Palmar-Plantar Fibromatosis in Children and Preadolescents

A Clinicopathologic Study of 56 Cases With Newly Recognized Demographics and Extended Follow-Up Information

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Abstract: Palmar-plantar fibromatosis, the most common type of fibromatosis, is well recognized in the adult population, but many clinicians and pathologists are unfamiliar with the fact that children may also be affected by this process. This report describes the clinicopathologic findings in 56 cases of palmar-plantar fibromatosis in children and preadolescents. Our study group included 19 males and 37 females, ranging from 2 to 12 years of age at the time of their first surgical procedure (median age, 9 years). The patients typically presented with solitary, lobular or multilobular masses in the 0.5- to 2.5-cm size range. The preoperative duration of the lesions ranged from 1 month to 6 years, with 1 patient purportedly having clinical evidence of disease since birth. All but two of the initial lesions occurred on the plantar aspect of the feet, typically in the region of the arch. Only 2 patients presented with palmar disease. The tumors were usually painless, except when pressure was applied. Seven patients had a history of trauma, sometimes involving a foreign body. One patient presented with concurrent disease involving both feet, and 12 additional patients subsequently developed palmar-plantar fibromatosis in another extremity, knuckle pads on the hands, or had other clinical findings linked to this disease. A family history was available for 25 patients, and 11 individuals had relatives with palmar-plantar fibromatosis, and 4 others had relatives with a history that was either suspicious for palmar-plantar disease or positive for other disorders associated with this disease. Histologically, the tumors involved aponeurosis and commonly formed discontinuous, moderately cellular, nodular masses composed of spindled cells with intervening collagen. Mitotic counts for 79 separately submitted tumor specimens ranged from 0 to 31 mitotic figures per 25 wide-field high power fields (mean mitotic count, 3.4 mitotic figures per 25 wide-field high power fields). Eight tumor had ≥10 mitoses per 25 wide-field high power fields. All patients were initially managed by local excision, and in most of cases, histologic examination showed tumor extending to the tissue edge. Thirty-two of 38 patients (84.2%) with clinical follow-up, ranging from 4 months to 33 years (mean, 14 years 9 months; median, 16 years 1 month), had one (n = 16) or more (n = 16) local recurrence of their fibromatosis.

Key Words: aponeurosis, contracture, clinodactyly, Dupuytren's disease, epilepsy, fibroma, fibromatosis, foot, hand, keloid, Ledderhose's disease, palmar, plantar, superficial fibromatosis, soft tissue tumor

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Palmar and plantar fibromatoses are well-recognized diseases of the adult population. However, there are proportionally very few reports of these lesions in juveniles, and in most instances, specific histologic findings and long-term follow-up are not included.[2–4,6,16,19,22,23,32,41,45,50–52,56,63,65] This study represents the first truly large series of palmar-plantar fibromatosis in children and preadolescents. Detailed clinical and histologic data are presented for this subgroup of patients, and for comparative purposes, general demographic data are presented for all patients, regardless of age, whose surgical material was reviewed at the Armed Forces Institute of Pathology (AFIP) and diagnosed as palmar or plantar fibromatosis over a 28.5-year period.

MATERIALS AND METHODS

Archival material, accessioned to the AFIP between January 1970 and July 1998, was the sole source of cases for this study. Computer printouts were obtained for all tumors of the hands and feet coded as palmar fibromatosis, Dupuytren's disease (or contracture), plantar fibromatosis, aggressive fibromatosis, juvenile (including congenital and infantile) fibromatosis, desmoid tumor, and fibromatosis, not otherwise specified. All tumors from this group with available histopathologic material that occurred in individuals ≤20 years of age were reviewed. All tumors coded as a fibromatosis, not otherwise specified, regardless of age, were also reviewed, and a wide sampling of cases coded as palmar or plantar fibromatosis from individuals over the age of 20 years was examined for comparative purposes and to assure uniformity of diagnosis. The cases previously coded as a juvenile (including congenital and infantile) fibromatosis were screened

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separately as part of an earlier study.[20] As a result, the present glass slide review consisted of approximately 340 cases.

By design, the primary focus of this study was the evaluation of palmar and plantar fibromatoses in children and preadolescents, defined as individuals 12 years of age and younger. Therefore, a detailed histopathologic analysis is only provided for these individuals (n = 56). However, demographic information is presented for comparative purposes for all patients, regardless of age, who received a diagnosed of palmar or plantar fibromatosis (n = 661) at the AFIP over the 28.5-year review period.

All hematoxylin and eosin-stained sections were examined. Mitotic activity was assessed by reporting the number of mitotic figures identified in 25 wide-field high power (40×) fields (Olympus BX40 microscope with WH10X-H/22 eyepieces and a UPlan Apo 40X/0.85 objective; field area: 0.237 mm^2).

Follow-up information was obtained by reviewing submitted medical records and by telephonic or written communication with the patients, their guardians, or their clinicians. When possible, additional family members were also interviewed for evidence of disease.

RESULTS

Clinical Findings

The core study group contained 56 patients who were 12 years of age or younger at the time of their initial surgical procedure (Fig. 1). There were 19 males and 37 females with a male-to-female ratio of approximately 1:2. The mean and median ages for the group were 8.6 and 9 years, respectively. The youngest patient was a 2-year-old. Only 6 patients were ≤5 years of age at first resection. The initial surgical specimens were from the right hand (n = 2), right foot (n = 22), left foot (n = 27), and a foot, not further specified (n = 5). One patient with a right foot lesion had concurrent disease in the left foot that was not excised. Precise localization was provided for 27 tumor nodules from 26 patients, all with plantar disease: 22 lesions were medially located, in the region of arch; 3 lesions was located in the posterior portion of the foot near the heel; 1 tumor nodule was laterally located near the fifth metatarsal head; and 1 lesion was situated at the base of the toes between the first and second digits.

FIGURE 1. Palmar-plantar fibromatosis in children and preadolescents: age and sex distribution for 56 patients.

The preoperative duration of the initial tumor nodules ranged from 1 month to 6 years (median, 5 months). The lesions were described as painful in 5 cases, painless in 7 cases, and asymptomatic except with pressure or prolonged weight bearing in 15 cases. Seven patients with plantar fibromatosis reported antecedent trauma that occurred a few weeks to 5 years before surgical removal of their foot mass. In 6 instances, the trauma was piercing (eg, 2 patients stepped on a nail), lacerating, or iatrogenic (1 patient had surgical removal of a histologically confirmed myxoid liposarcoma involving the same foot, 6 months earlier). The type of trauma in 1 case was not stated.

Additional clinical information was available for 26 patients from our study group, and 16 individuals had noteworthy findings (Fig. 2). One patient presented with bilateral plantar disease, reportedly present since birth. Four patients, who initially presented with unilateral plantar disease, subsequently developed plantar fibromatosis in the opposite foot (n = 3) and/or palmar fibromatosis in the right or left hand (n = 2). One of the four also has fifth finger clinodactyly (also present in other relatives), a "geographic" tongue (also present in 1 daughter), unerupted maxillary and mandibular incisors, a hypertrophic scar versus keloid (associated with surgery for carpal tunnel syndrome), and a history of "inflammatory bowel disease" (also present in other relatives), and another patient in this group has a history of seizures, bilateral knuckle pads (requiring surgical correction), mandibular bone spurs, and a "birthmark" overlying the hip. Two additional patients reported a possible, but less conclusive, history for the development of palmar fibromatosis. Both of these had a transient palmar mass below the left ring finger that, in one instance, regressed during pregnancy. One of these individuals also has bilateral knuckle pads, a history of seizures, a keloid, "curvature" of the spine, and possible (though not conclusively established) fifth finger clinodactyly. Nine patients, who presented with unilateral plantar fibromatosis and did not develop the disease in the opposite foot or the palms, have other clinical findings: 1 patient has bilateral knuckle pads; 1 has a probable knuckle pad on the right ring finger only; 2 have a history positive for keloids only; 1 has a history positive for seizures only; 1 has multiple café-au-lait spots on her buttocks; 1 had a previous myxoid liposarcoma involving the same extremity; 1 has a keloid, fifth finger clinodactyly (also present in other relatives), a bifid uvula, "curvature" of the spine, and a past history of a pilomatricoma removed from her left arm; and 1 has extreme joint hyperflexibility (Elhers-Danlos-like), fifth finger clinodactyly, scoliosis, a choroid plexus cyst, a history of seizures, and a positive family history (involving the paternal grandmother) of "rheumatoid arthritis" and a ruptured thoracic aortic aneurysm.

An abbreviated family history was obtained for 25 patients. Eleven patients have a child, sibling, parent, grandparent, or niece with palmar and/or plantar fibromatosis. Two of these have a sibling, half sibling, and/or grandparent with a history of seizures. One has a son with a keloid and fifth finger clinodactyly; a father with clinodactyly and curvature of the back; and a brother with clinodactyly. Another has 1 daughter with fifth finger clinodactyly; 1 daughter with clinodactyly, hypopigmented skin patches, a keloid, a

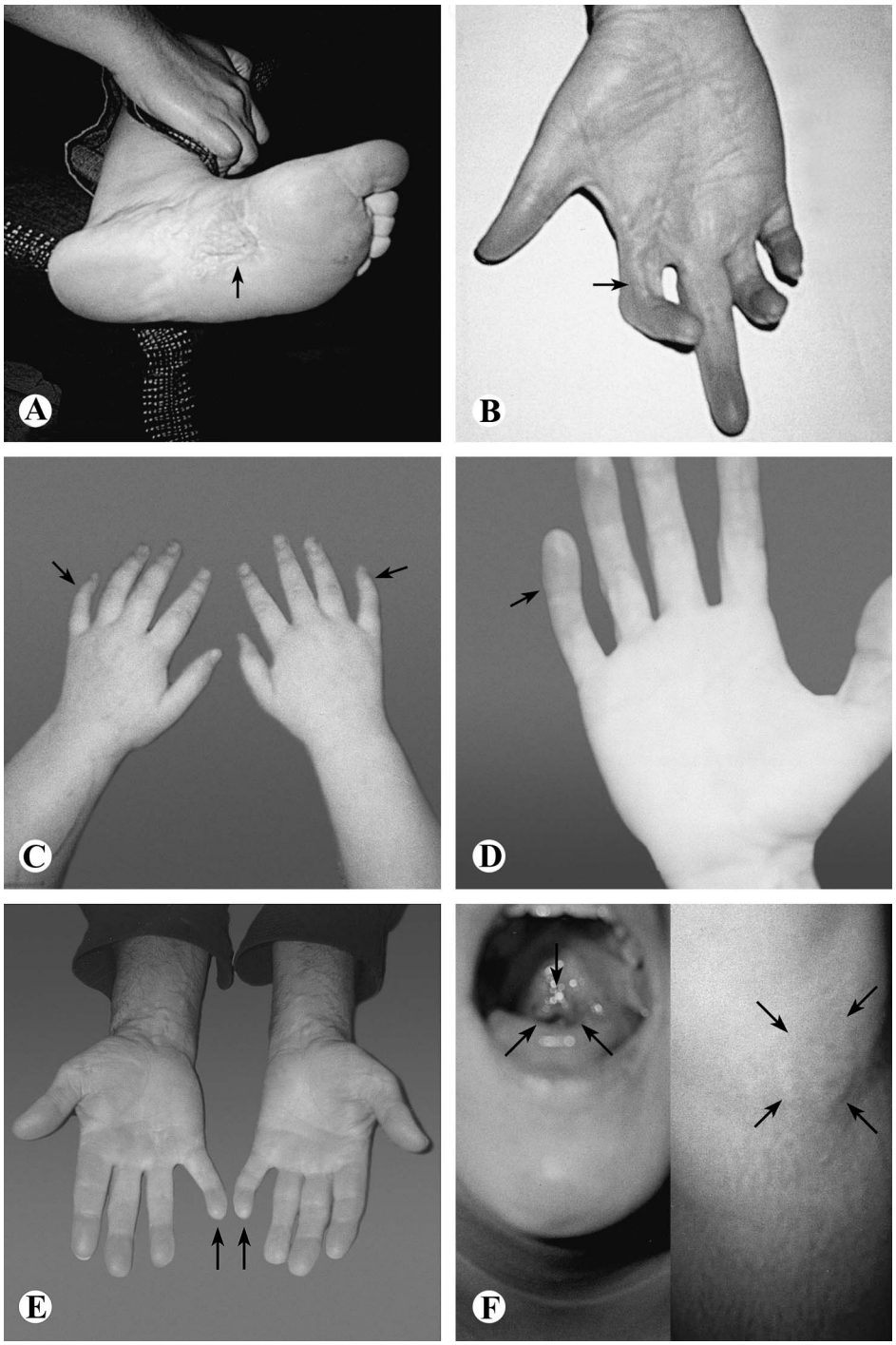

FIGURE 2. A–F, Clinical findings associated with palmar-plantar fibromatosis. Note the plantar scar in the region of the arch of this adult patient who presented with disease at the age of 6 years (A). The same patient now has knuckle pads and active palmar disease [note finger contractures and the presence of a ''fibrous cord'' (arrow)] (B). Fifth finger clinodactyly in 3 individuals: a child of a patient (now an adult) with a positive family history for clinodactyly (best illustrated in the right hand) (C); a patient (also now an adult) who has Elhers-Danlos-like findings (D); and the father (E) of the patient illustrated in figure (F) who has other findings that include a bifid uvula and a lower extremity keloid.

"geographic" tongue, and "inflammatory bowel disease"; and a mother with equivocal clinodactyly, a hypertrophic scar versus keloid, and "inflammatory bowel disease". Two additional patients have a possible, though less conclusive, family history for plantar fibromatosis in a parent or grandparent, and 2 patients have no known family history for palmar or plantar fibromatosis, but they do have a positive family history for disorders linked to this disease: 1 has a mother with "idiopathic seizures" that began at the age of 19 years, and another has a mother and brother with keloids. Ten patients have no family history of palmar-plantar fibromatosis or other conditions that may be part of the disease complex.

Preoperative clinical impressions for the patient cohort included plantar fibromatosis, palmar fibromatosis (Dupuytren's disease), a foreign body, ganglion cyst, fibroma, neurofibroma, scar, synovial or tenosynovial hyperplasia, and a mass, not otherwise specified. All patients were initially managed by local excision.

The differential diagnosis provided by the contributing pathologists included reactive changes (including scar tissue and nonspecific fibrosis), nodular fasciitis, juvenile or infantile fibromatosis, desmoid-type fibromatosis, plantar fibromatosis (sometimes with the notation "cellular" or "aggressive"), calcifying aponeurotic fibroma, neurofibroma, and schwannoma. For one tumor recurrence, a diagnosis of well-differentiated fibrosarcoma was also considered.

Gross and Microscopic Findings

A partial or complete gross description was available for 37 initial and 26 reexcision specimens. Most of the initial specimens consisted of a single piece of irregular, rubbery to firm, tissue with an off-white color. However, a few specimens contained multiple tissue fragments. The initial resection specimens range from 0.6 to 8.0 cm in greatest dimension. Four of these were <1 cm in size, 24 were 1 to 2 cm in size, and 9 were >2 cm in greatest or aggregate dimension. Reexcision specimens were typically larger than the initial surgical specimens, and they more often contained multiple tissue fragments. The reexcision specimens ranged from 0.9 to 10 cm in greatest dimension. Only 3 of these specimens were <2 cm in size, and 17 were ≥ 4 cm in at least one dimension.

Microscopic examination was performed on 79 specimens, including 48 initial tumor specimens and 31 tumor recurrences. By low-power microscopic examination, all tumors had an infiltrative growth pattern and involved dense regular connective tissue, consistent with aponeurosis (Figs. 3, 4). The tumors consisted of a proliferation of spindled (myo)fibroblastic cells with a tendency to form short intersecting fascicles (Figs. 4, 5). The spindled cells often had amphophilic cytoplasm and an "activated" nucleus with an "open" or finely granular chromatin pattern and a small, central nucleolus. Nuclear atypia was typically mild, but it was slightly more pronounced is some instances (Fig. 6A, B). Many of the plantar lesions formed distinctive nodules with a small central "umbilicated" area with normocellular aponeurosis. This feature was not seen in the 2 cases of palmar fibromatosis in this study and is less commonly encountered in the hands, in general (personal observation based on reviewed cases of palmar fibromatosis in adults).

All tumors had notably increased cellularity as compared with normal aponeurosis, and none were regressive or end-stage lesions. Mitotic counts for the 48 primary tumors ranged from 0 to 15 mitotic figures per 25 wide-field high power fields (WHPFs) (Fig. 6C). The mean and median mitotic counts were 2.5 and 1 mitotic figure(s) per 25 WHPFs, respectively. Thirteen tumors (27%) had no identifiable mitotic figures, and 3 had ≥ 10 mitotic figures per 25 WHPFs. The mitotic counts for the 31 recurrent tumors ranged from 0 to 31 mitotic figures per 25 WHPFs. The mean and median mitotic counts for this group were 4.9 and 3 mitotic figures per 25

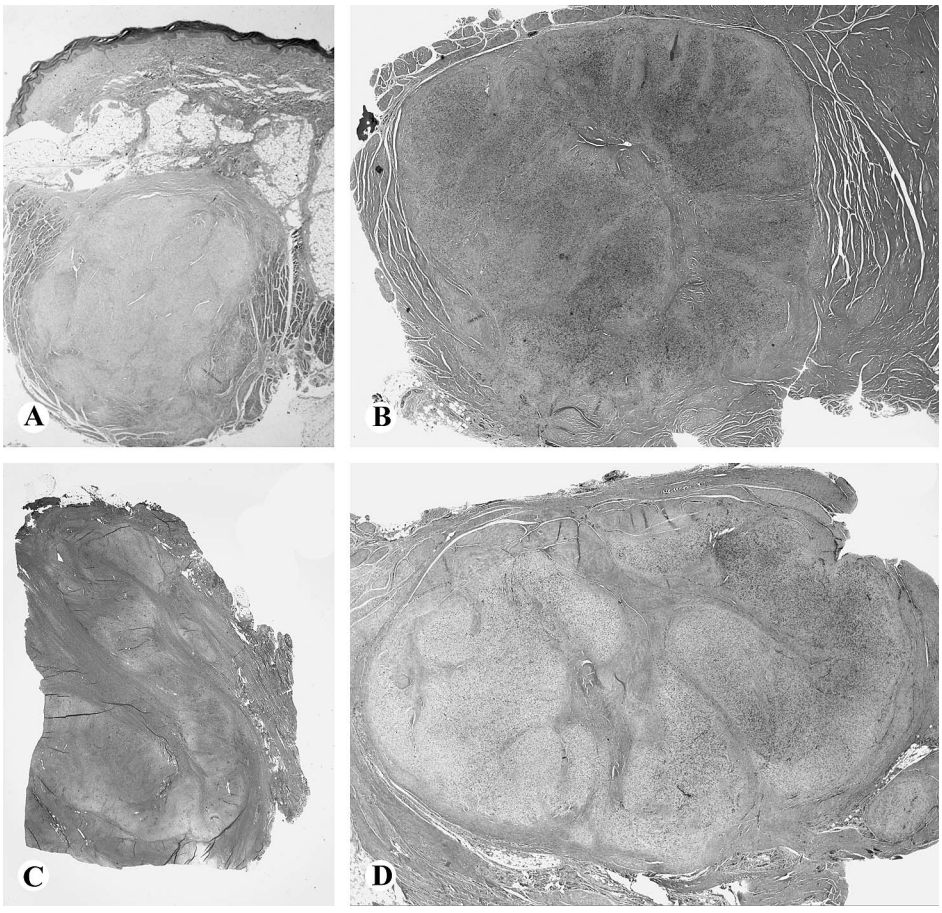

FIGURE 3. A–D, Plantar fibromatosis involving aponeurosis (4 different pediatric cases). Note a tendency for the process to form a nodular mass with a paucicellular center.

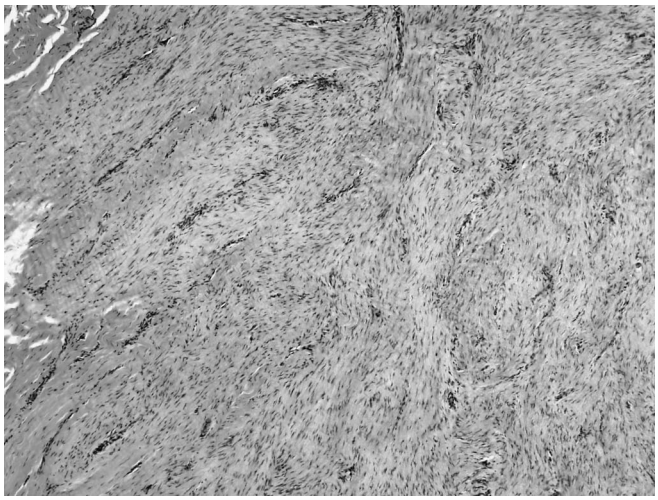

FIGURE 4. Palmar fibromatosis involving aponeurosis from a 12-year-old boy.

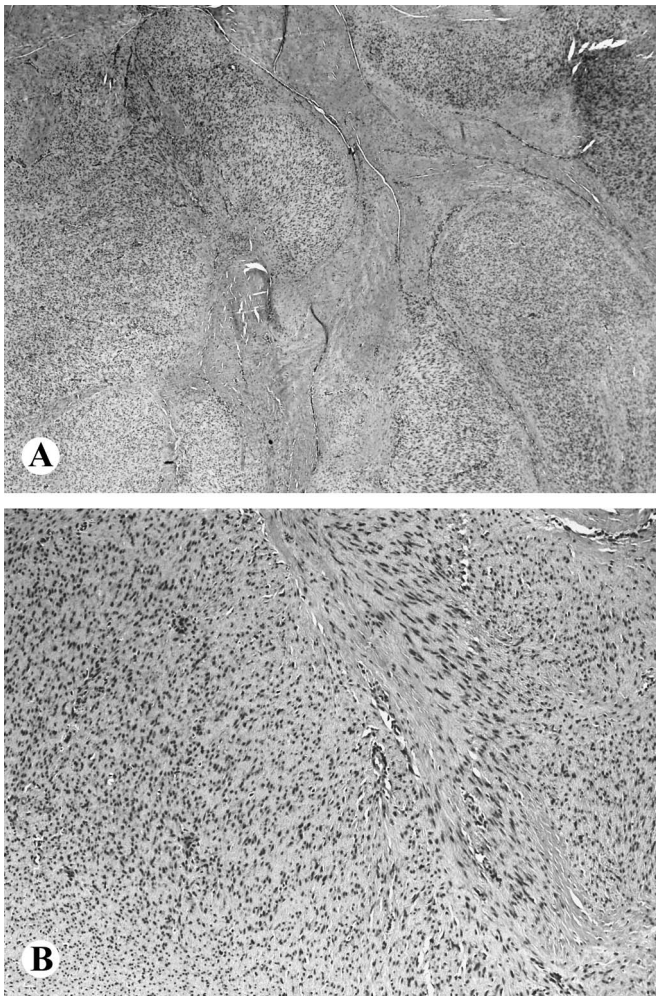

FIGURE 5. Intermediate-power views of plantar fibromatosis demonstrating central paucicellularity (A) and fascicular growth (B).

WHPFs, respectively. Only 4 (13%) of the recurrent tumors lacked identifiable mitotic figures, whereas 5 had ≥10 mitotic figures per 25 WHPFs. None of the 79 tumor specimens had mitotic figures that were morphologically abnormal.

Multinucleated stromal cells were identified in 44 of 48 primary tumors and all 31 recurrent tumors (Fig. 7). These cells were generally rare to infrequent, but in 13 tumors (6 primary and 7 recurrent tumors) they were more abundant. On average, they were somewhat more common in the recurrent tumor group. The multinucleated cells had varying morphology. Most often, nuclei were cluster or "clumped" together in a random pattern, but sometimes they were present in a linear, semicircular, or wreath-like arrangement.

Necrosis was a very rare finding in our cases. Ischemic-type necrosis was a focal finding in only 2 primary tumors, both from the feet. Necrosis was not identified in any recurrent tumor.

Only 3 of the 48 initial surgical specimens contained skin (both epidermis and dermis) as part of the resection specimen, and 7 contained a small amount of underlying skeletal muscle. In contrast, 12 of 31 recurrent tumor specimens contained some skin and 14 contained some skeletal muscle. Only two tumors clearly extended beyond the boundaries of the aponeurotic layer. One of these was a primary tumor of the hand that focally infiltrated fat and entrapped some overlying skin adnexal glands. The other was a recurrent tumor of the foot that focally infiltrated fat and underlying skeletal muscle. Only one specimen in the entire series had inked margins. Tumor extended to the tissue edge in 45 of the 48 primary tumors and 23 of the 31 tumor recurrences. Ten specimens had negative margins and one specimen (a tumor recurrence) had margins indeterminate for involvement.

Additional microscopic findings included the presence of suture granulomas (n = 6), traumatic neuromas (n = 6), and scar tissue in recurrent tumor specimens. A myxoid liposarcoma, removed from the right foot of an 8-year-old girl who developed a plantar fibromatosis of the same foot approximately 6 months later, was reviewed, and the diagnosis was confirmed.

Follow-Up Information

Clinical follow-up, ranging from 4 months to 33 years (mean and median follow-up intervals, 14 years 9 months and 16 years 1 month, respectively), was available for 38 patients (68% of the study group). Thirty-two patients had one (n = 16) or more (n = 16) local recurrence of their fibromatosis. The interval to first reexcision for a recurrence ranged for 1.5 months to 10 years. While the majority of patients (n = 19) had their second procedure within 12 months of initial surgery, 6 patients did not have a reexcision until 3 or more years after first intervention. The maximum number of local recurrences was 9. Currently, 17 patients with follow-up information are free of palmar-plantar fibromatosis, and 5 patients are alive with recurrent disease at the site of presentation (in all instances, a foot). One of the latter now has involvement of both feet, and one has involvement of both feet and her left palm. Additionally, one patient, who has no residual or recurrent disease at the site of presentation, now has palmar fibromatosis. Unfortunately, the current disease status for 15 patients with

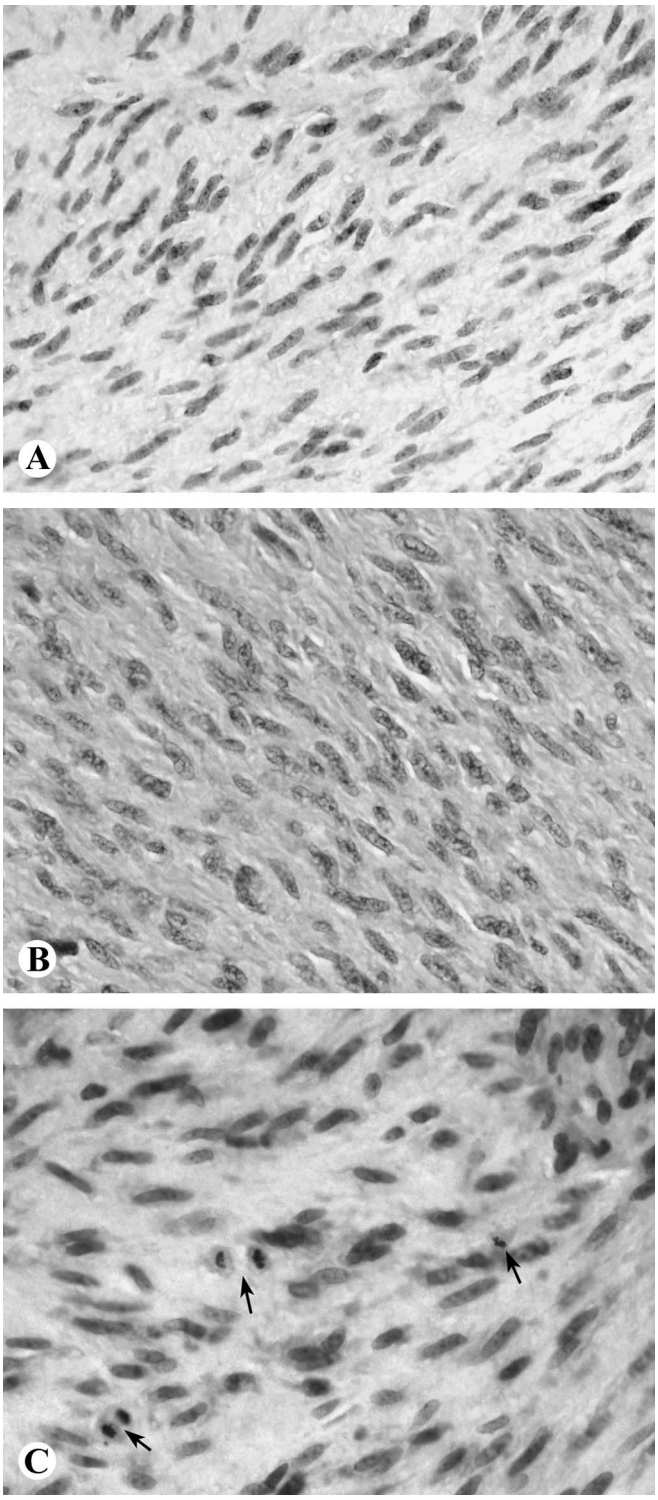

FIGURE 6. High-power views of plantar fibromatosis. Note some variation in the degree of atypia (A vs. B), and the presence of 3 mitotic figures within one small area of a tumor (C).

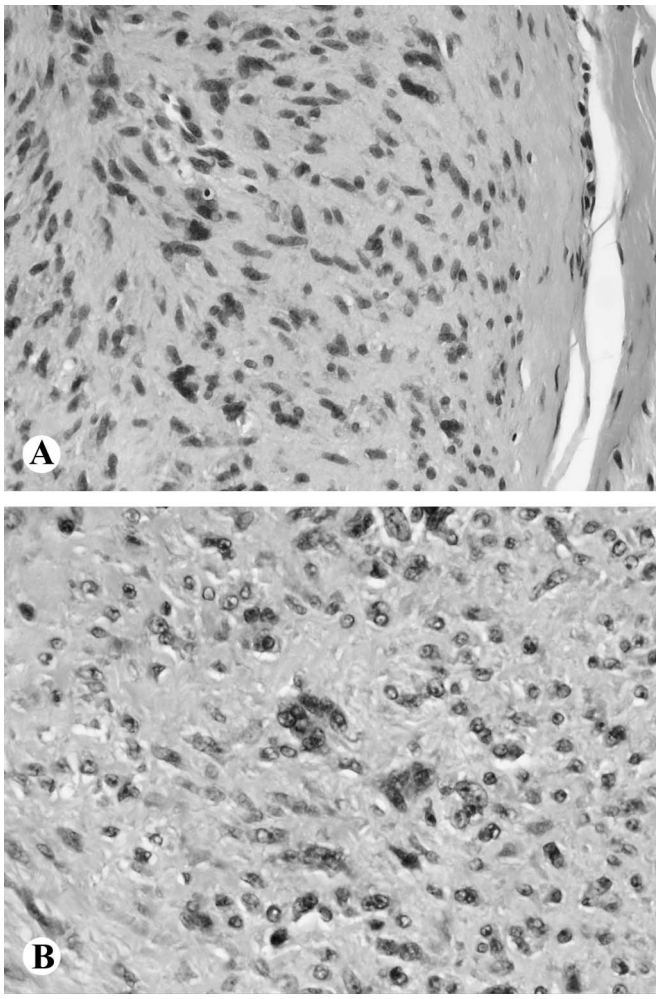

FIGURE 7. A and B, Intermediate- and high-power views of plantar fibromatosis demonstrating multinucleated lesional cells with varying morphology.

follow-up information is unknown because the follow-up was incomplete (range, 4 months to 10 years; mean, 3 years 1 month; median, 1 year 2 months). All 15 patients were last seen shortly after having a recurrence excised.

DISCUSSION

Palmar and plantar fibromatoses are well-recognized, closely related entities that arise within, and commonly remain confined to, the aponeurosis of the hands and feet, respectively. As such, they are sometimes designated "superficial fibromatoses." These two entities, as a group, represent the most common type of fibromatosis. Both processes may occur in the same patient,[3,18,19,23,40,44,50,56,58,62] both may be bilateral,[3,6,18,22,39,40,42,45,50,56,58,62,73] and both may be associated with other clinical findings, including knuckle pads overlying the extensor surfaces of the finger joints,[3,18,30,40,53,61] Peyronie's disease of the penis,[3,11,19,37,40,48] epilepsy,[3,18,28,38,40,43,50,57,61] and possibly, an increased propensity for keloids[3,24,37,50,64] and other less well-characterized

fibrogenic lesions.[3,36,40,66] Palmar and plantar fibromatoses have a documented genetic predisposition (many, if not most, pedigrees appear to follow an autosomal dominant pattern of inheritance with age-related and incomplete penetrance),[11,38,39,48,57,61] and both are reported to occur with greater frequency in patients with a history of chronic alcohol abuse[10,28,38,57] and diabetes.[5,57]

Palmar and plantar fibromatoses are most commonly encountered in individuals of northern European ancestry,[11,57] and the frequency of both processes increases with advancing age.[18,28,57,73] The prevalence of palmar fibromatosis is reported to increase sharply in the fifth decade for males and in the sixth decade for females,[26,38,45,57] with substantially more males affected than females in mid adult life but a nearly 1:1 ratio for males and females by the eight and ninth decades.[18,28,57] Plantar fibromatosis has been less frequently documented in the literature, so demographic information is less complete for this process. This may, in part, be due to the fact that plantar involvement rarely produces a contracture and often has limited symptoms,[36] so it is less frequently brought to the attention of physicians and is often overlooked on routine physical examination.[44] By most accounts, plantar fibromatosis has a somewhat younger onset than palmar fibromatosis,[2,3,50,66] and it is generally believed to affect males and females with similar frequency.[6,36,44,66]

Palmar fibromatosis most commonly involves the ulnar aspect of the palm with greatest effect on the fourth and fifth fingers.[39,45,53,66] In contrast, plantar fibromatosis typically affects the medial plantar arch from the region of the navicular bone to the base of the first metatarsal.[3,6,36,44,66] Both processes progress from a *proliferative* nodular phase with mitotic activity and minimal collagen deposition to an *involutional* stage with substantially decreased proliferative activity, increased myofibroblastic differentiation, and increased collagen deposition to an *end* (resting or residual) stage with abundant collagen and minimal cellularity.[39,44,55,66] In the case of palmar fibromatosis, it is during the involutional stage, with diminution of the nodule and emergence of a fibrous band, that a contracture forms.[39,53] However, not all palmar lesions have contractures of the fingers as their end result, and as stated earlier, contractures are a rare complication for plantar fibromatosis. The rate of disease progression is highly variable, and the likelihood of a contracture is strongly influenced by the proximity of the proliferative nodule to a digit.[26,39,42]

The current series represents the largest collection of histologically confirmed palmar and plantar fibromatoses diagnosed in children and preadolescents. Our study group contained 19 males and 37 females, ranging from 2 to 12 years of age (median age, 9 years). It is notable that most of lesions occurred on the feet, there being only two examples of palmar fibromatosis in our study group. Also, the process is very uncommon before the age of 5 years, and at least for plantar lesions, there appears to be a female predominance throughout much of childhood. Although it is difficult to retrieve specific pediatric data from many of the published surgical and population-based series on palmar and plantar fibromatosis, a predilection for plantar surfaces in childhood is supported by the literature. We are unaware of any other reports showing such a compelling female predilection for pediatric plantar fibromatosis, but we did identify one much smaller series with a slight female predominance.[2] The reason for this sex predilection is unclear, but hormonal or other factors may come into play. It is noteworthy that the Dupuytren diathesis, in general (and palmar fibromatosis, in particular) is expressed to a greater degree in males than females from early adulthood until approximately the sixth decade of life, when the incidence in females is on the rise (roughly coinciding with menopause).

Our study reaffirms the well-established association between palmar fibromatosis, plantar fibromatosis, knuckle pads, and a seizure disorder, and it strengthens the much less frequently reported association between palmar-plantar fibromatosis and keloids. Keloids were reported to be present in 4 (possibly 5) of our patients with follow-up information, and 2 of these individuals have other relatives also prone to keloid formation. To our knowledge, we are the first to report an apparent association between palmar-plantar fibromatosis and fifth finger clinodactyly. This finding was present in 3 of 23 patients (13%) in which this specific question was addressed, and it may be present in at least 1 other. Two individuals with clinodactyly also have other relatives with this finding. Other interesting observations noted in our study group included 3 patients with "curvature" of the spine, 1 patient with a bifid uvula, 1 patient with a "geographic" tongue and inflammatory bowel disease, and 1 patient with some Elhers-Danlos-like findings and a positive family history for thoracic aortic rupture.

For comparative purposes, we tabulated clinical data for 661 patients with histologically confirmed palmar or plantar fibromatosis diagnosed at the AFIP over a 28.5-year period (Fig. 8). The data are segregated by sex and presented in two formats: tables labeled (A) include all patients and tables labeled (B) contain civilian patients only. Neither set of tables is completely free of gender bias, but the latter eliminates skewing toward the male sex, introduced by the inclusion of military personnel and the veteran population. Also, it should be pointed out that our sample population deviates in several respects from that generally reported in the literature. First, because the AFIP is a well-known consultative referral center, there is a greater tendency for cellular (and mitotically active), recurrent, or unusually large tumors to be submitted for review because of concern on the part of the contributor about biologic potential. Second, given the relatively high percentage of pediatric cases (8.5%) in our series, there is probably also some minor skewing of the data toward childhood, as the disease is largely unexpected in this age group. Finally, in clinical practice, one typically encounters many more cases of palmar fibromatosis than plantar fibromatosis, yet our files have a palmar to plantar fibromatosis ratio of about 1:3. This phenomenon has been reported in other pathology-based series and likely reflects the facts that: 1) surgeons often do not submit typical examples of palmar fibromatosis for histologic review[2] and 2) pathologists are generally more comfortable making a diagnosis of palmar fibromatosis than plantar fibromatosis (perhaps because better clinical correlation is provided for the former), and therefore, are less likely to send an example of palmar fibromatosis for second opinion.

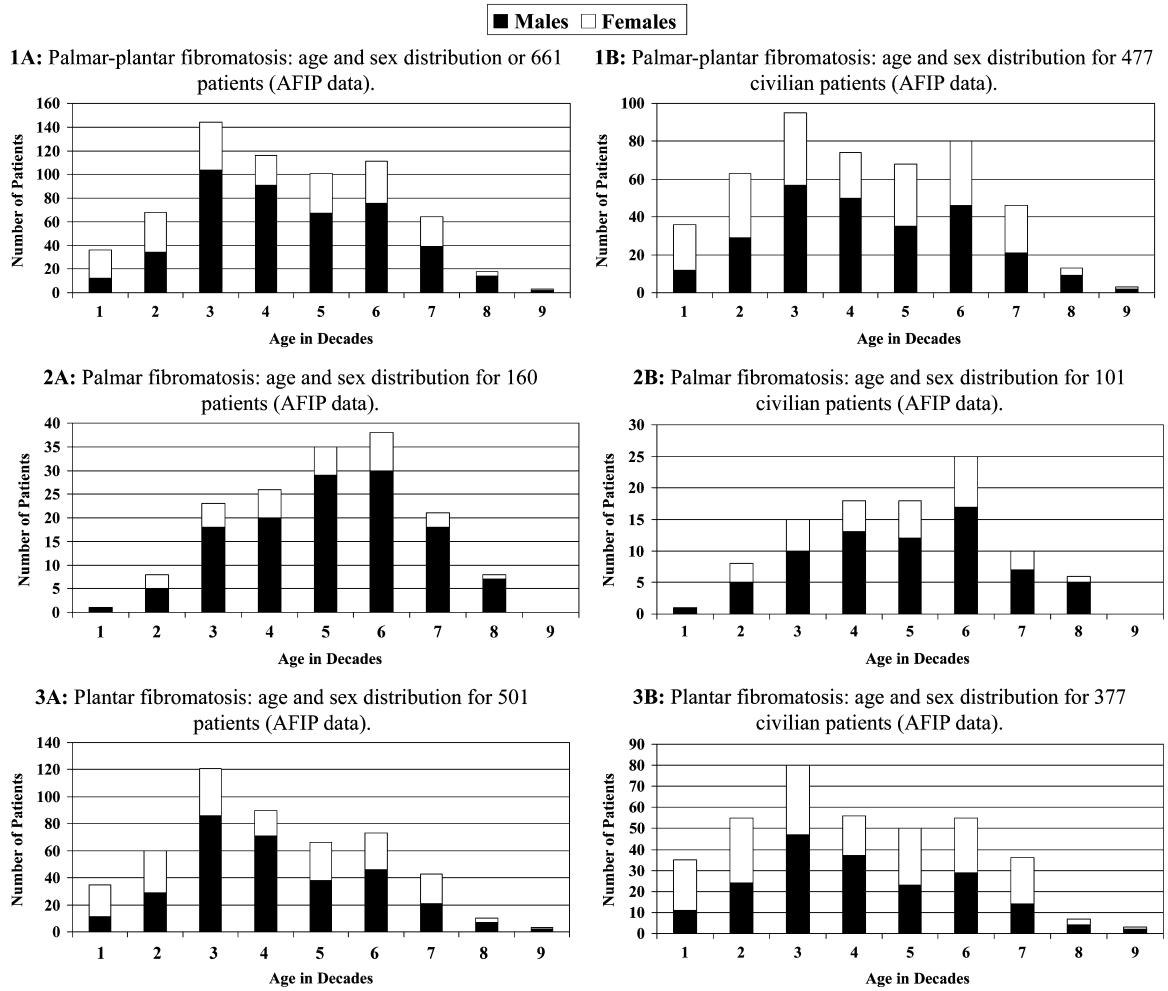

FIGURE 8. Age and sex distribution for 661 patients with palmar or plantar fibromatosis diagnosed at the AFIP over a 28.5-year period. Note that when palmar and plantar fibromatoses are plotted together, a bimodal distribution is obtained. However, when plotted individually, palmar fibromatosis has a peak surgical incidence in the sixth decade, and plantar fibromatosis has a peak surgical incidence in the third decade.

Nevertheless, even with the inherent biases noted above, the age and sex distributions for our adult populations are largely consistent with that previously reported in the literature. AFIP data demonstrate peak surgical incidences for palmar and plantar fibromatoses in the sixth and third decades, respectively. Because these two processes peak at significantly different time intervals, combined data produce a bimodal distribution, as illustrated in graph 1B in Figure 8. We found palmar fibromatosis to be more common in males than females in essentially all decades, whereas plantar fibromatosis was more common in females in the first two decades, more common in males in the third and fourth decades, and relatively equally distributed thereafter.

Palmar and plantar fibromatoses are notably uncommon in children and predolescents, to the point that many clinicians and pathologists are reluctant to make either diagnosis in this age group. Compounded on this is the fact that pediatric examples, as demonstrated in our series, are typically both cellular and mitotically active, and tumors with this level of proliferative activity have sometimes been mistakenly diagnosed as sarcomas.[3,6,13,44,50,66]

Eight of our plantar cases had ≥10 mitotic figures in 25 WHPFs, and the maximum mitotic count obtained was 31 mitotic figures in 25 WHPFs. However, it is noteworthy that necrosis was only present in 2 cases, and in both instances, it was of the ischemic type. Also, nuclear atypia was typically mild, and there was minimal pleomorphism. Finally, only two tumors clearly extended beyond the boundaries of the aponeurotic layer, and both of these were epicentered in aponeurosis with secondary extension into either the overlying subcutis or underlying muscle. The one example with skeletal muscle involvement was a recurrent tumor.

The presence of multinucleated giant cells has, until recently,[19,71] been largely overlooked in plantar and palmar fibromatoses, although it is briefly mentioned in several earlier reports.[2,3] We noted the presence of multinucleated cells in 44 of 48 (92%) primary tumor specimens and in all 31 recurrent tumor specimens in our study group. While these cells are

generally uncommon, careful examination almost always uncovers their presence. Sometimes, especially in overstained sections, the multinucleated cells may, at first glance, erroneously lead one to suspect tumor cell pleomorphism, which is very uncommon in this setting.

Although many authors maintain that it is not possible to accurately predict the behavior of individual cases of palmar-plantar fibromatosis, a variety of clinical and histopathologic factors are reported to correlate with a more aggressive outcome. These factors include early disease onset,[25,26,29,30,43,55,70] a strong family history,[4,29,30] the presence of knuckle pads,[29,30] bilateral or coexisting palmar-plantar disease,[4,30] proliferative stage nodules,[39,55,66] a history of epilepsy,[30,43] and alcoholism.[29,30,43] To this list, some authors add the male sex.[43,70] Additionally, the type of surgical intervention (limited vs. wide or radical fascietomy) also strongly influences the recurrence rate.[4,6,36,58]

We documented an 84% recurrence rate and a 42% risk for multiple recurrences among our 38 patients with follow-up information. These figures are very high and greater than one would generally expect for adults with palmar-plantar disease. The figures may be skewed toward recurrence, as a number of cases were specifically submitted for review because of regrowth of a mass. Nevertheless, the fact that 48% of patients we contacted directly had recurrences previously unknown to us fuels some support for the generally held view that the pediatric population has an inherently higher risk for local recurrence (possibly because they have actively growing, proliferative stage lesions). However, interpretation is complicated due to a strong tendency for surgeons to initially undertreat pediatric palmar-plantar disease and to reserve wide or radical plantar fasciectomies for multiply recurrent cases with an established diagnosis. As noted in our results, 45 of 48 primary tumor resections (94%) in our study involved the tissue edge-margin. The failure of many clinicians to correctly consider palmar-plantar fibromatosis in the preoperative differential diagnosis of a palmar-plantar mass in childhood likely contributes to the initial undermanagement of this disease. Familiarity with the tendency for children to present with a mass in the arch of the foot, localization of the process to aponeurosis (evident by a combination of physical examination and imaging studies),[47,49,69,72] and the frequent presence of a positive family history (for palmar or plantar disease) serve as preoperative guidance to the correct diagnosis.

When we compared our patients with multiple extremity palmar-plantar fibromatosis or palmar-plantar disease documented in association with other findings (ie, knuckle pads, keloids, clinodactyly, and/or a history of seizures) with individuals who had localized disease and no other findings, we noted a trend for individuals in the former group to have recurrences more often (92% vs. 70%), to have a greater number of recurrences (58% had between 2 and 9 local recurrences, whereas 40% of patients with no additional clinical findings had 2 recurrences, but none had more than 2 recurrences), and to have a greater likelihood of persistent disease at last follow-up (36% of patients with multiple clinical findings and complete follow-up had persistent disease at the site of presentation and another 18% had active palmar fibromatosis or knuckle pads, whereas only 10% of patients without other clinical findings and complete follow-up had persistent disease at the site of presentation). When we compared our patient groups with and without a positive family history of palmar-plantar fibromatosis, we noted a weak trend for patients in the positive family history group to also have recurrences more often (90% vs. 70%), to have a greater number of recurrences (60% had multiple recurrences vs. 50%), and to have a greater likelihood of active disease at last follow-up (40% vs. 30%).

In the pediatric population, there is a strong tendency for recurrent palmar-plantar fibromatosis to be clinically evident within 12 months of the initial resection. This was the case for at least 62.5% of patients in our series with a documented recurrence, and this figure is likely an underestimate, because for some patients, we have only documentation of the interval to reexcision, not the actual point of recurrence. This observation is consistent with published results for plantar fibromatosis in general, demonstrating a tendency for recurrences to occur within the first 2 years of follow-up.[4] However, there are infrequent instances where recurrent disease, involving the same site, is not clinically detected for $\geq$5 years after initial resection.

Optimal treatment of palmar-plantar fibromatosis is controversial.[4,6,9,26,27,29,31,36,39,42,46,49,50,54,58–60,67] This is because the process is often relatively asymptomatic in the nodular stage, not all nodular lesions progress to contracture, the rate of disease progression is variable,[26,39,45,53] surgical intervention can lead to complications,[4,8,26,27,39,54,58,67] postsurgical recovery can be slow,[54,58,60] there is a strong tendency for local recurrences after surgery (especially when early nodular lesions are removed),[4,6,46,54,67,70] and patients often develop new, independent lesions in other sites with the passage of time. Nonoperative intervention is often considered to be first-line management and is directed at minimizing the risk of contracture.[4] Triamcinolone acetonide injections are reported to have some success in this regard,[35] and collagenase percutaneous fasciotomies have been proposed as an alternate to surgery for contracture correction in selected instances.[31] Radiation therapy has been examined in several studies, but potential complications and long-term risks appear to overshadow perceived benefits in most instances.[15,31,34] Surgery is generally reserved for early contractures overlying the proximal interphalangeal joints of the hands (because a contracture in this location, even when of short duration, is difficult to correct, especially when the little finger is involved), lesions associated with significant disease progression or symptoms that have not responded to nonsurgical intervention, and cases in which the diagnosis remains in question.[4,26,42,43,67] When surgery is contemplated, a wide or radical fasciectomy or dermofascietomy is usually advocated (especially for patients with a strong Dupuytren diathesis) because the risk of recurrence is substantially diminished.[6,36,58,67] However, lesser intervention (eg, a fasciotomy or limited fascietomy) is a reasonable consideration in selected instances.[27,54] Magnetic resonance imaging can aid in preoperative diagnosis, operative planning, and postsurgical follow-up.

The differential diagnosis for palmar and plantar fibromatoses includes cellular fibrous histiocytoma, calcifying aponeurotic fibroma, desmoid-type fibromatosis, monophasic

fibrous synovial sarcoma, and fibrosarcoma. Cellular fibrous histiocytomas are typically dermal-based, stellate-shaped lesions that secondarily involve the subcutis.[12] It is very unlikely that one would encounter a cellular fibrous histiocytoma epicentered in aponeurosis. This lesion commonly has central fascicular growth and focal necrosis, but a peripheral storiform growth pattern is generally maintained and aids in its recognition.

Calcifying (juvenile) aponeurotic fibroma is a rare soft tissue tumor with a strong predilection for the palms, fingers, and soles of pediatric patients, although infrequent examples are encountered in adults and in other anatomic sites.[1,21] This entity features a more permeative growth pattern than palmar or plantar fibromatosis. It contains a spindled (fibromatosis-like) fibroblastic component that commonly involves aponeurosis but typically also infiltrates fat and skeletal muscle. In its early stages, it often contains small foci where epithelioid fibroblasts are arranged in parallel cords, and in later stages, it contains highly distinctive chondroid nodules with peripheral epithelioid fibroblasts, and sometimes, central calcification. The process has a high local recurrence rate, but it usually does not cause significant morbidity. Calcifying aponeurotic fibroma is separate and distinct from palmar-plantar fibromatosis, and it is not, as some authors have suggested,[3,58] a subtype or variant of the latter.

Desmoid-type fibromatosis only rarely involves the hands or feet. In a review of 367 examples from the AFIP files, $<2\%$ occurred in these locations,[68] and in our experience, at least with regard to the feet, it more commonly affects the dorsal regions (personal observation, J.F.F.). It is a more permeative process than palmar-plantar fibromatosis, and it would be highly unusual for this entity to be confined to aponeurosis.

Monophasic fibrous synovial sarcoma can present as a relatively small mass in the hands or feet, but it typically arises deep to the aponeurosis, and by imaging, it often has stippled calcifications or necrosis. From a histologic standpoint, monophasic fibrous synovial sarcomas may be highly cellular and mitotically active, or they may be only moderately cellular with scant mitotic activity and notable amounts of collagen. Clues to the diagnosis include the presence of scattered epithelioid tumor cells admixed with relatively small, slender, fibroblast-like cells, stromal microcalcifications, and the presence of a hemangiopericytoma-like vascular pattern. Once the diagnosis is suspected, it can be confirmed with immunohistochemistry for keratins and epithelial membrane antigen and by RT-PCR for *SYT-SSX* fusion transcripts.[7,14,17,33]

In the past, cellular (proliferative stage) palmar and plantar fibromatoses have occasionally been misinterpreted as fibrosarcomas.[3,6,13,36,44,50] In actual fact, fibrosarcomas are extremely uncommon in the hands and feet, so much so, that a healthy degree of skepticism is warranted whenever this diagnosis is suggested. Many tumors previously viewed as fibrosarcomas in these locations are now known to be other tumor types (eg, monophasic fibrous synovial sarcoma, malignant peripheral nerve sheath tumor, or dermatofibrosarcoma protuberans with fibrosarcomatous transformation). Conventional fibrosarcomas (arising outside of the setting of dermatofibrosarcoma protuberans) are typically deep-seated tumors with infiltrative growth. These neoplasms features well-developed fascicular or herringbone growth patterns, they have more cytologic atypia than palmar-plantar fibromatosis, and they frequently contain necrosis.

In summary, we have reported the largest series of histologically confirmed palmar and plantar fibromatoses in children and preadolescents. While plantar fibromatosis is very uncommon, palmar fibromatosis is extremely rare in this age group. In our study, plantar fibromatosis occurred with increased frequency after the age of 5 years, and it occurred more commonly in females than males by a margin of approximately 2:1. We documented a very high local recurrence rate and the frequent presence of multiple recurrences. The strong tendency for recurrences in this age group is likely linked to several factors, including failure to consider palmar-plantar fibromatosis in the preoperative differential diagnosis, a tendency for more limited surgical intervention in pediatric patients, a strong Dupuytren diathesis in some individuals, and the fact that the lesions are typically cellular, actively growing nodules that may inherently possess greater recurrent potential than involutional or end-stage lesions. Many pediatric patients have a positive family history, both for palmar-plantar fibromatosis and for other disorders linked to this disease. The coexistence of palmar fibromatosis, plantar fibromatosis, knuckle pads, idiopathic epilepsy, keloids, fifth finger clinodactyly, and other findings suggests that, at least in some patients, palmar-plantar fibromatosis represents part of a disease complex.

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