Suspension effect and dynamic evaluation of the total surface bearing (TSB) trans-tibial prosthesis: a comparison with the patellar tendon bearing (PTB) trans-tibial prosthesis

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Abstract

X-ray and cineradiography measurements were used to compare the suspension effect and stability of a TSB trans-tibial prosthesis with an Icelandic Roll-On Silicone Socket (ICEROSS) system to that of a PTB trans-tibial prosthesis. The suspension effect was measured by the distance between the tibia and the socket in both suspension position and weight-bearing position in both type of prostheses. The suspension effect of the TSB prosthesis (2.53 ± 0.90cm) was superior to that of the PTB prosthesis (3.60 ± 0.56cm) ($p<0.05$) by x-ray measurement. The suspension effect of the TSB prosthesis (0.1, 0.4, 0.72cm) was superior to that of the PTB prosthesis (0.3, 0.48, 1.03cm) ($p<0.01$, $p<0.05$) by cineradiographic measurement. The stability was measured as the angle between the axis of the tibia and the prosthesis at the time of heel contact and toe off. The angle change of the TSB prosthesis was statistically smaller than that of the PTB prosthesis.

Introduction

The use of total surface-bearing (TSB) trans-tibial prosthesis with an Icelandic roll-on silicone socket (ICEROSS) (Kristinsson, 1993) has recently become popular in prosthetics. This new trans-tibial prosthesis does not require the knee cuff that is used as a suspension device in the conventional patellar tendon bearing (PTB) prosthesis. Due to the large friction between the silicone socket and skin in the TSB prosthesis, there is a reduction in the piston motion when the heel contacts the ground and an increase in the flexion angle of the knee in the swing phase (Yokogushi *et al.,* 1996; Cluitmans *et al,* 1994; Datta *et al.,* 1996). The sense of stability and the feeling of secure attachment are also superior in the TSB prosthesis.

However, there have been no reports presenting objective measurements that confirm the superiority of the suspension and stability of the TSB prosthesis compared to those of the PTB prosthesis. Therefore, in the present study, a comparative x-ray evaluation was performed of the suspension effect between TSB and PTB prostheses, and a comparative cineradiographical evaluation was carried out of the suspension and anteroposterior stability between TSB and PTB prostheses.

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Subjects

The subjects were 9 trans-tibial amputees (10 limbs), including 8 men and 1 woman aged 19 to 74 years (mean 33.9 years). The reasons for amputation were traumatic injuries in 6 cases (6 limbs), tumours in 2 cases (2 limbs), and burns in 1 case (2 limbs). The length of amputation was 13 to 29cm (mean: 19.8cm). All the subjects had previously used a PTB prosthesis for either temporary or normal walking before changing to the present TSB prosthesis for normal walking. The period of TSB prosthesis use was 6 months to 2 years and 11 months (mean: 1 year and 4 months).

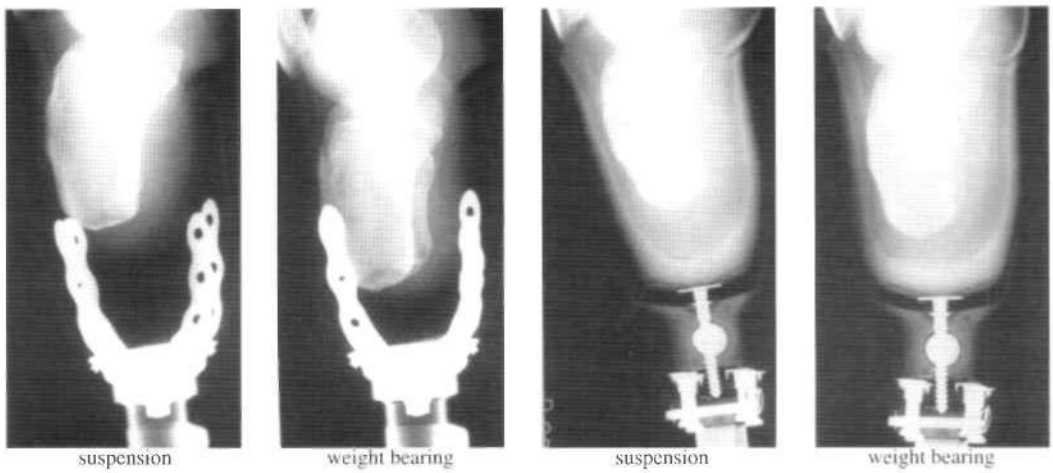

Fig. 1 Lateral view x-rays of PTB and TSB prosthesis during attachment

Methods

Comparative x-ray evaluation of the suspension

Lateral view x-rays were taken in the one leg standing position while wearing the PTB prosthesis or TSB prosthesis in the weight-bearing and suspension positions. For the suspension phase, a 5kg mass was applied to the foot of the prosthesis, and an x-ray was taken with the prosthesis suspended at a knee flexion angle of 30°. For the x-ray measurement, the distance between the tibial end and the base of the socket was measured, and the movement of the stump was calculated by subtracting the value in the weight-bearing position from the value in the suspension position (Fig. 1).

Comparative cine radio graphical evaluation of the suspension

Cineradiography was taken in walking on the walking machine while wearing the PTB prosthesis or TSB prosthesis with measurements subsequently made in the foot contact phase and the swing phase. For the cineradiographical measurement, the distance between the tibial end and the base of the socket was measured and the movement of the stump was calculated by subtracting the value in the weight-bearing position from the value in the suspension position in each five times. These evaluations were done for three cases.

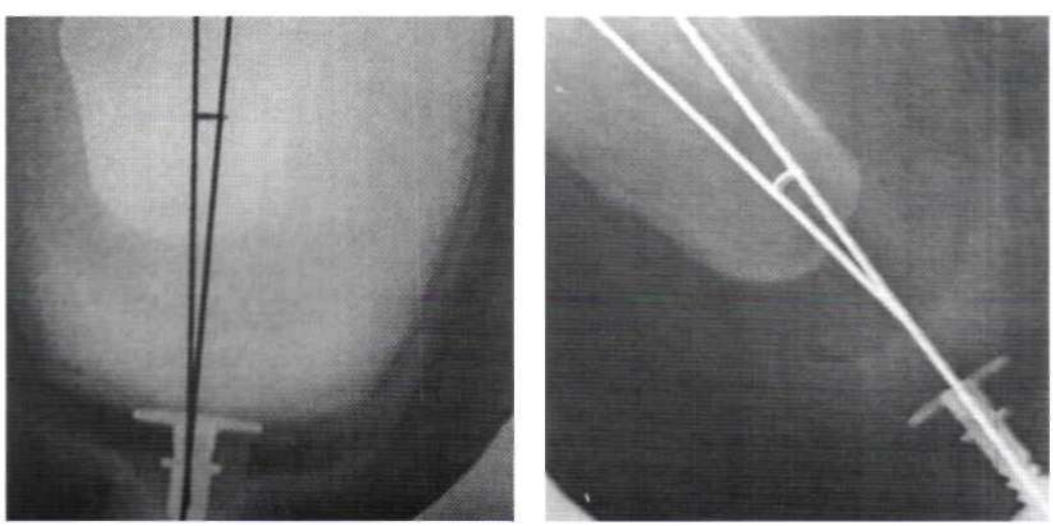

Fig. 2 Cineradiographical evaluation of tibial stability in the socket of the TSB prosthesis

Comparative cineradiographical evaluation of the tibial stability

The angle between the tibial shaft and the axis of the prosthesis was measured. The angular change was calculated by subtracting the value at toe-off from the value at the heel contact. These evaluations were carried out on three cases and for each, five trials were completed (Fig. 2)

Results

Comparison the suspension effect by x-ray

The translation of the tibial end between the suspension position and weight-bearing phase was 2.53±0.90cm for the TSB prosthesis and 3.60±0.56cm for the PTB prosthesis. The translation for the TSB prosthesis was significantly lower ($p<0.05$) (Fig. 3) and the suspension effect of the TSB prosthesis consequently superior to that of the PTB prosthesis.

Comparison of the suspension effect by cineradiography

The stump translations on average in each of the three cases with the PTB prostheses were 0.3cm, 0.48cm and 1.03cm. For the same cases with TSB prostheses the translations were 0.1cm, 0.4cm and 0.72cm. The latter values were statistically smaller than the mean stump translation of PTB prostheses (Fig. 4). Thus, the suspension effect of the TSB prostheses was superior to that of the PTB prosthesis in walking.

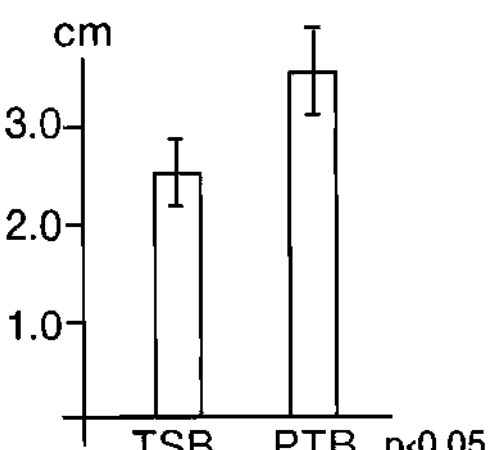

Fig. 3. Comparison of the suspension effect of TSB and PTB prostheses by x-ray,

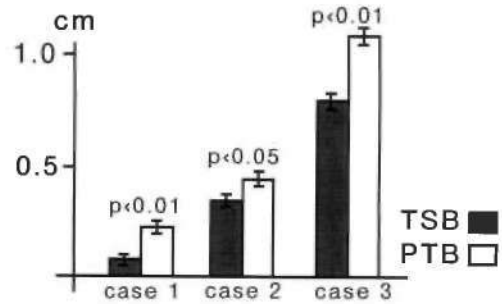

Fig. 4, Comparison of the suspension effect between TSB and PTB prostheses by cineradiography.

Comparison of the tibial stability in the socket by cineradiography

The changes of angle on average in each of the three cases with the PTB prostheses were 14.1°, 5.6° and 9.0°. On the other hand, these cases with TSB prostheses had angle changes of 2.5°, 4.0° and 6.4°. These values were statistically smaller than the mean angle change of PTB prostheses (Fig. 5). Thus, the anteroposterior stability of the TSB prosthesis was superior to that of the PTB prosthesis in the dynamic situation.

Discussion

Lilja *et al.* (1993) estimated the mean tibial movement for walking with a PTB prosthesis to be 2.8cm. This value is smaller than the result obtained by the authors (3.60 ± 0.56cm) for the PTB prosthesis with a 5kg mass applied during the swing phase to simulate the estimated centrifugal force acting on the prosthesis. However, in the present study an even smaller movement (2.53 ± 0.90cm) was obtained for the TSB prostheses with a 5kg mass applied, indicating that the TSB prosthesis has a superior suspension effect.

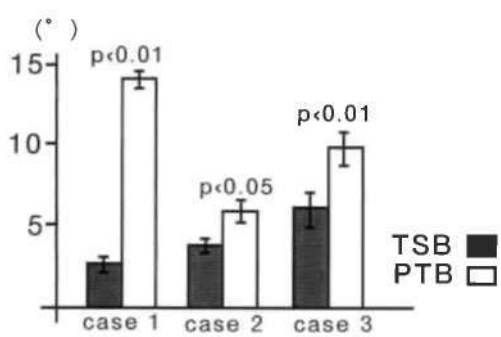

Fig. 5. Comparison of the tibial stability in the socket of TSB and PTB prostheses by cineradiography

According to Tazawa (1991), the characteristics of the suspension of a TSB prosthesis with an ICEROSS silicone socket are an improvement in the feeling of fit and lightness, which means an improvement in the feeling of stability during the stance phase and secure attachment during the swing phase. The results of the x-ray cineradiographical measurements conducted in the present study clearly show that the suspension effect of the TSB prosthesis is superior to that of the conventional PTB prosthesis, and this improved suspension effect supports the feeling of more secure attachment during the swing phase.

Satisfactory results obtained from using the TSB prosthesis with the ICEROSS silicone socket were attributed not only to the better suspension effect but also the improved stability in the stance phase compared with the PTB prosthesis.

Conclusions

1. The suspension effect of the TSB prosthesis with an ICEROSS silicone socket is superior to that of the PTB prosthesis evaluated both by static x-ray and dynamic cineradiography.
2. In dynamic evaluation by cineradiography in three cases, the changes of angle in the TSB prostheses were less than those in the PTB prostheses. Thus, anteroposterior stability of the TSB prosthesis was superior to that of the conventional PTB prosthesis.

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