Electrothermal Shrinkage
For the ACL Deficient Knee

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Abstract

The effectiveness of electrothermal shrinkage for the anterior cruciate ligament (ACL) deficient knee was evaluated. There were fourteen patients in the study, with nine native ligaments, one patellar tendon graft and four quadrupled hamstring tendon grafts. All patients with a native ligament were found intraoperatively to have greater than 50% continuity of their ACL, and those with a prior reconstruction were found to have anatomically appropriate tunnel positions. The patients were treated with radiofrequency thermal shrinkage and followed prospectively for an average duration of 18.9 months. . At the time of surgery the laxity was chronic (as defined as greater than three months duration since injury) in all but one of the patients. The pre-operative KT-1000 arthrometer side-to-side difference averaged 5.9 mm of translation, with an immediate post-operative change to an average of 1.3 mm. There were only two failures in the study. Failure was defined as the requirement of re-operation to achieve a stable knee, or a side-to-side difference of greater than 5mm. Our study shows that it appears that in a select population, thermal shrinkage can be an appropriate surgical alternative to reconstruction.

Using heat as a mode to modify tissue is not a new concept. Heat is the resultant of molecular friction that occurs when an ionic current is passed through the tissue. This ionic current is caused by the electromagnetic energy applied to the tissue from the radiofrequency probe. An alternating current occurs between the application probe and the grounding plate (as with a monopolar design) or between the tips of a bipolar designed probe (1,2).

The composition of the anterior cruciate ligament is known to be primarily type 1 collagen with highly ordered and heat labile bonds and it has also been established that with age these heat labile bonds become replaced with multivalent crosslinks (5)

The net effect of the radiofrequency energy is dependant on a number of variables. These include the wattage used, the duration of treatment, as well as the electrode type. The main goal is to expose the desired tissue to a temperature of approximately 65 ^{0}C for the duration of time required to shrink less than 20 % of the tissue. A temperature greater than 60 ^{0}C is required to break the heat sensitive bonds and unwind the quaternary structure of the ligament (7,8). The net result is a randomly ordered, contracted collagen mass. This then serves as scaffolding for the reactive fibroblasts from neighboring tissue to initiate the repair process (12). However the temperature should be achieved quickly and remain only for the desired treatment interval, as once 45 ^{0} C is obtained cell death occurs (9,10).

Wall et. al. showed that if greater than 20 % of shrinkage occurs the tissue will elongate beyond its preshrinkage state, despite achieving a desired contracted length (3). One way to achieve an adequate shrinkage amount without surpassing the 20 % ceiling is to use a grid pattern method, instead of a painting technique. In a grid pattern more native tissue remains viable and therefore faster healing and recovery occurs (4).

It has been shown that the tissue modification continues to occur for upwards of 12 weeks, and therefore a protected period of rehab is imperative to the eventual outcome (6). Hayashi et al showed that immediately post shrinkage the amount of collagen synthesis was only 64% of normal, but this increased to 196% of normal by day 14 and eventually normalized by day 30 (11).

The purpose of our study was to prospectively evaluate the effectiveness of electrothermal shrinkage for the anterior cruciate ligament (ACL) deficient knee.

Materials and Methods

All patients that were examined for an unstable knee and were subsequently diagnosed as having a deficient ACL from August 1998 until October 2001 were considered. Clinical evaluation by the senior author showed a positive lachman and pivot shift. In addition the ACL laxitiy was confirmed with an increase in excursion as measured by the KT-1000 arthrometer (MEDmetric Corp., San Diego, California). There were fourteen patients in the study, with nine native ligaments, one patellar tendon graft and four quadrupled hamstring tendon grafts. The patients were followed prospectively for an average duration of 18.9 months. At the time of surgery the laxity was chronic (as defined as greater than three months duration since injury) in all but one of the patients. . All patients with a native ligament were found intraoperatively to have greater than 50% continuity of their ACL and those with a previous reconstruction were found to have anatomically appropriate tunnel positions. A strict post-operative rehab protocol was followed (table 1)

Table 1

Post-Operative Routine

- FWB and ROM early on
- Routine ACL strengthening
- Functional brace 3/12
- Return to sports 3-4/12
    - Full ROM
    - Stable
    - Equal strength

Outcome was defined as the requirement of re-operation to achieve a stable knee, or a side-to-side difference of greater than 5mm.

Results

The patient profiles are summarized in tale 2, with their results summarized in table 3. Our patient population mostly consisted of chronic tears in thirty year old recreational athletes. There was equal number of males and females with the average age at the time of operation being 33.4. Only one patient had surgery in the acute period (as defined as surgery within three months of injury). The pre-operative KT-1000 arthrometer side-to-side difference averaged 5.9 mm of translation, with an average response to thermal shrinkage of 4.6 mm, making the post shrinkage side-to-side difference an average of 1.3 mm. At last follow up the SSD equal an average of 2.1 mm.

Table 2

	Male	**Female**	**Totals**
Acute	0	1	1
Chronic	7	6	13
Native	4	5	9
PT	1	0	1
ST/G	2	2	4
KT	5.2	6.6	5.9

There were two failures in the group. One with an initial great result and subsequent return to full return to sports, who went on to rupture while playing soccer, and another whom never really responded well to the surgery. Please refer to figure 1.

Our results show that radiofrequency thermal shrinkage is a viable option for ACL deficient knees, as long as there exists a significant bundle in the correct place. We have also showed that a good result can be obtained in both native and reconstructed ligaments, even in the chronically lax ACL. This is in contrast to Carter et al who state that the technique is not to be used in either the chronic state or in previously reconstructed knees (13).

Figure 1

Patient 1	*Patient 2*
24 y.o female *Native knee *Chronic laxity (treated at 5 mos. post injury) *Pre-op SSD 7 mm *Post-op 4 mm, 6/12 at 3mm *Re-ruptured at 23 mos. while playing soccer *Went on to have a reconstruction	*39 y.o female* *Previous ST reconstruction 34 mos. prior to injury *Chronic laxity (treated 7 mos. post injury) *Pre-op SSD 8 mm *Post-op 5mm, 35/12 at 6mm *C.C is instability

Table 3

Patients	Pre-SSD	Amt Shrunk	Last fu SSD
SS	7	1	3
WM	7	6	4
LD	4	5	2
HG	6	3	3
SB	7	11	2
PL	9	3	3
JF	3	6	1
LM	11	10	1
KG	3	4	2
MM	4	2	2
KM	2	2	1
KM	8	3	6
BB	3	4	-1
DS	9	6	0

*SSD = side to side difference as measured on the KT-1000 arthrometer

Table 4

Patient	Age	Sex	Mos. To Surgery	Ligament Type (mos since prev. Sx)	Pre-SSD KT	Amt shrunk	Post SSD KT	FU
S.S	24	F	5	Native	7	1	3	23/12
W.M	45	F	3	Native	7	6	4	13/12
L.D.	31	F	84	Native	4	5	2	10/12
H.G	45	M	4	Native	6	3	3	10/12
S.B	20	F	10	STG (19)	7	11	2	21/12
P.L.	32	M	13	STG (37)	9	3	3	9/12
J.F.	33	M	10	BPTB (22)	3	6	1	26/12
L.M.	29	F		Native	11	10	1	16/12
K.G.	39	M	11	Native	3	4	2	22/12
M.M.	36	M		Native	4	2	2	19/12
K.M.	30	F	6	Repair 1985	2	2	1	43/12
K.M.	39	F	7	STG (34)	8	3	6	38/12
B.B.	35	M	6	Native	3	3	-1	8/12
D.S	30	M	4	STG (8)	9	6	0	6/12
Avg	***33***		***13.7***		***5.9***	***4.6***	***2.1***	***18.9***

Discussion

With an understanding of the tissue response to radiofrequency thermal energy and a post-operative rehab regimen that coincides with the healing response, ACL shrinkage is a good option in a select population. By no means is it a good choice in a reconstructed ligament with improper tunnel placement. If however, patients are selected with greater than 50% bundle of a native graft, and proper tunnel position in a reconstructed ligament, retensioning the tissue with thermal shrinkage can lead to good results. Techniques such as grid pattern have been shown by Lu et al to preserve more viable tissue and therefore a better healing response as well (4). Another outstanding variable is the use of a monopolar versus a bipolar probe. It appears that a bipolar probe can deliver a controlled temperature more precisely than a monopolar probe and therefore more tissue can be spared to initiate the healing response. It is also known that because the response to the radiofrequency energy is also a product of time of exposure the probe should not be left in one place too long and therefore limits the resultant tissue damage (14).
In conclusion, with proper patient selection and a 3 – 4 month protected rehab program, radiofrequency thermal shrinkage is a good option.

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