Effect on knee disarticulation on bone growth in immature rabbits

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Abstract

This study was designed by the University of Ankara Experimental and Research Laboratory for animals in 1997. In the study an anteroposterior skin flap technique was used for 20 knee disarticulation amputations and also in 20 trans-femoral amputations on immature rabbits, in order to investigate their effects on the femoral epiphyseal growth plate. The femurs of the rabbits were observed radiographically for 8 weeks. It was observed that the femurs tended to grow at a slower rate compared to the normal contralateral femur.

These studies showed that the disarticulated limb femurs grew 0.68cm shorter on average compared to the contralateral femurs and the femurs in the trans-femoral amputated limbs 3.58cm shorter on average compared to the contralateral ones. These results were found to be statistically significant.

Introduction

To date the prostheses used in knee disarticulation have never been popular, and as a consequence, this level has never gained any great prominence in the prosthetic field. Not only does the distal bulbous structure of the bone at the amputated level create problems in its doffing and donning, many other surgical and aesthetic problems occur, which altogether have disfavoured knee disarticulation as an amputation of choice. Nevertheless, from the late 1970s and onwards Burgess (1977); Jensen and Mandrup-Paulson (1983); Stirnemann *et al.* (1987) and Houghton *et al.* (1990); have all reported positive and encouraging results in favour of knee disarticulation (Atlas of Limb Prosthetics, 1992; Burgess, 1977; Lower Extremity Amputation, 1989; Amputation Surgery and Lower Limb Prosthetics, 1988).

Despite the fact that many advantages can accrue in adults by knee disarticulation (KD) compared to trans-femoral amputation (TF), such as, providing a longer lever for attachment of the prosthesis, having a lesser degree of muscular atrophy, having the ability to tolerate full end weight bearing on the stump and with good rotational control and suspension being easily acquired, it is even more advantageous in children because it protects the distal epiphyseal plate and does not result in unusual growth of the joint (Atlas of Limb Prosthetics, 1992; Donaldson, 1962; Jensen and Mandrup-Paulson, 1983; Kegel *et al*, 1978; Mensch, 1983; Prosthetic and Orthotic Practice, 1970; Tooms, 1992).

Material and methods

The study was performed on immature, 3-week-old male New Zealand rabbits whose ossifications were yet incomplete. Ten rabbits were chosen for KD and 20 for TF amputation. The femoral growth rates of the operated legs were then compared to the contralateral intact ones.

Na Cefazol 50mg/kg was administered in all cases, 30 minutes prior to surgical intervention. The drugs used for anaesthesia were Ketalar 70mg/kg and Rompun 30mg/kg intramuscularly.

For those rabbits undergoing disarticulation, an anteroposterior flap technique defined by Batch *et al.* (1954) was used. Following the removal of hair, under surgically accepted aseptic conditions, approximately 0.5cm distal to the tibial tuberosity an anterior flap was prepared equal in length to the knee diameter

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(Atlas of Limb Prosthetics, 1992; Amputation Surgery and Lower Limb Prosthetics, 1988; Tooms 1992). The posterior flap was designed from the popliteal region and was about half the length of the anterior flap. The patellar and pes anserinus tendon were separated from the tibia as part of the anterior flap. The tibia and peroneal nerves were then clamped and cut proximal to the plane of amputation. The popliteal artery and vein were isolated and cauterized. The iliotibial band, the insertion of the biceps on the fibula and the medial and lateral heads of the gastrocnemius at the femoral condyles were then freed. Patellar excision was not done. The posterior joint capsule together with the popliteal and plantaris muscles were freed. The patellar tendon, cruciate ligament and the gastrocnemius origins were sutured to each other. Following hemostasis, the deep fascia, subcutaneous and cutaneous layers were sutured.

The procedure for TF amputation in rabbits was a follows: under surgical aseptic conditions, at the site of amputation, the anteroposterior diameter was measured and posterior and anterior flaps were made, each half the diameter in length. The incision divided the skin, the fascia and quadriceps muscle up to the bone. The femoral artery and vein were located and cauterized. The surrounding periosteum was removed and then the femur was cut in the distal one-third. The sciatic nerve was located and divided just proximal to the incision level. The posterior group of muscles were also cut in a transverse plane. Finally the distal ends of the muscles (quadriceps, adductors and hamstrings) were sutured over the distal femur cortex by nonabsorbable sutures. Following hemostasis the tissues were sutured in their respective layers.

The rabbits undergoing KD and TF amputation, were followed for femoral growth until 11 weeks old by taking radiographs every 2 weeks. Standard laboratory diet and free activity was applied to all rabbits. The results were compiled and are presented in Table la and lb respectively. Prior to radiographs Ketalar 7mg/kg was administered intramuscularly, in order to achieve the same degree of extension and adduction of the hip for each of the rabbits. All films were taken at a distance of 1 metre (magnification rate: 1/1.15). Four measurements for KD length were recorded from the thickest part of the femoral condyle distally, to the widest portion of the greater trochanter proximally. Four measurements for TF amputation were recorded from the most distal portion of the amputated femur to the widest portion of the greater trochanter proximally. All results were statistically correct using *Student t test.*

Findings

Carrying out KD and TF amputations when the rabbits were 3 weeks old, the first measurements were taken at the 5th week, the second at 7th, third at 9th, and fourth at 11th weeks. Results were as shown in Tables 1 and 2. Femoral longitudinal growth continuing on both limbs. In the case of KD amputation this

Table 1. Measurements for knee disarticulated and sound femur (all measurements in cm)

Measurement			Rabbit Number																			
No.	Age	Side	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
I	5 week	KD	6.0	6.6	6.7	6.5	6.8	5.0	6.4	6.8	6.4	6.1	6.3	6.7	6.6	6.5	6.5	6.8	6.9	6.4	6.4	6.7
		S	6.2	6.6	7.0	6.5	7.1	5.1	6.6	6.9	6.6	6.4	6.4	6.9	6.9	6.5	6.7	6.8	7.0	6.6	6.6	6.8
II	7 week	KD	6.4	6.9	7.4	7.0	7.6	5.0	6.9	7.0	6.7	6.9	6.8	7.3	6.8	7.0	6.9	7.4	7.4	6.7	6.6	7.1
		S	7.3	8.2	7.5	7.5	8.0	5.3	7.0	7.3	7.1	7.2	6.9	7.5	7.3	7.1	7.0	7.5	7.6	7.1	6.9	7.5
III	9 week	KD	6.9	7.2	7.4	7.9	7.9	5.0	7.4	7.5	7.2	7.3	7.2	7.6	7.2	7.4	7.3	7.7	7.9	7.3	6.9	7.5
		S	7.7	8.9	7.6	8.3	8.4	5.6	7.7	7.9	7.6	7.7	7.6	8.0	7.9	7.7	7.6	7.9	8.1	7.6	7.4	7.9
IV	11 week	KD	7.4	7.2	8.6	8.8	9.3	5.3	8.1	8.4	8.4	7.9	7.9	8.6	8.3	8.5	8.6	8.4	8.7	8.8	7.7	8.6
		S	8.6	8.9	8.9	9.0	9.5	6.0	8.6	8.9	8.7	8.9	8.7	9.1	9.0	8.9	9.0	9.0	9.2	9.3	9.0	8.9

Table 2. Measurements for trans-femoral amputated and sound femur (all measurements in cm).

Measurement			Rabbit Number																			
No.	Age	Side	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
I	5 week	TF	2.6	2.7	3.4	3.9	2.6	2.7	2.9	3.0	3.1	2.7	3.3	3.5	3.0	3.0	3.2	3.1	2.9	2.7	3.0	3.3
		S	6.1	6.6	6.8	6.7	6.4	6.2	6.8	6.7	6.3	6.3	6.5	6.4	6.5	6.8	6.8	6.3	6.9	6.6	6.8	6.7
II	7 week	TF	3.0	3.7	3.9	4.0	3.9	3.5	3.9	3.7	3.6	3.7	4.3	4.0	3.5	3.5	3.7	3.6	3.8	3.7	3.7	4.3
		S	6.9	7.7	7.5	7.7	6.9	7.3	7.7	7.5	7.0	7.2	7.5	7.3	7.8	8.0	7.5	6.9	7.9	7.7	7.6	7.0
III	9 week	TF	3.4	3.9	4.1	4.2	4.7	3.8	4.1	4.0	3.9	4.6	4.6	4.5	3.8	3.8	4.0	3.9	4.2	4.0	3.9	4.7
		S	7.5	8.0	7.8	7.2	7.3	7.7	8.1	7.9	7.6	7.6	7.8	7.7	8.3	8.4	7.9	7.7	8.3	8.0	7.9	8.0
IV	11 week	TF	3.7	4.2	4.4	4.5	5.0	4.1	4.4	4.3	4.2	4.1	4.9	4.7	4.0	4.0	4.2	4.0	4.3	4.1	4.2	4.9
		S	7.7	8.4	8.1	7.7	7.8	8.0	8.5	8.4	7.9	8.0	8.1	8.0	8.7	8.7	8.2	8.0	8.5	8.4	8.2	8.3

produced femurs 0.15cm shorter than the contralateral one on the first measurement, 0.35cm on the second, 0.47cm on the third and 0.63cm on the fourth measurement (Table 3). The measurements for the TF amputation displayed femurs that were 3.53cm, 3.68cm, 3.73cm and 3.87cm respectively at the first to fourth measurements (Table 4).

Discussion and results

Early (1968) suggested that children who underwent knee disarticulation continued to show growth at the physis, even though at a slower rate when compared to its normal counterpart. However, to date, no such studies have been documented comparing the rate of physeal growth between patients who underwent knee disarticulation and trans-femoral amputation.

Frantz and Aitken (1960) suggested from radiographic studies, that children who underwent trans-femoral amputation, developed atrophy of the opposite pelvis, which resulted in coxa valga deformity. In the authors' studies, one of each type of surgical intervention resulted in coxa valga together with a minimal degree of opposite pelvis atrophy.

One year ago in the authors' studies, an eight-year-old who underwent knee disarticulation, had within 20 months a 3.5cm degree of shortness of the operated leg compared to the normal. Another 2-year-old child who underwent trans-femoral amputation, illustrated 0.7cm femoral growth, during a period of 8 months, which when compared to the unoperated side was very similar. In the same patient exositosis was present at the distal end of the residual femur, making the measurement

Table 3. The linear growth of knee disarticulated and sound femur.

Measurement No.	Age(week)	Side	x (cm)	Std Dev.	Min.	Max.	N
I.	5	KD	6.46	0.41	5.00	6.90	20
		S	6.61	0.43	5.10	7.10	
II.	7	KD	6.89	0.54	5.00	7.60	20
		S	7.24	0.57	5.30	8.20	
III.	9	KD	7.29	0.61	5.00	7.90	20
		S	7.76	0.62	5.60	8.90	
IV.	11	KD	8.18	0.84	5.30	9.30	20
		S	8.81	0.70	6.00	9.50	

Table 4. The linear growth of trans-femoral amputated and sound femur

Measurement No.	Age(week)	Side	x (cm)	Std Dev.	Min.	Max.	N
I.	5	TF	3.03	0.34	2.60	3.90	20
		S	6.56	0.24	6.10	6.90	
II.	7	TF	3.75	0.29	3.00	4.30	20
		S	7.43	0.35	6.90	8.00	
III.	9	TF	4.11	0.35	3.40	4.70	20
		S	7.84	0.32	7.20	8.40	
IV.	11	TF	4.31	0.34	3.70	5.00	20
		S	8.18	0.30	7.70	8.70	

invalid (Alsancak and Korkusuz, 1996).

Growth at the distal femoral epiphyseal plate is more pronounced compared to its proximal counterpart according to research conducted by Digby (69%: 31%); (Bisgard, Gill and Abbott (70%: 30%); Green (70%: 30%) (Atlas of Prosthetics, 1992; Frantz and Aitken, 1960). In the lower limb growth is most pronounced for girls at age 14; for boys at 16. After this period growth continues at an average of 2cm annually until femoral ossification is completed (Ege and Gungor, 1980). Klein *et al.* (1994) stated that femoral linear growth of rabbits is more than 7.5 times faster than of humans. According to Pritchett (1982) of the University of Washington Orthopaedics Department, between the ages of 7 and the completion of ossification age, the average growth rate per year of the femoral distal physis was 1.3cm as obtained from radiographic studies performed on 244 normal children.

In the authors' study first measurements carried out on 20 rabbits 2 weeks after KD, showed that femurs were 0.16cm shorter, on average, compared to the contralateral one. The last measurement 8 weeks after operation revealed a 0.63cm average shortness. The difference between the lengths of the disarticulated and intact femurs on the first and second measurements were statistically significant ($p<0.05$). This difference was again found to be significant between the first and the third measurements $p<0.01$ level and between the third and the fourth measurements on $p<0.001$ level (Table 5).

Similarly 20 TF amputated rabbits' femurs were found to be 3.53cm shorter on average, than the intact ones on the first measurements

Table 5. The comparison of knee discarticulated femur to the sound femur.

Measurement No.	x (cm)	Std Dev.	Min. (cm)	Max. (cm)	N
I.	-0.16	0.11	-0.30	0.00	20
II.	-0.35	0.30	-1.30	-0.10	20
III.	-0.47	0.33	-1.70	-0.20	20
IV.	-0.63	0.40	-1.70	-0.20	20

Table 6 The comparison of trans-femoral amputated femur to the sound femur,

Measurement No.	x (cm)	Std Dev.	Min. (cm)	Max. (cm)	N
I.	-3.53	0.34	-4.00	-2.80	20
II.	-3.68	0.44	-4.50	-2.70	20
III.	-3.73	0.52	-4.60	-2.60	20
IV.	-3.87	0.49	-4.70	-2.80	20

Table 7. "t test pairs" for knee disarticulated rabbits.

Measurement No.	t	p	
I.-II.	2.64	0.016	p<0.05*
I.-III.	3.88	0.001	p<0.01*
I.-IV.	5.07	0.000	p<0.001*

Table 8. "t test pairs" for trans-femoral amputated rabbits.

Measurement No.	t	p	
I.-II.	1.63	0.120	p>0.05
I.-III.	1.89	0.074	p>0.05
I.-IV.	3.58	0.002	p<0.05*

carried out at the 2nd postoperative week, and 3.87cm on the last measurement at the 8th week. The difference between the first and the last measurements were statistically significant ($p<0.05$) while this difference was not significant between the first and the 2nd and 3rd measurements ($p>0.05$) (Table 6).

In this study although growth in length has continued at the KD and the TF amputated femurs, it is found to be not the same as that of the contralateral femurs. This result can be easily understood in the TF amputated immature rabbits whose distal femoral physeal growth is absent. Shorter growth in the KD rabbits where proximal and distal femoral physeal growth was taking place was interesting. This result may be explained by the positive effect of load stress on bone growth of intact extremities compared to the non-weight bearing limb.

Conclusion

In summary, it was possible to take radiographic measurements of 20 knee disarticulated and 20 trans-femoral amputated rabbits over a period of 8 weeks. The studies showed that the operated side of the femur on average is approximately 0.63cm shorter compared to the unoperated side for KD and this difference is statistically significant ($p<0.001$). The operated side is 3.58cm shorter compared to the unoperated side for TF amputation and is statistically significant ($p<0.05$). In addition, no complications were observed concerning bone development.

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