Original Article International Journal of Paediatric Orthopaedics | Jan-April 2020 ;6(1): 7-10

Observational Study on Impact of Pediatric Foot Pathology and its Management in Ossification of Midfoot Tarsal bones

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Abstract

As Julius Wolff in 1868 stated that every change in the form or function of a bone is followed by adaptive changes in its internal architecture and its external shape, we conducted an observational study radiologically in the children attending our hospital to note the trend in the ossification of the midfoot tarsal bones in normal and in pathological conditions and determine the impact that each disease levies on the bone re-modelling and maturation. We studied the ossification status of 402 foot with a sex ratio of M: F 2.86:1. The mean age of the children enrolled in the study is 50.23 months (range 0.3-144). There was equal distribution of the side of the foot studied. The pathological distribution of the foot was as follows: 278 Club Foot, 88 Normal Foot, 16 Congenital Vertical Talus, 8 Flat foot, 4 Coalition of tarsal bones, 4 Cerebral Palsy, 4 Hereditary Sensory and Autonomic Neuropathy. We compared the rate of ossification of pathological foot with the normal foot. Out of the 278 club foot involved in the study 20 underwent Tibialis Anterior Tendon Transfer (TATT) for residual deformity following Ponsetti correction. We found that there is a significant delay in the ossification of the medial midfoot tarsal bones like intermediate and medial cuneiform and navicular in club foot cases. Intervention in the form of Ponsetti casting and tendon transfer significantly altered the rate of ossification of the tarsal bones. This establishes the pathology involved in the disease like club foot which results in the varus positioning of the foot in children resulting in faster ossification of the lateral midfoot tarsal bones and significant delay in the ossification of the medial midfoot tarsal bones comparing to the normal population of same age. By procedures like Ponsetti and TATT which normalises the weight bearing of all the midfoot tarsal bones resulted in a significant change in the rate of ossification of the midfoot tarsal bones compared to the untreated patients of same age.

Keywords: Foot Ossification, Club Foot, TATT, Ponsetti casting

Introduction

The development of children's feet begins in-utero, being mainly derived from basic embryological tissue called mesenchyme. In simple terms, the mesenchyme differentiates to form a cartilage foot template, which is largely complete by the end of the embryonic period (8 weeks after conception). The lower limb buds appear around the 4th embryonic week, slightly later than the upper limb buds, and the developing nervous system is already evident. The blood supply of the foot then begins to infiltrate the tarsal bones, whilest the process of endochondral ossification sees cartilage become bone. Not all of the foot bones are formed at birth. The navicular is the last bone to ossify, occurring between 2 and 5 years of age. The ossification of the cuboid occurs reliably at 37 weeks of gestation, and its appearance is often used as a marker of foetal maturity. The foot growth continues to be very rapid in the first 5 years of life; slower development continues until skeletal maturity of the feet, which occurs on average at 13 years in girls and 15 years in boys. Final foot length is achieved before maximum height is reached in both genders[1, 2, 3]. Congenital deformities of the foot are readily identified and given treatment as early as possible to normalizes the development of the foot. We studied the appearance of the ossification in the foot in children to note the impact of these disorders in the rate of ossification of the bones and thereby formulating the patho-mechanics involved in the disorder. Talipesequinovarus (clubfoot) is one such complex foot deformity that involves abnormalities of the bones as well as surrounding vasculature and musculature. Historically, the poor understanding of the underlying anatomical deformity has given way to different methods for treating clubfoot and less than satisfactory outcomes[5]. Where asile the etiology of the deformity is still unknown, the improved understanding of the anatomical deformity has led to an improvement in treatment and correction. Multiple studies over the last two decades have demonstrated that the Ponseti method is the preferred method to begin treatment in children with idiopathic as well as syndromic clubfeet [8]. Resistant or relapsing clubfoot is managed with soft-tissue procedures, likesuch astibialis anterior tendon transfer (TATT) to counteract the abnormal pull in the soft tissue, which resists the correction by serial casting[8]. In addition to the clubfoot, there are other conditions, which are identified in the infants and children like such as congenital vertical talus (CVT), flat foot, coalition of tarsal bones, foot deformities in cerebral palsy (CP), and hereditary sensory and autonomic neuropathy (HSAN). Relative to the skeletally mature foot structure, it is

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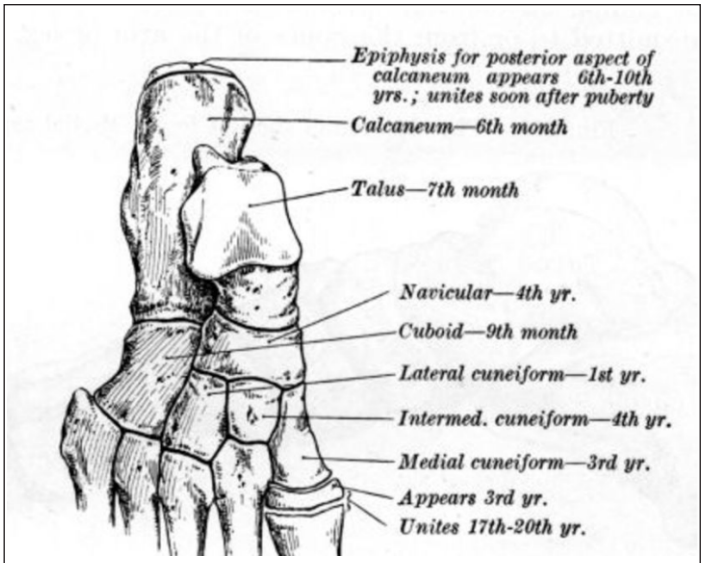

Figure 1: The normal age of ossification of the tarsal bones [1].

expected that an infant and young child should display a flat foot posture with a lower medial longitudinal arch and everted heel position. We did a serial radiographic observational study to determine the role of these pathologies in altering the rate of ossification of the mid foot tarsal bones, namely cuboid, navicular, and the three cuneiforms and thereby to understand the patho-mechanics of the disease under study.

Methods

This is a prospective study conducted in the Institute of Child Health, Egmore, after getting approval from the Institutional Ethical Committee. All children, who presented to the foot clinic, were included in the study after getting proper consent to involve in the study. They are investigated radiologically to note the appearance of the ossification center in them and recorded serially in cases identified with the pathological foot. Normal children are also included in the study to form a comparative cohort for the recorded pathological foot. To minimizse the intraobserver error in the identification of the ossification center, we involved three investigators of which two are paediatric orthopaedics postgraduate residents and one professor of paediatric orthopaedics. We noted the appearance of the ossification center in all these subjects participants and analyzed the results to find the sequence of ossification in the above-mentioned pathological conditions. The patients identified with clubfoot are treated by using ponsetti method of serial casting, and cases with refractory or replacing clubfoot are treated with soft-tissue procedures like such as TATT. We also analyzed the impact of the soft-tissue procedures in the rate of ossification of the tarsal bones in restoring the normal anatomy of the foot.

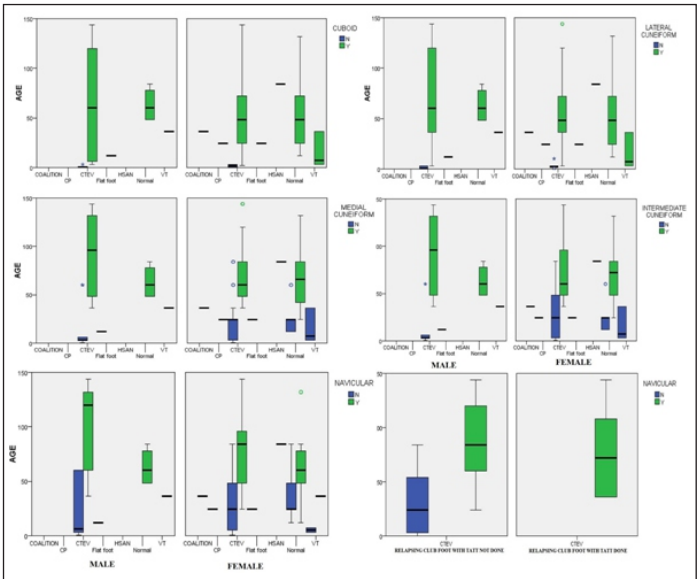

Figure 2: A-C shows the plotting of the trend of ossification in normal and pathological foot with age comapred with genders and it clearly shows in tarsal bones like navicular, medial cuneiform and intermediate cuneiform ossification was significantly delayed in conditions like club foot and congenital vertical talus. D shows that on soft tissue procedure like TATT for resistant/relapsing club foot there is a significant change in the trend of ossification of tarsal bones compared to patients of same age who did not undergo the procedure.

Statistical analysis

We used IBM SPSS software (Version 25) to analyze our results. We used box plot for the descriptive analysis of the appearance of the ossification center of the tarsal bones. We also used Fisher's t-test to compare the impact of the TATT in the rate of ossification of the tarsal bones compared to the normal subjects participants.

Results

We studied the ossification status of 402 foot with a sex ratio of M: F is 2.86:1. The mean age of the children enrolled in the study is 50.23 months (range 0.3--144). There was an equal distribution of the side of the foot studied. The pathological distribution of the foot was as follows:

We compared the rate of ossification of the pathological foot with the normal foot. Out of the 278 clubfeeoot involved in the study, 20 relapsing or residual clubfoot patients under went a soft-tissue procedure likesuch as TATT Tibialis Anterior Tendon Transfer. The rate of ossification of the tarsal bones are compared among both the sexes and between normal and pathological conditions. The distribution of ossification center of major tarsal bones are compared in the analysis. It was found that, although tarsal bones likesuch as calcaneus, talus, and cuboid, are ossified at birth; in congenital clubfoot, the ossification of the cuboid is delayed compared to the normal trend of ossification. It was also noted that the ossification of medial structures, likesuch as medial cuneiform and intermediate cuneiform, was significantly delayed in conditions likesuch as clubfoot CVT congenital vertical talus. We found that there is a significant delay in the Ossification of

Table 1: Demographic profile of the foot taken into study

Sl.no	Foot disorder	Sample size (n)
1	Normal foot	88
2	Clubfoot	278
3	CVT	16
4	Flat foot	8
5	Coalition of tarsal bones	4
6	CP	4
7	HSAN	4

HSAN: Hereditary sensory and autonomic neuropathy, CP: Cerebral palsy, CVT: Congenital vertical talus

navicular, mostly in boys compared to girls from our study in patients with clubfoot. For relapsing and resistant clubfoot which were subjected to soft-tissue procedures likesuch as TATT tibialis anterior tendon transfer, we noted a significant change in the trend of ossification of the foot post procedure which is mainly due to the restoration of the normal weight-bearing posture of the foot in them. The ossification of navicular is being compared in the patients who presented with relapsing clubfoot among those who underwent soft-tissue procedures for the same, and it was noted that there is a significant return of normalcy in the ossification of the navicular bone compared to the patients of the same age who did not underwent soft-tissue procedures for clubfoot.

Discussion

the anterior tibial tendon transfer does not change the axial direction of the muscle function; it also does not change the phasical pattern of anteriotibial tendon during walking. Therefore, it is expected that muscle strength stays the same after the transfer. It is obvious from our data that muscle-strength grade did not change preoperatively and post operatively. The significant improvement of plantar flexion power may be explained in two ways: one is improvement of the functional axis of the ankle joint, and the other is a gradual increase of Achilles tendonpower after clubfoot release in longer follow-up. The increase of eversion strength is the result of correction that places the foot in a more effective position for eversion function. TATT has classically been performed for a clinically diagnosed dynamic supination deformity in older children[6, 7, 8, 9, 10]. Performing this surgery early is thought to prevent later varus recurrence in the hindfoot. While dynamic supination has been the classic indication for this procedure in ponseti-treated patients, the deforming force of the tibialis anterior likely exists before the child establishes normal gait. Recent studies have also shown that there may be a muscle imbalance between the peroneals laterally and the tibialis anterior medially [11, 12, 13]. If patients with an overpowering tibialis anterior could be identified earlier, transferring this tendon might prevent recurrences and balance the foot more normally. In a study done by Miyagi et al., [14] on the onset of ossification of the tarsal bones in congenital clubfoot involving 56 patients, they concluded that there is a significant delay in the ossification of the second cuneiform and tarsal navicular compared to the normal volunteers involved in the study. They also noted the earlier ossification of the tarsal bones in girls compared to girls & boys . It is also noted from our study that the girl children ossified earlier compared to the boys. In our study, we found a significant delay in the ossification of the navicular and medial and intermediate cuneiform compared to the normal population and earlier ossification of the lateral cuneiform which re-establishes the dynamic pathomechanics of the clubfoot, where the weight-bearing axis in a clubfoot is more towards the lateral end of the foot which resulted in the earlier ossification of the above-mentioned midfoot tarsal bones under study which is in accordance with the Wolff law of bone remodelling. Since the sample size of the other pathological conditions, likesuch as CVT, CP, HSAN, flat foot, and coalition of tarsal bones, we could not establish a statistically significant relationship with the change in the ossification rate of the midfoot tarsal bones in this study. Further research with larger sample size is need for establishing a stronger relationship with the above-mentioned pathological conditions and the rate of ossification in them.

Conclusions

For our study, we conclude that in pathological condition of the foot likesuch as clubfoot, the normal rate of the ossification of the midfoot tarsal bones is affected and the medical tarsal bones, i.e., navicular, medial, and middle cuneiform are significantly delayed in an appearance on serial radiological follow-up. By using the procedures likesuch as Ponsetti and TATT which normalizses the weight bearing of all the midfoot tarsal bones resulted in a significant change in the rate of ossification of the midfoot tarsal bones compared to the untreated patients of the same age.

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Conflict of Interest: NIL
Source of Support: NIL

How to Cite this Article

Pasupathy B, Sathish M.| Observational Study on Impact of Pediatric Foot Pathology and its Management in Ossification of Midfoot Tarsal bones.| International Journal of Paediatric Orthopaedics | Jan-April 2020; 6(1): 7-10