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Stress radiography in the assessment of residual deformity in clubfoot following postero-medial soft tissue release

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Abstract X-ray is important in the assessment of clubfoot. Stress radiographs give more information than routine radiographs. Because of the inaccuracy of the positioning and the disadvantages of radiation, paediatric orthopaedic surgeons do not like and do not use X-ray examination. In this study we report a technique we use to obtain stress radiographs in paediatric patients with clubfoot using a custom-made radiolucent modular splint. This technique provides better assessment of the initial status and the result of treatment. Although this method has limitations it can help to compare different feet and treatment results with regard to axis and angle. We validated this splint by means of a prospective study in 11 patients with 21 feet having type 2 clubfoot who underwent (PMSTR) in our centre. Two sets of radiographs were taken, one with manual positioning and one with our splint. We found significant differences in the values of midfoot and forefoot radiological parameters between the two sets. We found that the correlation between the clinical and radiological assessment of residual deformity improved significantly for these values when a splint was used to obtain stress views. Hence we recommend routine use of a radiolucent splint for taking stress views to assess residual deformity in clubfoot.

Résumé Les radiographies sont un élément important dans l'analyse des pieds bots, les radiographies dynamiques donnant plus d'informations que les radiographies standards.

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Cependant, les chirurgiens orthopédistes n'aiment pas utiliser les radiographies dynamiques, celles-ci entraînent une exposition plus importante aux rayons. Au cours de cette étude, nous rapportons une technique permettant d'obtenir ces clichés dynamiques en utilisant une attelle modulaire, transparente aux rayons X. Cette technique permet de faire une meilleure analyse des stades initiaux de la maladie et des résultats du traitement. Cependant, cette technique a également ses limites. Néanmoins, elle permet de comparer les résultats des différents pieds et des différents traitements en terme d'analyse des axes et d'analyse angulaire. Nous avons validé l'utilisation de cette attelle lors d'une étude prospective chez 11 patients présentant 21 pieds bots de type 2 qui ont bénéficié d'une PMSTR en notre centre. Des radios dynamiques ont été pratiquées, soit en utilisant l'attelle, soit en radio dynamique manuelle. Nous avons trouvé une différence significative dans les valeurs du médio-pied et de l'arrière-pied, lorsque les clichés dynamiques ont utilisé l'attelle en comparaison avec les examens dynamiques manuels. Nous avons également trouvé une meilleure corrélation entre les résultats cliniques et radiologiques de la déformation résiduelle lorsque l'on utilisait l'attelle. Aussi, recommandons-nous d'utiliser cette attelle radio-transparente, en routine habituelle, pour les clichés dynamiques a fin d'analyser les déformations résiduelles dans le pied bot.

Introduction

Clubfoot is the most common paediatric foot disorder. Lehman [7] classified clubfoot into three types. Type 1 is mainly postural in nature, i.e. packing syndrome. Type 2 is idiopathic and is the most common type, and type 3 includes those cases secondary to conditions such as arthrogryposis multiplexa congenita and myelomeningocele. Postero-medial soft tissue release (PMSTR) is the most common, surgery performed on clubfoot. Residual deformity is a very frequent problem following PMSTR [15]. Various methods have been described in the literature for the assessment of residual deformity in clubfoot following PMSTR [5, 15]. Plain radiography continues to be the most commonly used

investigation for the assessment of residual deformity clubfoot in most centres.

Few authors recommend routine use of intraoperative and postoperative radiography in the assessment of clubfoot [12–14, 16, 19]. Tarraf [20] and Catterall [2] recommended stress views for the assessment of clubfoot. Simons [13] proposed a standardised technique for obtaining radiographs of clubfoot. He recommended that the foot be held in the maximally corrected position. In practice, however, obtaining such a stress view in a paediatric foot is a difficult and cumbersome task, requiring a minimum of two assistants to hold the foot in the maximally corrected position and also to hold it against the cassette. Despite best efforts, a true stress view is seldom obtained in a paediatric foot. Moreover, it is often difficult to reproduce the same views for future comparisons. A few authors [3, 4, 8] have suggested the use of a radiolucent splint to overcome these difficulties. However, no study has been conducted to evaluate the usefulness of a radiolucent splint in obtaining a stress view in a clubfoot. In this study, comparisons were made between radiological parameters obtained by stress views taken using a specially designed radiolucent splint and those obtained by the conventional technique of manual assistance. Further, we attempted to find out whether there is any change in clinico-radiological correlation and agreement when a splint was used compared with the conventional technique.

Materials and methods

In this study all Lehman type 2 clubfoot patients who underwent PMSTR in our hospital between June 2002 and December 2002 were randomly selected for the study by tossing a coin. The process of choosing the child for the study was randomised to avoid the possible selection bias towards more cooperative and weaker children. Both unilateral and bilateral cases were included in the study. Patients with clubfoot secondary to arthrogryposis multiplexa congenita, myelodysplasia, or other neuromuscular disorders were not included in the study. Eleven patients with 21 involved feet were included in the study. There were ten boys and one girl. All ten male children had bilateral involvement and the female child had unilateral involvement. All patients underwent single-stage PMSTR. No pins were used for internal fixation. X-rays were taken routinely at six weeks post-operatively. Two sets of X-rays were taken, one comprising stress views taken with the foot held in position by well-trained assistants (group A) and the other taken with the foot maintained in maximally corrected position using a specially designed radiolucent splint (Fig. 1; group B). Both antero-posterior (AP) and lateral (lat) views were taken. All X-rays were taken according to Simons' standardised technique [13] except for the fact that in one set the foot was held in maximally corrected position using the splint (Fig. 2) and in

Fig. 1 a Front view of splint; b side view of splint; c radiograph being taken with splint

Fig. 2 Stress X-rays with the splint. **a** Anteroposterior view; **b** lateral view

the other set manual assistance was used. Two assistants were used to obtain the stress views in the one unilateral case, and three assistants were used in bilateral cases. The assistants were of the junior resident grade and were properly trained in holding the foot. They were blinded about the nature of the study. The same team of assistants was used for all cases. The splint is custom-made, modular and radiolucent, and has three detachable components. The footplate is made of aluminium alloy 001 and has a pointer to measure the amount of dorsiflexion achieved while taking the X-ray. The footplate has holes for a Velcro strap to hold the foot plantigrade against the plate. The leg bar is made of stainless steel with a Velcro cuff and has an angle guide (protractor) attached to it. The knee piece is also made of stainless steel and is used to hold the knee in flexion as recommended by Simons [13]. The components are attached to each other using a hinge (fly nut). After the two sets of X-rays had been taken the child was assessed clinically by an experienced paediatric orthopaedic specialist (S.S.G.) using the Dimeglio score [18]. Another paediatric orthopaedic surgeon made the radiological measurements. Measurements were made for deformities such as equinus, varus, cavus, forefoot adduction, calcaneocuboid dislocation [20] and talonavicular dislocation [12, 13].

Statistical analysis

The paired *t* test was used to determine the significance of the differences in the radiological values obtained with the splint and the conventional technique. For those parameters for which a significant difference was revealed, an attempt was made to establish whether there was any significant change in clinico-radiological correlation and agreement. For the purpose of assessing correlation and agreement, the radiological values were converted to a binomial scale of 'yes' or 'no' for that deformity based on the standard proposed by Vanderwilde et al. [17] for that age group. The Dimeglio score [18] was also converted to a binomial scale of 'yes' or 'no'. Those with grade 0 deformity were considered normal (no) and those with grade 1 to grade 4 deformities were

considered to have residual deformity (yes). The task of converting the values to a binomial scale was assigned to a person of junior statistician grade who was blinded about the nature of the study in order to avoid conversion bias. Kappa statistics was used to ascertain clinico-radiological agreement.

Results

Of the 21 feet included in the study, five had residual equinus as assessed by Dimeglio scoring [18] six weeks post-operatively. One foot had residual varus. Six feet had residual midfoot cavus and in three feet, forefoot adduction remained uncorrected.

Hindfoot parameters

In this study tibiotalar angle (lat) [TT (lat)] [12] and tibiocalcaneal angle (lat) [TiC (lat)] [12] were used as radiological parameters to predict equinus, and talocalcaneal angle (AP) [TC (AP)] [9, 12] talocalcaneal (lat) [TC (lat)] [9, 12] and talocalcaneal index [TC index] [1] were used to assess hindfoot varus. It was found that there was no statistically significant difference in the values obtained for the radiological parameters of the hindfoot between positioning with a splint and manual positioning (Table 1).

Forefoot parameters

Talo-first metatarsal angle (AP) [TFM (AP)] [10] and calcaneo-fifth metatarsal angle (AP) [CFM (AP)] were used as radiological measures of forefoot adduction [12, 13].

Talo-first metatarsal angle (AP)

The mean value of TFM (AP) differed significantly between groups A and B (Table 1). The clinico-radiological correla-

Table 1 Radiological values with and without the splint

Angle	Manual positioning (group A)	Positioning with splint (group B)	Significance of difference between group A and group B
TT (lat)	105.71±13.82	104.76±13.82	P=0.576
TiC (lat)	85±15.65	84.09±12.65	P=0.692
TC (AP)	35.33±10.48	35.09±11.98	P=0.926
TC (lat)	28.28±8.20	27.47±9.31	P=0.726
TC Index	62.80±15.62	63.38±16.72	P=0.878
TFM (AP)	24.71±12.52	18.14±10.53	P<0.05
CFM (AP)	27.85±12.70	20.47±12.13	P<0.05
CFM (lat)	136.90±19.20	151.90±14.09	P<0.05
CH (lat)	29.28±11.32	20.66±7.86	P<0.05

TT, Tibiotalar; TFM, talo-first metatarsal; TiC, tibiocalcaneal; CFM, calcaneo-fifth metatarsal; TC, talocalcaneal; CH, calcaneo-horizontal;

tion (Table 2) between TFM (AP) and forefoot adduction was $k=0.364$ in group A and $k=0.696$ in group B.

Calcaneo-fifth metatarsal angle (AP)

The mean value of calcaneo-fifth metatarsal angle (AP) [CFM (AP)] differed significantly between group A and group B (Table 1). The clinico-radiological agreement (Table 2) between CFM (AP) and forefoot adduction was $k=0.125$ in group A and $k=0.514$ in group B.

Midfoot parameters

Cavus was the most common deformity to remain uncorrected in this study. Six feet had cavus. Calcaneo-fifth metatarsal angle (lat) [CFM (lat)] [6] and calcaneo-horizontal angle (lat) [CH (lat)] [6, 11] were used as a radiological measure of cavus in this study.

Calcaneo-fifth metatarsal angle (lat)

The mean value of CFM (lat) differed significantly between group A and group B (Table 1). The clinico-radiological correlation (Table 2) between CFM (lat) and cavus was $k=0.10$ in group A and $k=0.451$ in group B.

Table 2 Clinico-radiological correlation with and without the splint

	Clinico-radiological correlation (manual positioning)	Clinico-radiological correlation (splint)
TFM (AP)	0.364	0.696
CFM (AP)	0.12	0.514
CFM (lat)	0.10	0.451
CH (lat)	0.077	0.489

Calcaneo-horizontal angle (lat)

The mean value of CH (lat) differed significantly between groups A and B (Table 1). The clinico-radiological correlation between CH (lat) and cavus was $k=0.077$ in group A and $k=0.481$ in group B.

Discussion

Radiography is the most commonly used assessment tool in clubfoot. However, some centres have stopped using radiography because it is cumbersome, unreliable and not reproducible. In this study we attempted to validate a splint which we have used in our centre to take radiographs of paediatric foot disorders. We studied the splint in 21 postoperative clubfoot patients. We found that using the splint changed midfoot and forefoot radiological measurements significantly. We also found a corresponding increase in the clinico-radiological correlation for those parameters.

In this study, since both sets of radiographs were taken from the same patient the confounding effects of variables such as age, gender and severity of deformity on the clinico-radiological correlation were neutralised.

We compared the radiographic values to the clinical appearance of the foot as assessed by a paediatric orthopaedic specialist (S.S.G.). This is in contrast to other studies that compared the radiological parameters to the revision rates [10]. We preferred the clinical appearance to the revision rate because criteria for revision vary from centre to centre and refusal of revision by the parent can significantly affect the revision rates. We used binomial values for the assessment of correlation. We preferred the binomial scale because comparison of the numerical values obtained for the radiological and clinical assessment will give an idea of statistical correlation but yield no clues about the clinical significance. However, converting the numerical values to clinically meaningful binomial values helped us derive a valid clinical conclusion from the statistical conclusion.

In this study there was no significant difference between the group A and group B radiographs in hindfoot measurements such as TC angle (AP, lat), TC index, TT angle (lat), TiC angle (lat). Forefoot adduction is the most common deformity to remain uncorrected following PMSTR. We found that both TFM (AP) and CFM (AP), used to measure forefoot adduction deformity, changed significantly when a splint was used. Further, we found a significant improvement in the correlation between the clinical assessment and radiological assessment for TFM (AP) when a splint was used. Hence, we feel that stress views taken using a splint were able to predict residual forefoot adduction deformity better than the conventional technique.

A few authors such as Tarraf [20] have highlighted the importance of cavus. In our study we found that the values of radiological parameters used to predict cavus, such as CH (lat) and CFM (lat), changed significantly when a splint was used. Further, we found an improvement in clinico-radiological agreement from 10% to 45.1% for CFM (lat), and from 7.7% to 48.1% for CH (lat), when the splint was used.

Hence, the ability to predict residual cavus deformity by radiological parameters such as CFM (lat) and CH (lat) improved significantly when a splint was used.

We feel this significant change in radiological values and the clinico-radiological correlation is most likely due to the difficulty in placing the hindfoot, midfoot and forefoot simultaneously in the maximally corrected position when manually holding the foot. Further, the tendency of a conscious child to lift the medial border of the foot from the X-ray cassette was prevented by using a splint, thereby increasing the reliability of the radiological parameter.

We understand that our study involved a small subset of patients (postoperative clubfoot patients) and was not randomised, that reproducibility was not assessed because it is not ethically possible to subject the child to repeated radiographs, and that tension in the straps was not standardised for initial cases, although later we standardised by dividing the straps into different coloured segments.

We did not formally check the reproducibility as a part of the study, but in those few patients who had subsequent radiographs for other reasons it was found to be comparable and reproducible. Further, using the splint reduces the consumption of human resources by eliminating the need for attendants to hold the foot in the maximally corrected position.

Conclusion

Since the forefoot and midfoot deformities are the most common deformities to remain uncorrected, and since there was a significant change in the values of radiological parameters used to assess midfoot and forefoot deformities when a splint was used to obtain stress views and a corresponding improvement in the clinico-radiological correlation when a radiolucent splint was used, we recommend routine use of a radiolucent splint to obtain stress radiographs for the assessment of clubfoot. Further, based on extensive experience of a myriad of paediatric foot problems we take the liberty to suggest that such a splint could be used in all paediatric foot disorders, because for all practical purposes a well-taken stress view in a paediatric foot is comparable to the weight-bearing view in adults.

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