FIBER COLLAGEN CONTACT LENS

This invention relates to a soft contact lens consisting of a collagen gel in which the collagen gel is prepared from fiber collagen, and from mixtures of fiber collagen with solubilized collagen.

Collagen constitutes about 20 to 30 percent of the total body protein in vertebrates. It is a fibrous protein and functions primarily as a supporting tissue and scaffolding for other proteins and cells. It is present throughout the body but exists in high concentrations in skin, tendon and bone.

Collagen is recovered from these tissues by a variety of techniques the oldest know method being the boiling of the tissue in water which denatures some of the collagen and forms the well-known gelatin on cooling. For use as a biomaterial however, collagen must be recovered in native, undenatured form, i.e., with little or no destruction of the basic rigid triple helical structure; (tropocollagen).

Undenatured native collagen is recovered principally by two methods, (a) solution by dissolving the collagen in acids, bases, salts or by enzyme digestion in which instances the collagen becomes actually dissolved, and (b) extraction in solid, undissolved, fiber form usually by the action of aqueous salt on minced, comminuted collagen raw material to produce a dispersion from which the solid is recovered by centrifuge, etc. Both the solution and extraction methods are well described in the collagen art.

The chemistry, molecular structure and biochemical properties of collagen have been well established. An up-to-date review article by the current inventors (Annual Review of Biophysics and Bioengineering, Vol. 3, p 231–253, 1974) contains an excellent compilation of references on the subject.

Contact lenses have been known as a commercial product for over 25 years. Contact lenses to date have been made from chemically synthesized materials which do not occur in nature. For example, most early contact lenses were made from polymethylmethacrylate or chemical modifications thereof, from hydroxyethylmethacrylate, from cellulose acetate butyrate, from silicones, etc. To the knowledge of the applicants no lens, prior to their own inventions, was made from naturally occurring animal materials and especially from materials having physiological and immunological properties possessed by constituents of the eye itself, e.g., the cornea. The state of the art on contact lenses is reviewed in a current article "A Contact Lens Update'-'—Contact Lens Forum, p. 16–23 (May 1976).

In copending application Ser. No. 026,945 filed Apr. 4, 1979 now U.S. Pat. No. 4,223,984 granted Sept. 23, 1980 which is a continuation of Ser. No. 753,556 filed Dec. 22, 1976 now abandoned, there is described and claimed a collagen gel contact lens in which the collagen is made from reconstituted, solubilized telopeptide-poor, defatted collagen, particularly enzyme-solubilized collagen.

We have now discovered that a soft contact lens of improved strength and improved resistance to bacteria attack is produced from purified fiber collagen, and from fiber collagen-solubilized collagen mixtures. The above improved properties are of great value when producing extended-wear disposable lenses. Applicants' preferred fiber collagen is fiber collagen made from beef leg tendon, while the preferred solubilized collagen for use in mixtures therewith is enzyme-solubilized type. Tendon collagen is relatively purer and more resistant to decomposition in that it is by nature more firmly cross-linked; while enzyme solubilization produces greater yields of extracted collagen and at the same time digests telopeptides and other undesirable bodies such as mucopolysaccharides, saccharides and other contaminating proteins.

Applicants have found that fiber collagen and fiber collagen-solubilized collagen gel mixtures appear to have greater resistance to bacteria than solubilized collagen gels alone. The difference, which is of great importance when such gels are formed into contact lenses for human use, is believed to be due to the greater extent of cross-linking of the native fiber collagen molecule and its resistance to decomposition when exposed to the rigors of additional crosslinking whether conducted by radiation or by chemical means. Applicants have frequently found that if the crosslinking by radiation is too severe the resulting collagen gels and lenses made therefrom are susceptible to bacteria growth thereon or in some cases to liquefaction or destruction by bacteria. It is believed that breakges in the linkages of the triple helix structure of the collagen molecule occur under too severe irradiation crosslinking conditions and provide sites that are susceptible to the action of proteolytic enzymes of bacterial origin.

When describing the collagens as purified, applicants mean to imply that the collagens prior to conversion to viscous solutions, are treated, either during their recovery stage or thereafter, for the removal of telopeptides, saccharides, mucopolysaccharides and other contaminating proteins. In addition the recovered collagens must be relatively free of lipids and fats, preferably by subjecting them to de-lipid and defatting solvents. Most animal collagen, of whatever type, contains at least small amounts of fats, and applicants make no distinction in the use herein of the terms defatted, fat-free or fat-poor.

When making collagen lenses from mixtures of fiber collagen and solubilized collagen the amounts of each present in the collagen mixture is not critical. The ratio of fiber to solubilized collagen may vary from 10 to 1 to 1 to 10; however, applicants prefer mixtures in the 40–60, 60–40 wt. % ranges.

RECOVERY OF COLLAGENS FROM CRUDE SOURCE

The method of obtaining solubilized or fibril collagens from the crude collagen source, e.g. skin, tendon, hide, etc., is not critical, and some flexibility may be used in the selection of the particular tissue and the method applied thereto; for example, applicants prefer enzyme extraction when preparing solubilized collagen regardless of the nature of the tissue.

(A) Solubilized Collagen

The greater part of native collagen is insoluble, but can be solubilized in dilute acids, e.g. acetic acid; in bases e.g. NaOH; and in dilute aqueous salts, e.g. NaCl. In all relatively low yields are obtained. All processes are well known in the collagen extraction art. Since applicants prefer enzyme extraction as the better method of obtaining solubilized collagen for their mixed collagen gel lenses, this extraction process will be described in more detail than the others.