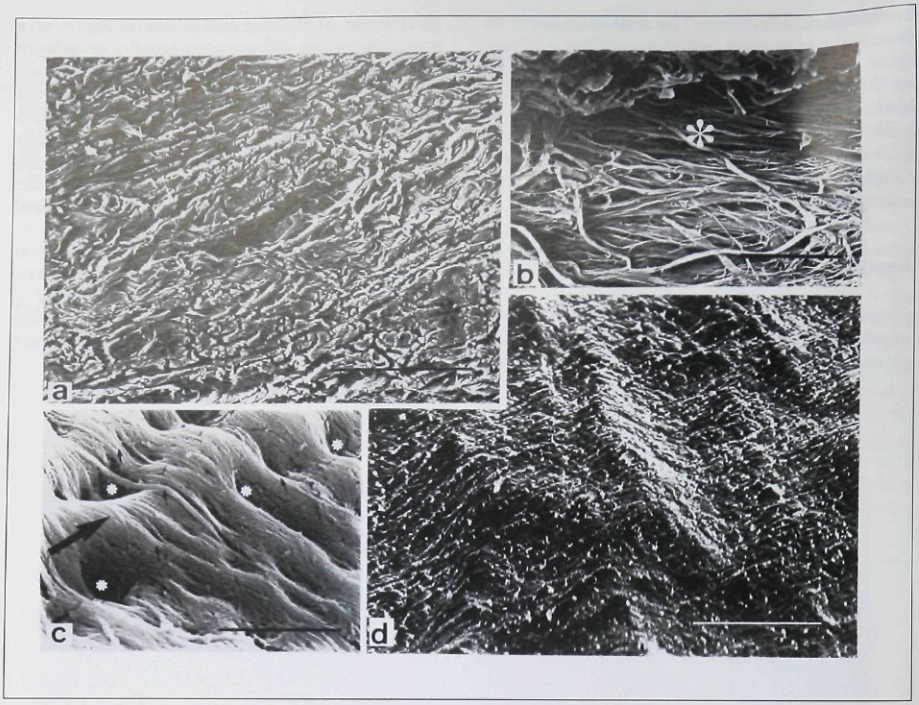

Fig 3 Anterior portion of the TMJ disc. *(a)* Few deep bundles of laterolateral collagen fibers (*) in the anterior portion of the TMJ disc (compare with Fig 2[b]) (sodium hypochlorite solution, sagittal plane, group 1, 28 weeks of intrauterine life) (bar = 100 μm). *(b)* Continuation of the thick posterior ring (*) in the anterior portion of the TMJ disc (group 3, aged 65 years) (bar = 100 μm). *(c)* Upper surface of the disc where several foveae are evident (*). Thick bundles in a laterolateral direction *(large arrow)* are covered by thin collagen fibers *(small arrows)* in an anteroposterior direction (group 3, aged 62 years) (bar = 10 μm). *(d)* Lower surface of the disc with an undulant aspect (group 1, 4 weeks of intrauterine life) (bar = 10 μm).

Bundles of predominantly anteroposteriorly and obliquely oriented collagen fibers, which were intermingled with fibers of laterolateral orientation, formed the anterior portion of the disc. The laterolateral fibers were more deeply located and represented a continuation of the thick posterior ring (Fig 3[a and b]). A thin layer of undulated and anteroposteriorly oriented collagen fibers with foveae of varying diameters was present on the upper and lower surfaces of the disc, covering the thick and laterolaterally disposed layer situated immediately below (Figs 3[c and d]).

Figure 4 displays the main regions of the articular disc.

Discussion

The SEM methods used involving different techniques such as collagenase digestion,[18] cryofracture, tearing, and sodium hypochlorite[17] constitute excellent procedures by which to examine the arrangement of collagen fibers in the TMJ disc.

The stratified nature of the middle portion of the disc was clearly revealed in group 1 and was found to be composed of compact bundles of collagen fibers oriented in anteroposterior and oblique directions, and alternated with other laterolaterally oriented bundles. These data are not in accordance with those of Yang et al,[13] who

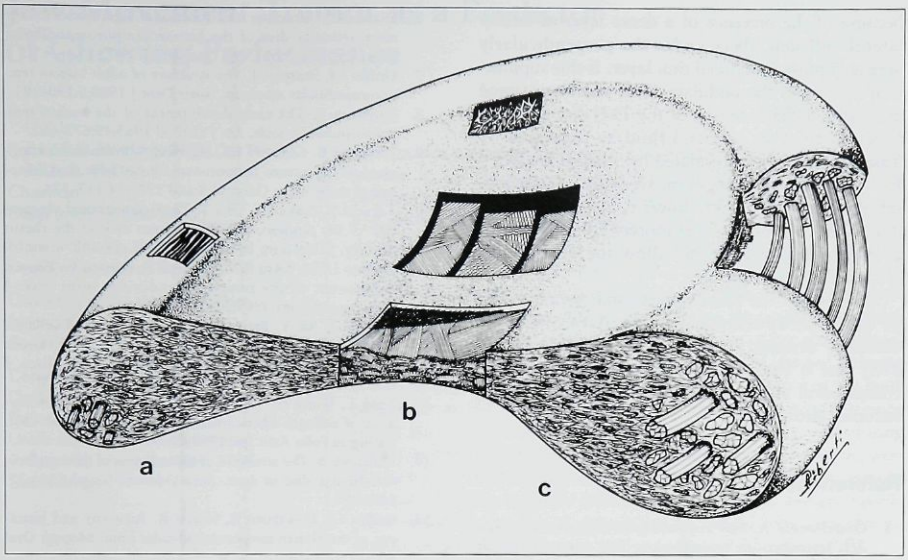

Fig 4 Temporomandibular disc of a human adult (a = anterior portion; b = middle portion; c = posterior portion).

observed most of the fibers in this compacted region in human fetuses to be anteroposteriorly oriented, with a few fibers in a laterolateral direction. These data also disagree with those of Jagger[16] for human adults, Taguchi et al[10] for monkeys, and Shengyi and Xu[12] for dogs, where only compact bundles of collagen fibers oriented in an anteroposterior direction were described. It is important to emphasize the undulating nature of the central deep layers in the thick discs of groups 2 and 3, as well as the loose arrangement of the collagen fibers in the peripheral area. In the present study, various orientations corresponded to the different regions of the same part of the disc.

The main characteristic of the posterior portion of the disc was the presence of laterolaterally oriented bundles of collagen fibers interlaced with others running in various directions from group 1 to group 3; thicker and more dense fibers appeared with age. This suggests that this region acts as a wedge that stabilizes the TMJ during the opening movement of the mouth, as described by El Mahdy.[19] The peripheral, ringlike structure observed in the upper and lower regions of the disc confirmed the SEM results of Taguchi et al[10] and Shengyi and Xu[12] in other species, but was not in agreement with the nonspecific orientation reported by Jagger[16] for humans.

Jagger[16] described the anterior portion of the disc as composed of loosely arranged collagen fibers of no specific orientation. Shengyi and Xu[12] reported compact laterolateral bundles that were interwoven with fibers in an anteroposterior direction. In the present study an anteroposterior orientation was the main pattern of the bundles in the anterior portion of the disc, with more deeply situated, laterolateral collagen fibers representing the anterior extension of the well-developed ringlike structure of the posterior portion. A similar arrangement with undulant anteroposterior fibers was observed in group 1, which confirms the observations of Yang et al[13] for the anterior portion of the disc in the human fetus.

Although de Bont et al[11] described the spiral nature of the thin, most superficial layer of the disc surface and have interpreted the undulant appearance of the disc surface described by Jagger,[16] Taguchi et al,[10] Shengyi and Xu,[12] and Yang et al[13] as technical artifacts, the upper and lower surfaces of the disc in groups 1, 2, and 3 of the present study did in fact exhibit an undulant appearance

because of the presence of a dense layer of laterolateral collagen fibers under the perpendicularly arranged most superficial thin layer. If this supposition is correct, the undulant form can be accepted as a normal characteristic of the TMJ disc and may function to store synovial fluid as suggested by Yang et al[13] and as postulated by Shengyi and Xu[12] for whom the undulant form represents a compensatory adaptation for the lower permeability of the disc. These theories were reinforced by the presence of foveae, which probably allow the diffusion of synovial fluid into the disc.

Thus, when the three-dimensional arrangement of the anteroposteriorly, laterolaterally, and obliquely oriented layers of collagen fibers in the TMJ disc is analyzed overall, its role in resisting compression and stretching during occlusal forces becomes clear.

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Resumen

La estructura del disco de la articulación temporomandibular humana: estudio atravez del microscópio eletrónico de barredura

El disco articular de la articulación temporomandibular fué estudiado en fetos y niños, adultos con dientes, y ancianos sin dientes atraves del microscópio de barredura La porción média del disco está constituída de fibras de colágeno estratificado agrupadas y orientadas sagitalmente, transversalmente y oclícuamente. La porción posterior, más espesa presenta un anillo de fibras transversales agrupadas. En la porción anterior del disco, son observadas fibras de orientación sagital y oblícuas. En la superficie superior e inferior del disco, una capa delgada de fibras de colágeno orientadas perpendicularmente cubren las fibras de colágeno transversales.

Zusammenfassung

Die Struktur des menschlichen Kiefergelenksdiskus: eine Elektronenmikroskopische Studie

Der Diskus des Kiefergelenkes wurde bei Föten und Kindern (16 bis 39 intrauterine Woche), bezahnten Erwachsenen (Alter zwischen 30 und 39 Jahren) und vollständig zahnlosen Erwachsenen (Alter zwischen 60 und 69 Jahren) mittels Elektronenmikroskopie untersucht. Die Hauptbündel von Kollagenfasern waren geschichtet und waren anterioposterior, laterolateral und schräg im mittleren Anteil des Diskus ausgerichtet. Ein Ring von laterolateralen Bündeln bildet den Hauptbestandteil des dicken hinteren Anteils. Im vorderen Anteil des Diskus zeigten die Fasern eine anterioposteriore und schräge Ausrichtung. Auf der oberen und unteren Oberfläche des Diskus bedeckt eine dünne Schicht von senkrecht angeordneten Kollagenfasern die darunterliegenden dicken laterolateral ausgerichteten Kollagenfasern.