ANALYSIS OF THE MECHANICAL PROPERTIES OF THE OSTEOCHONDRAL PLUGS IN AUTOLOGOUS OSTEOCHONDRAL TRANSPLANTATION

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Keywords: autologous osteochondral transplantation, mechanical load, compression, osteochondral plugs **Abstract:** The Osteochondral Autologous Transplantation is a technique which utilise implants in the area of the chondral defect osteochondral plugs harvested from a donor area, thus covering the defect with hyalin cartilage. The purpose of this study is to analyse the behaviour at compesion of the plugs harvested from the femoral trochlea. We have harvested 7 plugs from the trochlea of a beef femur and then we have positioned them at the Instron 5587 Testing Machine. We have loaden them along the mechanical axis with forces up to 1.500 N, with concomitent aquisition of optical data with the Aramis 2M System. The results show that the compression forces goes to 1.000 - 1.500 N, after the compression with 2-3 mm of the plugs. Similar behaviour has the variation of the tension in the cylinder. Regarding the specific strain, most of the cylinders were deformed over 80%.

Cuvinte cheie: transplant osteocondral autolog, încărcare mecanică, compresiune, cilindri osteocondrali **Rezumat:** Transplantul osteocondral autolog este o tehnică prin care se recoltează cilindri osteocondrali dintr-o zonă donoare și se implantează în zona defectului cartilaginos, ceea ce realizează repararea defectului prin cartilaj hialin. Scopul acestui studiu este de a analiza comportarea la compresiune a cilindrilor recoltați de la nivelul trohleei femurale. Pentru aceasta am prelevat 7 cilindri de la nivelul trohleei unui femur de vită care au fost poziționați la nivelul Mașinii de încercare Instron 5587, apoi s-a realizat încărcarea femurului în lungul axului mecanic pînă la 5.000 N, cu achiziția concomitentă a datelor optice cu ajutorul Sistemului Aramis 2M. Rezultatele obținute arată că forța de comprimare a cilindrilor osteocondrali ajunge relativ repede la o valoare de 1.000-1.500 N, după comprimarea doar cu 2-3 mm a cilindrilor. O comportare similară o are și variația tensiunii ce apare în cilindru. În ceea ce privește deformația specifică maximă, majoritatea cilindrilor testați s-au deformat cu peste 80%.

INTRODUCTION

The articular cartilage has a limited spontaneous regeneration capability. When it occur, the regeneration of a chondral lesion is partial and the repaired tissue is fibrocartilage with inferior mechanical properties compared to the hyaline cartilage.

The Osteochondral Autologous Transplantation is a technique wich implant in the area of a chondral defect osteochondral plugs harvested from a donor area for filling chondral defects, achieving a reparation with hyalin cartilage (1, 2).

AIM OF THE STUDY

The purpose of this study is to analyse the biomechanical behaviour on compesion of the osteochondral plugs harvested from the femoral trochlea used for an autologus osteochondral transplantation and to determine their biomechanical (3, 4, 5)

MATERIAL AND METHODS

For the determination of the biomechanical behaviour on compesion of the osteochondral plugs we have harvested 7 cylinders 8 mm diameter from the femoral trochlea of a beef femur. To achieve this we have used a fresh bovine femur. After the removal of all soft tissue we have harvested the osteochondral cylinders with the 8 mm OATS ancillary from Arthrex. Each plug was then measured in lenght with a calliper. We have also measured the diameter of each cylinder on two different planes perpendicular on each other. This measurement of the plug diameter shows surprisingly their imperfection, as they are not perfect cylinders with 8 mm diameter, despite the fact that they were harvested with the 8 mm diameter tool. This can be explained by the variation of the bone mechanical properties on different directions.

We have corrected the data achieved and aproximated the results considering the harvesting system as cylinders with 8 mm diameter. In table 1 are presented the dimensions of the cylinders harvested for the compression analysis. Two of the cylinders were then sprayed with white mate paint in order to be used for hte analyse of the deformation with optical methods using the Aramis 2M System (fig. 1.).

The processed cylinders were then positioned at the Instron 5587 Testing Machine. After the calibration of the Aramis 2M System we have then load the plugs along the mechanical axis separately and consecutive with forces up to 5,000 N, with simultanious aquisition of optical data in rhythm of 2 pictures/second

În figure 2. a is presented the specimen (osteochondral cylinder) positioned at the Machine for testing Traction, Compression and Flexion Instron 5587, as well as the data aquisition device (two video cameras) from the Aramis 2M System. In figure 2. b is presented in detail the area of the contact zone between the specimen and the plateau of the testing machine.

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har vested for the compression testing										
	Cyl. 1	Cyl. 2	Cyl. 3	Cyl. 4	Cyl. 5	Cyl. 6	Cyl. 7			
Φ ₀ [mm)	8,35	7,78	8,17	7,95	8,09	7,75	7,81			
Φ ₉₀ [mm)	7,92	8,25	7,72	8,13	7,80	8,29	8,37			
L [mm)	18,05	15,88	18,74	16,09	19,36	17,05	15,94			

Table no. 1. The dimensions of the osteochondral cylinders harvested for the compression testing

Figure no. 1. Osteochondral cylinders harvested for the compression tests (two of them were painted with white mate paint and sprayed with graphite)



Figure no. 2. The Testing Machine and the data aquisition device (two video cameras) from the Aramis 2M System. (a); Detail of the compression specimen (b)



RESULTS AND DISCUSSIONS

Each osteochondral cylinder was then separately tested on compression, the results of the tests are presented in table 2.

Table no. 2. The experimental results of the compression loading tests of the osteochondral cylinders

Specime n (cyl.) no.	Maximu m Load	Compressi on on Maximum Load	Tension on Maximum Load	Maximum Specific Strain	Energy at Maximum Load
	[N)	[mm)	[MPa)	[%)	[J)
1	3.601,24	15,01	71,64	83,14	21,02
2	4.684,09	13,33	93,18	83,99	13,44
4	2.280,66	7,00	45,37	36,17	9,06
5	7.847,13	15,00	156,11	93,28	18,35
6	2.131,63	8,31	24,41	42,93	7,33
7	608,72	3,43	12,11	21,52	1,76
Average	2.352,77	8,87	57,55	51,58	10,14

In figures 3. a and b are presented the specific curves (force - deformation) resulted from the compression tests on the 2 osteochondral cylinders painted with white mate paint and sprayed with graphite.

One can observe a good statistical distribution of the experimental results, regarding the maximum load, specific strain as well as the energy at maximum load.

Figure no. 3. The specific force – deformation curve (a) – specimen 1, (b) specimen 2



The specific curves obtained from the compression tests on the harvested osteochondral plugs shows that the compression forces goes quickly to 1,000 - 1,500 N (after the compression with 2-3 mm of the plugs), than it remains constant to the end of the test, when the increasing is sudden to the maximal value. Similar behaviour has the variation of the stress in the osteochondral cylinder.

Regarding the specific strain, most of the cylinders were deformed over 80%, but some are below 50%. These results can be the consequence of the geometric irregularities of the base of the harvested plugs seated on the testing machine plateau. Therefor is very important that the osteochondral cylinders are harvested in good conditions, with no alteration of their geometry during this process.

CONCLUSIONS

The compression forces goes quickly to 1,000 - 1,500 N after the compression with 2-3 mm of the plugs, than it remains constant to the end of the test, when the increasing is sudden to the maximal value of teh compression force. In vivo, this force is equivalent to a 1,500 kg beef in unipodal support, well over the real loading force. Similar behaviour has the variation of the stress in the loaded osteochondral cylinder. Regarding the specific strain, most of the cylinders were deformed over 80%.

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AMT, vol II, nr. 2, 2010, pag. 225

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