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UNDERSTANDING TARUNASTHI WITH SPECIAL REFERENCE TO ARTICULAR CARTILAGE IN THE LIGHT OF AYURVEDA

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ABSTRACT

Articular cartilage of any joint plays in important role in joint mobility and overall quality of life. Healthy articular cartilage is indispensable for good joint function. The unique and complex structure of articular cartilage makes treatment and repair or restoration of the defects challenging for patient, the surgeon, and the physical therapist due to its avascular nature.[1] The preservation of articular cartilage is highly dependent on maintaining its organized architecture. The concept of Articular Cartilage is not clearly stated in age old samhitas. But the similar structure of Tarunasthi is explained grossly in Sharir Sthan of many Samhitas. Modern medical science has given every details of Articular Cartilage structure and functions. With the help of Modern Medical Science, Ayurvedic Principles and different Modern technologies, one can find and prove number of the potential plant drugs effective in various pathophysiological changes in the Articular Cartilage.

KEYWORDS: Tarunasthi, Articular Cartilage, Increase and Decrease in Chondrocyte Number, Cartilage fibrillation, Chondrocyte Hypertrophy, Chondroprotective Ayurvedic Treatment, Articular Cartilage Inflammation.

INTRODUCTION

Scope of Ayurved: Ayurveda is a science of life with a comprehensive way towards health and personalized medicine. It is one of the oldest medical systems, which comprises thousands of medical concepts and hypothesis. Ayurved says health and wellness depend on a equilibrium between the mind, body, and spirit. Its main goal is to promote good health, not

to fight disease. Ayurveda has ability to treat many conditions like aging, menopause and chronic diseases such as cancer, diabetes, arthritis, and asthma, which are untreatable in modern medicine. Unfortunately, due to lack of scientific approval in various concepts, this precious gift from our ancestors is lagging behind. Hence, evidence-based research is highly needed for global recognition and acceptance of Ayurveda. Shri Ramnath Chopra and Shri Gananaath Sen had derived concept of Reverse Pharmacology which means the science of integrating documented clinical hits into leads by transdisciplinary exploratory studies and further these leads into drug candidates by experimental and clinical research. It is an interesting and important scientific approach to develop new drug candidates or formulations from already known facts in traditional medicines through sound preclinical and clinical researches. Though we have been using Ayurvedic medicines since many years and their efficacy have been proved, we need to understand the mechanism of actions at multiple levels to optimize safety, efficacy and acceptability. There is a need of involving all basic sciences such as Physics, Chemistry, Molecular Biology, and Biotechnology together with Ethnopharmacology, Ayurvedic Drug Discovery, Pharmacoepidemiology, Reverse Pharmacology and various other areas for the better understanding, and optimistic outcome of Ayurveda research. There is one more field called as Tissue engineering which means a combination of cells, engineering, and materials methods, and suitable biochemical and physicochemical factors to improve or replace biological tissues. There is a need to explore Indian medicinal plants as a potential source for bone and tissue engineering of articular cartilage. Although the principles of Ayurveda are immortal and are always applicable. updating Ayurveda, by integrating with modern technologies, without changing the basic principles, is a challenging task, but it is a need to be contemporary with the current scientific trends for the benefit of the society and for nurturing Ayurveda.

Cartilage and Its Functions: Cartilage and **bone** are both modified rigid forms of connective tissue. It has two main constituents - **cells** and **extracellular material.**

Functions: 1. Forms the supporting framework of some organs, such as the walls of airways (nose, trachea, larynx and bronchi), where it prevents airway collapse. 2. Present on articulating surfaces of bones. 3. It is the template for the growth and development of long bones, and most of the rest of the fetal skeleton (gradually replaced by bone). In children, the cartilaginous plates at the ends of long bones can be seen on X-rays. These templates disappear when adults reach their full height.

Articular Cartilage and Its Functions: Articular cartilage is the highly specialized connective tissue of diarthrodial joints. Its principal function is to provide a smooth, lubricated surface for articulation and to facilitate the transmission of loads with a low frictional coefficient. Articular cartilage is hyaline cartilage and is 2 to 4 mm thick. It is composed of a dense extracellular matrix (ECM) with a sparse distribution of highly specialized cells called *chondrocytes*. Articular cartilage is devoid of blood vessels, lymphatics, and nerves and is subject to a harsh biomechanical environment. Most important, articular cartilage has a limited capacity for intrinsic healing and repair. In this regard, the preservation and health of articular cartilage are paramount to joint health.[2]

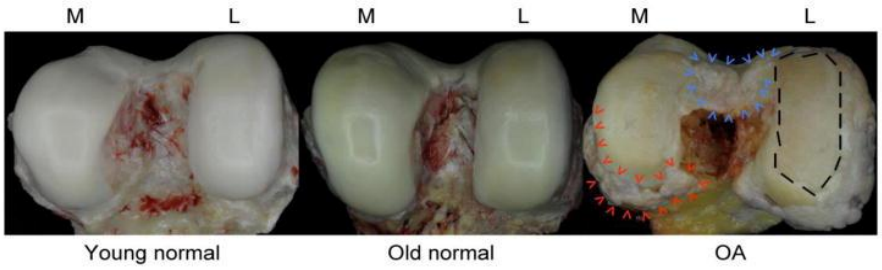
Functions: Articular Cartilage gives the tissue tensile strength for transmission of loads to the underlying subchondral bone. It provides a smooth, lubricated surface for low friction articulation and to facilitate to bear weight while retaining greater flexibility than bone.

Composition of Articular Cartilage[4]

TABLE 5-1 *Adult Articular Cartilage: Approximate Biochemical Composition*

CONSTITUENT	VALUE BY WEIGHT
Water	66%–79%
Solids	21%–34%
Inorganic	
Ash	5%– 6%
Organic	
Collagen	48%–62%
Protein	8%–15%
Glycosaminoglycan	14%–23%
Hyaluronate	< 1%
Lipid	< 1%
Lysozyme	< 1%
Glycoprotein	?

Structure of Articular Cartilage[5]



How Tarunasthi are Formed?

शणसूत्रवत्दृढ - सूत्रतन्तुजालकेषु कठिन चुर्णवद्वस्तु संयोगेन ह्यस्थ्नां निर्माणमित्यर्थः |तरुणास्थिनि तु नातिकठिनानि कोमलस्नायुभागस्याधिक्यात् | गणनाथसेन प्रत्यक्ष शारीर भाग1, अ.3, पत्र15टीका Author Gananath Sen in his book Pratyaksha Shariram in part 1, chapter 3 and page 15 commentary says Jute threads like strong and also hard particles from

sutratantujaal unite to form asthi. But Tarunasthi are not hard and rigid like Asthi. It has more soft snayu part in the formation.[6]

Panchmahabhut Composition of Tarunasthi: Bones are especially hard, rigid, and inflexible while cartilages are flexible, rubber like. Tarunasthi / cartilages are not as flexible as mansa peshi / muscle and are not as rigid as asthi / bone. Articular cartilage is thin, tough, flexible and pliable in nature. Jaliya Med dhatu with the help of Prithvi and Vayu mahabhutagni gets converted into hard, rigid, inflexible asthi dhatu. Tough, elastic, flexible Tarunasthis also take birth by the same process. In this process of tarunasthi creation, jaliya med dhatu does not get converted into hard, rigid, inflexible asthi dhatu totally but gets converted into soft, flexible elastic tarunasthi.

Concept of Articular Cartilage in Ayurved

तरुणास्थीनि तावत् द्विविधानि, संध्यन्तःस्थितानि - संधिवेष्टनानि, संध्यन्तरालानि चेति | तत्र संधिवेष्टनानि अस्थ्यंशानां छादकानि,इतराणि तेषां अन्तरालेषु स्थितानि चक्रत्रिकोणाकाराणि | तत्र चक्राकाराणि कषेरुकान्तरालेषु, त्रिकोनाकाराणि मणिबन्धादौ| तेषु च कानिचित् स्थितिस्थापकानि स्नायुसूत्रभूयिष्ठानि च |गणनाथसेनप्रत्यक्षशारीरअ.3, भाग1पत्र 118 Author Gananath Sen says in his book Pratyaksha Sharir about Tarunasthi that they are of two types. One is at the end of the joints and they cover the joint ends and another present inside the joint space. The concept of Tarunasthi explained in age old samhitas seems similar to the concept of cartilage in modern science. Author Gananath Sen says there are two types of tarunasthi, first Tarunasthi inside of the joint space are circular, triangular in shape. Circular tarunasthi are present in the kasheruka (vertebrae) and triangular tarunasthi present in manibandha sandhi (wrist joint). This article apprises about the Sandhivashtanani Tarunasthi which are present at the end of joints and cover the end part of the bone.[7]

Table 6: Changes in Components of Articular Cartilage due to Aging and osteoarthritis.

Factors	Aging	Osteoarthritis
Water	Decreased	Increased
Modulus /Stiffness	Increased (less elastic)	Decreased (more elastic)
Chondro cytes	1. 19 cells / mm^3 are present in cartilage of young human adults. 2. Cell density decreased. 3. Chondrocytes density decreases in superficial zone by 50% from age 20 to 90	1. Decreased chondrocyte number irrespective of & unrelated to age 2. Chondrocyte undergo terminal differentiation (hypertrophy and apoptosis)

	4. Decreased chondrocyte number	3. Osteophyte formation in osteoarthritis
Glycosaminoglycan	1. Decreased proteoglycan concentration, size and charge 2. Elastic properties lower down	1. Increased chondroitin 4 sulfate : keratan sulfate ratio
Proteo glycans	1. Increased decorin, 2. decreased proteoglycan size	1. Proteoglycans unbound from hyaluronate
Collagen	1. Aging modifies the collagen fibrils. 2. Accumulation of non-enzymatic glycation end products that 3. Increase the stiffness of the collagen network except the aging healthy ankle articular cartilage.	1. Collagen disorganized. 2. Increase in type II collagen denaturation in early OA. 3. Increased cleavage of the collagen by collagenases. 4. Increased synthesis of matrix molecules, type II collagen and aggrecan. 5. Newly synthesised damaged molecules 6. No effective attempt at cartilage matrix repair.7. Early, limited proliferation of chondrocytes restricted by the physical bulk of large damaged collagen. 8. No machinery to remove and repair of damaged tissue in mature avascular articular cartilages.
Advanced Glycosylation End products	1. Non-enzymatic glycation of proteins, such as collagen, results in the formation of advanced glycation endproducts (AGE). 2. AGE result in pathologic stiffening of cartilage, extracellular matrix	1. Pentosidine, an AGE, is present in serum, synovial fluid, and articular cartilage. 2. AGE levels are not always increased, and may be decreased locally.

Note: Denaturation, is process of modifying the molecular structure of a protein. Denaturation involves the breaking of many of the weak linkages, or bonds (e.g., hydrogen bonds), within a protein molecule that are responsible for the highly ordered structure of the protein in its natural (native) state.

Glycation: Non enzymatic bonding of a sugar molecule to a protein or lipid molecule.[14]

The level of cartilage cellularity determines the tissue volume that is being maintained by a single chondrocyte and appears to have implications for cartilage repair. Only 19 cells per mm^3 are present in the cartilage of young adults.[9,10] In full-thickness cartilage from a variety of human joints, cell density is decreased with aging.[8,11,12,13] In the articular cartilage of macroscopically normal cartilage from human femoral condyles the density of chondrocytes decreases most profoundly in the superficial zone by ~50% between age 20 and 90.[15]

Prevention, Promotion and Correction of Aging Changes In Articular Cartilage through Principles of Ayurved

Relationship of Vata Dosha, Asthi and Tarunasthi: तत्रास्थानिस्थितोवायुः| अ .हृ .सू .11/26

Vata dosha resides in Asthi Dhatu. Khara Guna of Vata is similar with Khara Guna of Asthi but Laghu and Chala Guna of Vata are opposite to that of Guru and Sthira Guna of Asthi. When Vata gets vitiated Asthi is the most susceptible Dhatu. Considering the role of Vata dosha predominance in the degeneration of body parts in humans and Vata - Aasthi dhatu relationship, general principle of vata dosha treatment can be adopted for better health of Tarunasthi / Articular cartilage. Also pursuation of Vata dosha pacifying - Dincharya (daily regimen), Ratricharya (night regimen) and Ritucharya (seasonal regimen) can be beneficial for upgrading the health of Tarunasthi / Articular Cartilage.

By strictly following Sadvritta (behavioral and ethical considerations), Achara Rasayana (rejuvenative healthy life-style), and rules of Dharaniya and Adharaniya vegas (suppressible and non-suppressible urges), Practices of Yoga, Rasayana therapy (rejuvenative therapy), timely Panchkarma and consumption ofappropriate ayurvedic medicines, battle against Jara or aging and against asthi, tarunasthi degeneration can be fought. Along with Abhyang and Basti panchkarma, Sthanik basti on joints like janu, shroni, Parisek or Dhara for knee, hip joint which undergo heavy stress, Avgaha swedanin Vatahar Liquids especially for degenerative joints Can be included regularly in once routine.[11]

Dravya Selection Principle for promotion of Health Articular Cartilage

जायन्ते हेतुवैषम्यात् विषमा देह धातवः | हेतुसाम्यात् समास्तेषां स्वभावोपरमः सदा || च सू 16 /27

All body components especially sapta dhatu become poor in quality and function by indulgence of troublesome wrong dravya. Nourishing, dhatu resembling dravya help to calm down and to develop balance of sapta dhatu. As Tarunasthi is mainly made up of Prithvi, Jala and Vayu Mahabhutpradhan tatva, plants containing these Tatva majorly, dravya with Madhur Rasa and Asthiposhak Quality can be wholesome for Articular Cartilage.[12]

सर्वदा सर्व भावानं सामान्यं वृद्धिकारणं| ऱ्हासहेतुर्विशेषश्च् प्रवृत्तिरुभयस्य तु || च. सू. अ. 1 / 44

Samanya – Vishesh Siddhant

This Siddhant is key principle of the Ayurvedic Treatment. Dosh, Dhatu and Mala are graced by consuming same or similar component, medicines. They can be abated by using dissimilar elements, ingredients, medicines or food. Samanya-Vishesh principle along with the basic principles of panchmahabhuta and shad-rasa from ayurved, treatments, lifestyle, medicinal plants can be selectedto keep articular cartilage healthy for a longer period.[16]

Maintenance of Water Percentage in Articular Cartilage

The detailed changes in Articular Cartilage due to Aging and Osteoarthritis are stated in Table no.6. According to the same, Water percentage in agingarticular cartilageshould be kept maintained in aging phase. For decreasing water content and increased stiffness of collagen network in Articular Cartilage Dravabahul, Madhur rasa pradhan, Tarpan (satiating) dravya which capture and store moisture can be implementedorally and for panchkarma treatments like aalepan, avagaha, basti, swedan, sthanik basti and parisek / dhara etc.

Maintenance of Number of Chondrocytes

To correct thedecreasing number of chondrocytesin aging articular cartilage, Madhur rasa Pradhan, Jeevaniya (restorative, refreshing) dravya along with vata dosha upkrama in numerous ways can be useful.

Maintenance of Proteoglycan Quality

Madhur rasa Pradhan, Balya (increase vitality) and Bruhaniya (nourishing, making fat, big) dravya can be used to preventdecrease in the concentration, size, and charge of the proteoglycanin aging articular cartilage.

Role of Vayasthapan Dravya in Aging Articular Cartilage

वयः तरुणं स्थापयतीति वयःस्थापनम् | च.द ., यो.

Madhur rasa pradhan and Snigha guna Pradhan dravya from Vayahsthapan gana (age stabilizing medicines - from book charak samhita, sutrasthan chapter 4) can be constructive in aging articular cartilage.[17]

Prevention, Promotion & Correction of Osteoarthritic Changes In Articular Cartilage through Principles of Ayurved: Half of the world's population, aged 65 and older, suffers from OA:[3]

Maintenance of Water Percentage in Osteoarthritis

According to modern medical science, water percentagein articular cartilage gets increasedand stiffness is decreased in Osteoarthritis. Imbalance in mahabhut composition of articular cartilage requires Prithvi mahabhut pradhandravya especially with Shoshan (absorbing) quality dravyato correct the water percentage imbalance.

Inflammation Recovery

To reduce the inflammatory changes in the articular cartilage in OA, Gandh bahul (are pitta shamak), Sheet, Prasadan guna pradhan and Tikta, Kashay rasa (Tikta - Vayu + Akasha and Kashaya - Vayu + Prithvi) pradhan dravya with Ruksha, Shoshan quality can be used.

Anti-inflammatory Effect of Sesamin on Chondroitin Sulfate Proteoglycan Synthesis

Numerous studies have reported on the health benefits of sesamin, a major lignin found in sesame (*S. indicum*) seeds. Recently, sesamin was shown to have the ability to promote chondroitin sulfate proteoglycan synthesis in normal human chondrocytes. This study assessed the anti-inflammatory effect of sesamin on proteoglycans production in 3D chondrocyte cultures.

The study provided new evidence about the dual effects of sesamin on inflammation induced chondrocytes through IL-1β expression suppression and through CSPGs synthesis induction, one of the therapeutic targets for OA. Sesamin supplementation can have a synergistic effect on drugs for osteoarthritis treatment that target IL-1β production and processing.[18]

General Treatment in Asthi and Tarunasthi disorders

अस्थ्यश्रयाणां व्याधीनां पञ्चकर्माणि भेषजं बस्तयः क्षीरसर्पीषि तिक्तकोपहितानि च | च .सू .28/ 27

This reference from text Charak samhita sutrasthan chapter 28 adds weightage to the speculation stated above about tikta and kashay rasa.[19]

For Declined Number of Chondrocytes

बलाय हितं बल्यम् | गङ्गाधर कविराज चरकव्याख्याकार

Osteoarthritis related decrease in chondrocyte numberirrespective of & unrelated to ageneeds asthi balya dravya (asthi nutritive) for different modes of treatments.[20]

Achrya Charak has noted ten balya medicines in sutra sthan adhyaya four. From the list of Balya dravya, plants those have Tikta Rasa (Vayu + Akasha mahabhut) and Kashaya Rasa (Vayu + Prithvi mahabhut) prominently can be used.

Hypertrophied Chondrocytes

Chondrocyte undergo terminal differentiation (hypertrophy and apoptosis) and osteophyte formationin osteoarthritis. For hypertrophied (volume enlargement) chondrocytes again Kashay rasa pradhan Shoshak, Kledshoshak dravya can be used.

To prevent formation of osteophytes Tikta rasa pradhan, Shoshak, Pralhadkar, Dipan, Pachan dravya can be used as a preventive and curative treatment.

Unbound Proteoglycans

संधानकं शरीरेऽन्तःसंहतिकर भावानां|(इन्दु)

Conditionsin which Proteoglycans unbound from hyaluronate can be treatedwith sandhaniya dravya. (Combing, joining, uniting quality) with specific vata dosha upakram.[21]

viii) Cartilage fibrillation

Fibrillation of cartilage in Osteoarthritis is associated with a defective adhesion of chondrocytes to fibronectin. Fibrillation is a local surface disorganization involvinga splitting of the superficial layers of the cartilage.[22]

श्रुतःशीतकषायो वा रोपणार्थं प्रशस्यते सु. सू. 37 / 22

For such cartilage changes ropan (to coat, to heal) and sandhaniya treatment (healing, joining) and dravya can be employed.[23]

Checking of Chondrocyte Apoptosis

नित्यगश्चानुबन्धश्च पर्यायैरायुरुच्यते || च. सू. 1 तस्मै हितं जीवनीयंजीवनीयशब्देनेहायुष्यत्वमभिप्रेतं | यत्र च मधुररसगुणे आयुष्यो जीवनीयः | च. सू. 26 जीवनः प्राणधारणः सु. सू. 38/ 36.

For prevention of Chondrocyte apoptosis (death) Jeevaniya dravya (life supporting, restorative, refreshing, reviving quality) can be used. According to Acharaya Charaka Madhur rasa pradhan dravas have jeevaneeya quality. According to Acharya Sushrut jeevan karma is Life Retention, Life Preservation.[24] [25] [26] To prevent death of chondrocytes jeevaniya dravya can be used in an oral medicines, in various panchkarma treatments like basti, stanik basti, abhyang, dhara and annalepan etc treatments.

For Disorganised Collagen

वातकर्म प्रवर्तकश्चेष्टानां उच्चावचानां | च. सू. १२ / ८

स्रंसव्यासव्यधस्वापसादरुक्तोदभेदनं |सङ्गाङ्गभङ्गसङ्कोच वर्तहर्षणतर्षणम् || कम्पपारुष्यसौषिर्य शोषस्पंदनवेष्टनम् |स्तंभः कषायरसता वर्णः श्यावोऽरुणोऽपि वा ||कर्माणि वायोः.. अ. हृ. सू. १२/ ४९,५०, ५१ वातस्योपक्रमः स्नेहः स्वेदः संशोधनं मृदु |स्वाद्वम्ललवणोष्णानि भोज्यान्यभ्यङ्गमर्दनं || वेष्टनं त्रासनं सेको मद्यं पैष्टिक गौडिकं | स्निग्धोष्णा बस्तयो बस्तिनियमः सुखशीलता || दीपनैः पाचनः सिद्धाः स्नेहाश्चानेक् योनयः | विशेषान् मेद्य पिशितस्तैलानुवासनं || वा. सू, 13

Cheshta / movements, dropping, fatigue, contraction, decrease, pain, thirst, tremors, roughness, dryness, disjoining, piercing, numbness, dehydration, palpitation, wrapping, stiffness are lfunctions of Vata Dosha.

For abnormallyorganised collagen, articular cartilage fibrillation (parushya and saushirya), unbound proteoglycans, declined number of chondrocytes (saad) in Osteoarthritis and - mrudu samshodhan, snehan, veshtan, sek, snigdha basti, bruhan basti - Vata Dosha Upakram can be opted.[27] [28][29]

Increase in the synthesis of matrix molecules, including type II collagen and aggrecan

All physiological activities, movements are created by chal guna of vata dosha, also exaggerated activities are created due to vitiated vata dosha.

Treatment can be planned with the help of sthir, snigdha, stambha gunpradhan, prithvi mahabhut, madhur rasa pradhan and with alpa kashay rasa dravya.[30]

Damaged New Matrix Molecules

For damaged matrix molecules Pachan medicines can be used along with other chikitsa upkrama.

Traditional South African Plants in Tissue Engineering of Articular Cartilage

Potential Effect of Medicinal Plants on Cartilage Generation:

In South Africa, numerous plants used traditionally havebeen employed in tissue engineering of articular cartilage. Studies haveobserved medicinal plants such as Pleurostylia capensis, Pterocarpusangolensis and Eucomis autumnalis, having resveratrolplaying

proliferation and differentiation roles in tissue engineering ofarticular cartilage. High regulation of collagen type II has been observed chondrocytes treated with resveratrol.[31]

CONCLUSION

Efforts are made to explore the structure of healthy and diseased Articular Cartilage in the light of Ayurveda. There are many more studies conducted on traditional plant based remedies to explore the exact role of plants and their phytochemicals on changed components of Articular Cartilage.

For the promotion of health and prevention of aging in articular cartilage, it is important to know that the treatments, therapies and medicines which can be availed regularly before time or before agingstarts.

In Ayurved local treatments like Janubasti, Janudhara (sek), Aalepan, Abhyang, Potli-Swed are effective for aging, diseased articular cartilage and also for promotion of articular cartilage health.

There is a need to incorporate animal study and modern techniques like tissue engineering to know the exact role of whole plants and their phytochemicals in the promotion of articular cartilage health and diseased articular cartilage.

These techniques will help investigators to prove exactly which plants of Madhur Rasa, Prithvi Mahabhut primarily, Bruhaniya Gana, Jeevaniya Gana etc. are useful in maintaining **Sandhiveshthangat Tarunasthi**(Articular Cartilage) Health and are remedial for particular pathophysiological changes of Jiryaman (aging) as well as Sandhigatvata vyadhit (osteoarthritic) **Sandhiveshthangat Tarunasthi** (Articular Cartilage). Also these modern techniques will help to know safety and optimal dosing of articular plant useful for articular cartilage health which is a need of this era.

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