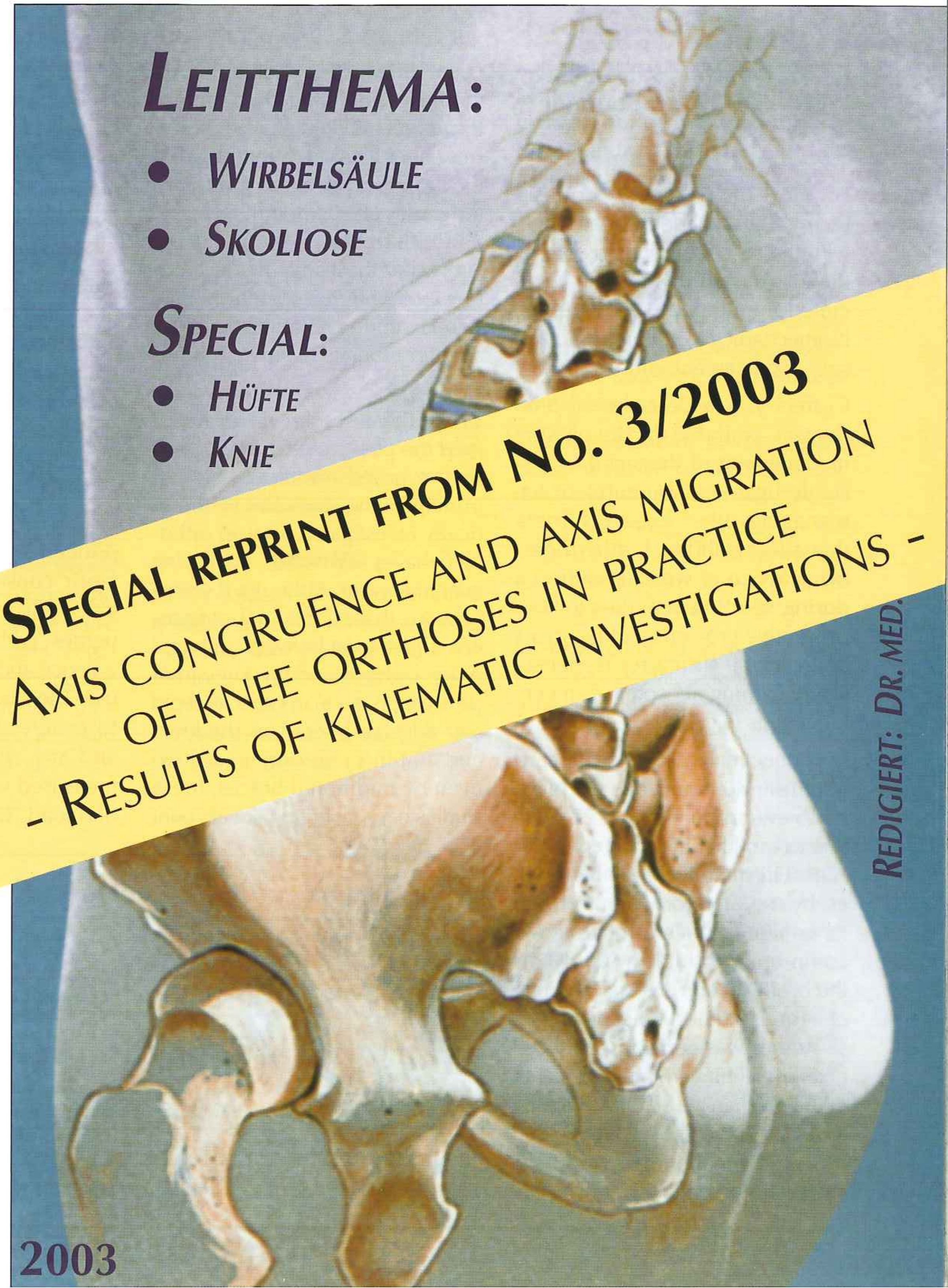
Medizinisch-Orthopädische Technik -2003- 3

MOT • 123. Jahrgang
ISSN 0340-5508



LEITTHEMA:

- WIRBELSÄULE
- SKOLIOSE

SPECIAL:

- HÜFTE
- KNIE

SPECIAL REPRINT FROM No. 3/2003

AXIS CONGRUENCE AND AXIS MIGRATION OF KNEE ORTHOSES IN PRACTICE - RESULTS OF KINEMATIC INVESTIGATIONS -

REDIGIERT: DR. MED.

Verlagsgesellschaft Tischler, Postfach 301770, D-10747 Berlin • Schriftleitung: Prof. Dr. B. Greitemann
DPAG, Postvertriebsstück, Entgelt bezahlt, 61489 • Stellvertreter: Prof. Dr. R. Baumgartner

2003

AXIS CONGRUENCE AND AXIS MIGRATION OF KNEE ORTHOSES IN PRACTICE - RESULTS OF KINEMATIC INVESTIGATIONS -

Dr. G. Berschin, V. Schneider, Prof. Dr. H.-M. Sommer

Introduction

For more than a century orthosis technology has been concerned with the task of helping to control the loss of stability and the associated impairment of knee joint biomechanics resulting from capsule and ligament injuries.

Currently, a wide range of products is available for the passive management of damaged or unstable ligament structures or for managing other knee disorders that affect stability. Furthermore, the practice of wearing orthoses during sporting activities for the preventive protection of ligament and capsule structures is increasingly gaining acceptance in certain sports (e.g. SITLER, 1990).

In connection with the healthcare reforms in Germany and the planned new product group 23 "Orthoses" in the List of Technical Aids (Hilfsmittelverzeichnis) issued by the Statutory Health Insurance Funds, knee orthoses have come under criticism, partly on the basis of controversial findings of various studies. Efficacy in these studies was generally established through in vitro measurements of the mechanical stabilization potential of the orthoses when subjected to mechanically-induced external moments, taking into account differing leg geometries, on moment-simulating knee simulators (e.g. LUBER et al., 1997). Researchers have also investigated the proprioceptive and sport-related motor effects of orthoses (e.g. JEROSCH et al., 1994) and the effect of orthoses on the development of anterior-posterior knee stability during rehabilitation after anterior cruciate ligament injuries (e.g. REER et al., 2001).

While these studies have confirmed the positive efficacy of knee braces based on various design principles, no study has systematically investigated how an orthosis behaves in practice, i.e. during everyday wear. Although it seems obvious that substantial congruence must exist between the axes of the orthosis and the knee joint (axis congruence) in order to avoid any adverse effects on the knee and that this criterion is satisfied even by traditional braces, these studies have failed to take account of the fact that the adequately secure maintenance of this congruence, i.e. the avoidance of axis migration during movement under a corresponding load, must be a crucial factor for the relevance of this evaluation.

In this study, a rigid frame orthosis (Bauerfeind SecuTec Genu) and a knitted orthosis (Bauerfeind SofTec Genu) were tested on a group of subjects according to a largely standardized procedure.

Materials and methods

Two braces with different design principles (rigid frame vs. knitted fabric construction) were investigated for their mechanical properties with respect to axis congruence and axis migration during use. The study was designed so as to enable the fit of the orthosis and any change in the fit to be measured visually during a defined load. The combined running

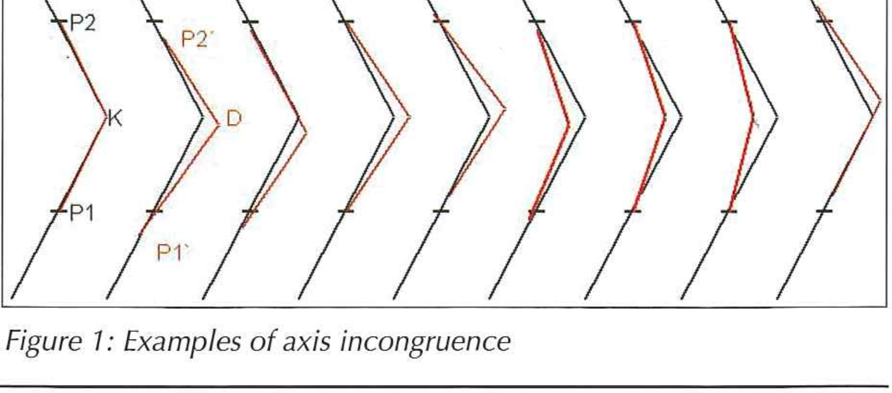


Figure 1: Examples of axis incongruence

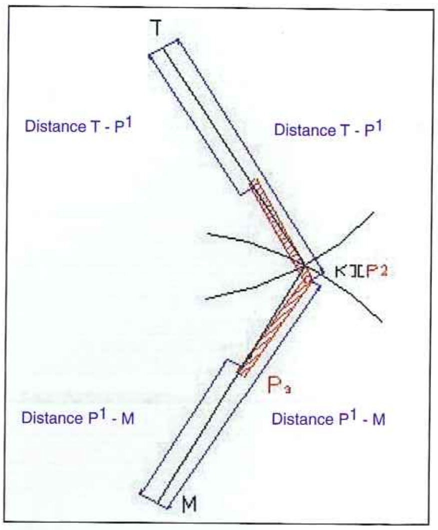


Figure 2: Distance principle

and walking movements were recorded simultaneously from five perspectives using DV camcorders and then evaluated using 3D-video motion analysis software (SIMI Motion 6.1). The measuring accuracy was 1mm. The calculations were based on points marked on the orthoses with reflecting marker balls (diameter: 12 mm) and defined anthropometric points on the legs. The distances between the anthropometric points and the orthotic points during the running and walking cycles were calculated. Cycle-dependent length differences at the start formed the basis for the determination of axis incongruence. Any changes in length difference during exercise were used as a measure of axis migration.

In each case, measurements were recorded after the orthosis was fitted at the start of the exercise period and then at the end of the exercise. Length discrepancies at the start of exercise were used as a measure of axis incongruence. Any change over time during the course of exercise served as a measure of orthosis migration.

The investigated group consisted of 8 healthy male volunteers (age: median=25.1 years; range 22-30 years) with a broadly similar physical constitution and build. They were also healthy from the orthopaedic standpoint with normal lower extremities.

In view of the small number of volunteers, the data was evaluated descriptively with medians and ranges. The results were not subjected to a comparative investigation with interference statistics.

Results

Axis congruence was evaluated according to the aforementioned schedule, taking into account the distance profile of the recorded orthosis points in relation to the reference points on the leg. The deviations between the orthotic axis and the approximated joint axis were determined indirectly from the course of cyclical and cycle-dependent distance changes. It was assumed that no distance changes would be measured in the ideal case of complete congruence. In view of the small study sample, all average figures stated below relate to the median.

For the SecuTec orthosis, the results for the maximum distance changes during the walking cycle (maximum change in the distance from fixed points) showed median deviations of 5.5 mm medially and 5.7 mm laterally between the calculated orthotic axis and the joint compromise axis. This degree of medial and lateral incongruence is well below the reference values stated for other orthoses on the market.

The corresponding median deviations measured for the SofTec orthosis were 9.6 mm medially and 9.5 mm laterally, i.e. within the range of the cited reference values, albeit those based on other rigid frame orthoses.

Slightly higher incongruence figures were calculated during the running exercise as a result of the greater acceleration and the inertia forces. The results for the SecuTec for the maximum distance changes during the running cycle showed median deviations of 5.8 mm medially and 6.1 mm laterally between the orthotic and joint axes. This degree of medial and lateral incongruence was also well below the existing reference values. For the SoftTec, the corresponding median values were 10.0 mm medially and 10.3 mm laterally and thus within the range of the reference values.

The results for the temporal-spatial consistency of the positions of

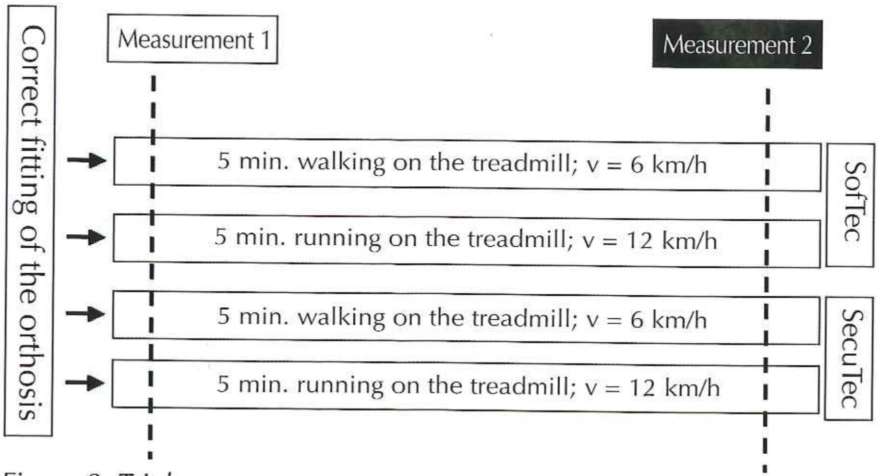


Figure 3: Trial sequence

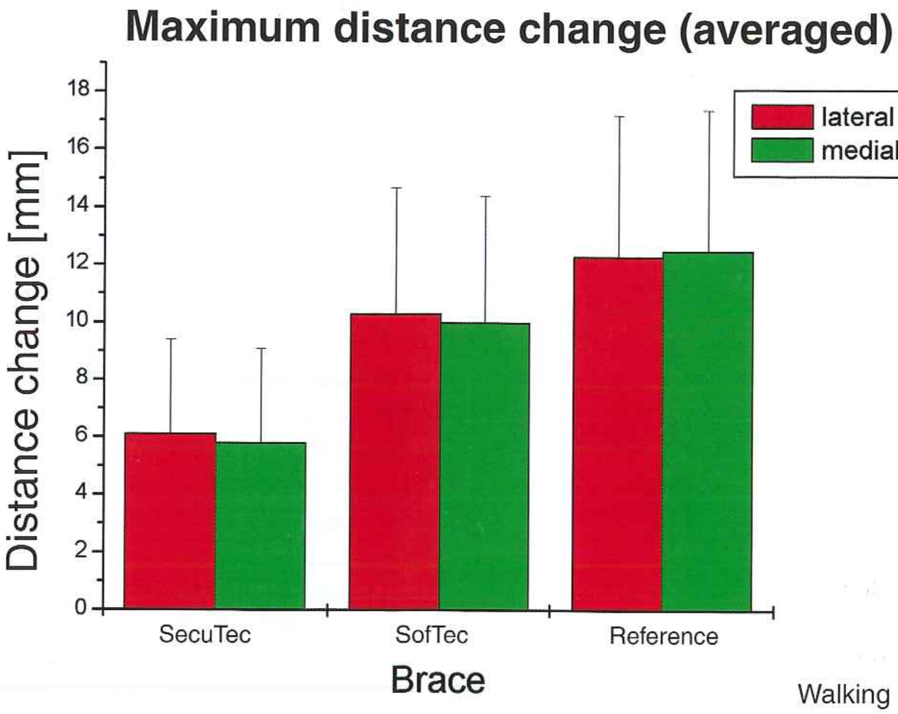


Figure 4: Axis congruence during walking (6 km/h)

the axes in space indicate some - albeit slight - migration (change from the baseline incongruence): the values were within the range of measuring error both for the knitted SofTec design and the rigid frame design of the SecuTec, although the existing reference values are also within this range.

The changes in the orthotic axis, in terms of migration, measured during running were also slight, indicating good inhibition of migration. As expected, the migration tendency of the SofTec (median = 2 mm) was slightly lower than that of the SecuTec (median = 3 mm) with its rigid frame design, primarily because of the general anti-slip action of the knitted SofTec design.

Discussion

The results of this investigation with two differently designed orthoses (rigid frame vs. knitted construction) and other reference orthoses showed axis incongruence in the millimeter range. Although this incongruence can generally be minimized through the use of polycentric joint designs and designs based on compromise axes, e.g. that of NIETERT (1975), complete congruence does not appear to be achievable in practice. A more important factor seems to be the temporal-spatial stability of the position of the orthotic axis, which is characterized by the ability of an orthosis to counteract slippage and thus axis migration. In this context, the assertion by ULRICH (1994) that migration represents a kind of self-adjusting effect of a poorly fitting orthosis is only valid to a very limited extent. In fact, a distal migration tends to result in an increase in what should be considered as pathogenic moments on the knee joint, so that the stabilizing effect of the brace could potentially counter this with the opposite action. The method presented in this study, in contrast with static investigations (e.g. HÜGEL, 2001), produces values that take into account axis incongruence during movement and throughout the movement cycle.

Axis incongruences that can be rated as slight were measured for both tested braces. The rigid frame design of the SecuTec produced good figures in relation to the inhibition of pathogenic move-

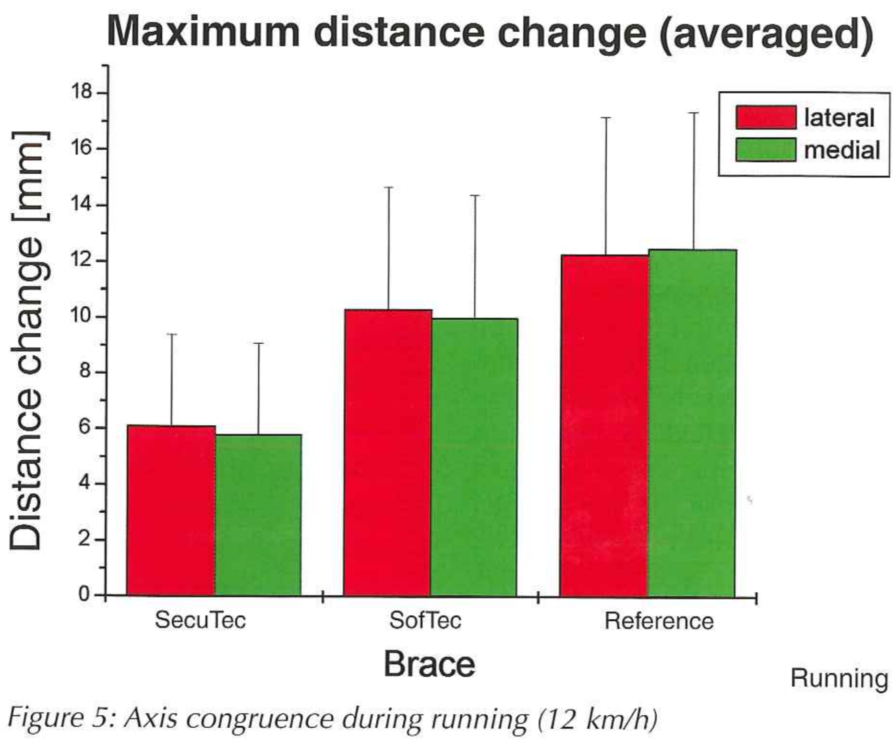


Figure 5: Axis congruence during running (12 km/h)

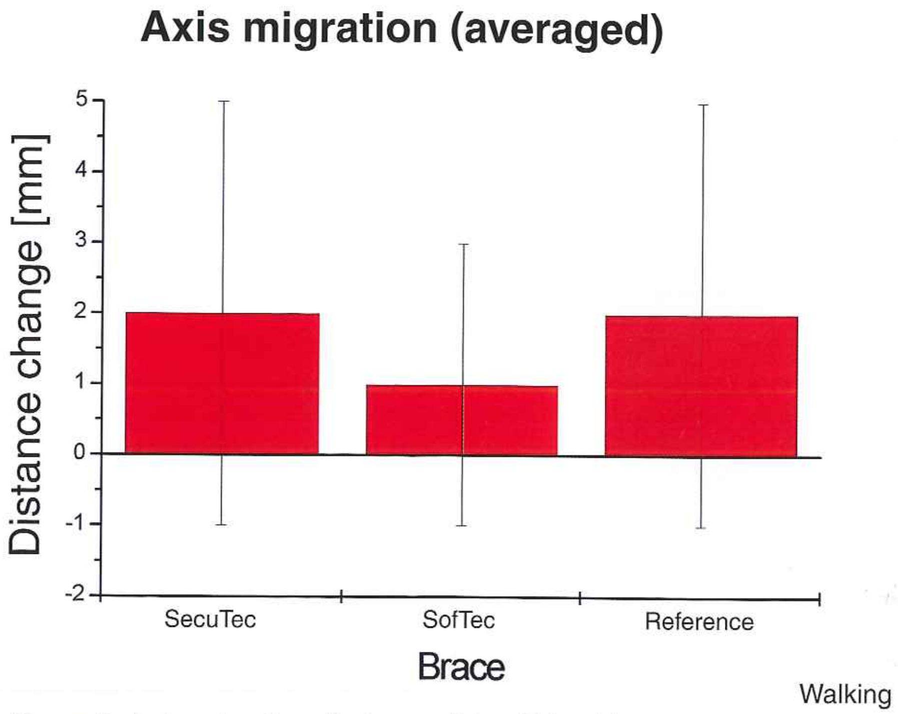


Figure 6: Axis migration during walking (6 km/h)

ments in the knee joint (Basis, 2002). With a bilateral polycentric joint design, the orthosis showed slight axis incongruence and a very good migration resistance effect.

The independently positioned sidebars in the knitted orthosis allow the individual compromise axis of rotation to be adjusted independently of each other on the medial and lateral sides. The resulting orthotic axis shows good approximation, with a compromise axis of rotation aligned with the actual knee axis (compromise axis of the knee: sloping down slightly in the medial to lateral direction and, in the sagittal direction, running from medial-anterior to lateral-posterior (ULRICH, 1991). This bi-lateral independent adjustment also offers the advantage of better adaptation to inter-individual axes positions in space. The positive results reported by HÜGEL (2001) were confirmed in this series of investigations. In addition to all aspects of mechanical stabilization, another important factor is the distribution of forces across soft tissues, since, apart from the tibial area, the brace construction lies flat against the knee and transmits forces as pressure. Accordingly, the flexible textile section, in contrast with the rigid upper and lower leg shells, allows almost unrestricted muscle flexing and distributes the load uniformly over a wide area. REER et al. (2001) refers to the minimal effect on performance resulting from this type of design.

In a comparison of the two orthosis design principles, one has to offset the better mechanical stabilization (e.g. rotational stability, varus-valgus stability) and lower compartment pressure of the rigid frame brace against the better axis congruence and greater comfort, potential for sensorimotor influence, and patella control of the knitted design.

In conclusion, the findings of this study would suggest that knee-stabilizing orthoses need to be further evaluated simply from the standpoint of maintaining axis congruence and that hitherto accepted design features should be reviewed in with respect to their competence, limitations and options for modification.

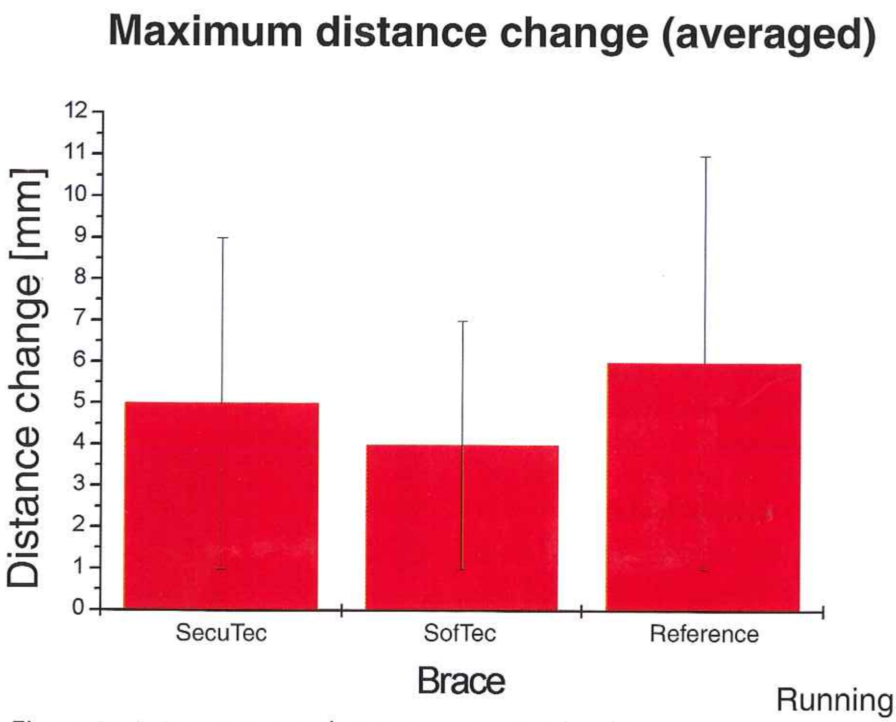


Figure 7: Axis migration during running (12 km/h)

Figure 8: Posterior camera perspective

References

HÜGEL, M.-C. (2001): Effizienz und Handhabbarkeit eines neuen Knieorthesenkonzepts unter Berücksichtigung klinischer Parameter. Dissertation. München.

LUBER, M. et al. (1998): Stabilisierungseigenschaften von Hartrahmenorthesen und Bandagen mit Gelenkschienen gegen vordere Schublade - Erste Ergebnisse. Orthop. Technik 49.

JEROSCH, J. et al. (1994): Se-condary effects of knee braces on the intracompartmental pres-sure of the anterior tibial compartment; Sekundäreffekte von Knieorthesen auf das intrakom-partmentale Druckverhalten der Tibialis-anterior-Loge. Dt. Z. f. Sportmed. 45 : 457 - 465.

NIETERT, M. (1975): Untersuchungen zur Kinematik des menschlichen Kniegelenks im Hinblick auf ihre Approximation in der Prothetik. Dissertation. Berlin.

REER, R. (2001): Die Anwendung äußerer Kniestabilisatoren – Einflussnahme auf mechanische Stabilisierung und körperliche Leistungsfähigkeit. Sportverletzung, Sportschaden 15: 62-67.

SCHAFF, P. et al. (1995): Aktiv-muskuläre reflektorische Knieorthesen: Darstellung neuer experimenteller und klinischer Ergebnisse. Orthopädie-Technik 5/95: 398 - 415.

SITLER, M. et al. (1990): The efficacy of a prophylactic knee brace to reduce knee injuries in football. Am J Sports Med 18 : 310 - 315.

ULRICH, H.-W.: Der Einfluss von Knieorthesen auf das Spannungsverhalten der Kreuzbänder. Habilitationsschrift (1991), Orthopädische Klinik im Zentrum operative Medizin II der Christian-Albrechts-Universität zu Kiel.

ULRICH, H.-W. (1992): Knieorthesen - funktionelle Ansprüche aus Sicht des Operateurs. Orthop. Technik 43 : 174 - 182.

ULRICH, H.-W. (1994): Knieorthesen bei Kreuzbandverletzungen. Springer-Verlag, Berlin.

Adress for Correspondence

Dr. Gereon Berschin
Philipps-Universität Marburg, Institut für Sportwissenschaft und Motologie - Abteilung Sportmedizin, Kugelgasse 10, 35032 Marburg,
Tel: 06421-2823987
Fax: 06421-2828972