A 10-year Review of Surgical Management of Dermatofibrosarcoma Protuberans

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What's already known about this topic?

- Surgical management of dermatofibrosarcoma protuberans (DFSP) includes wide local excision with or without margin control.
- Although Mohs micrographic surgery (MMS), or similar margin-controlled excision is advocated in the UK, this appears to be based on consensus guidance and low-quality data, with few centres routinely providing this expertise.

What does this study add?

- This is the largest case series of DFSP reported from the UK to date with three quarters of the 483 primary DFSP treated between 2004 and 2014 being managed with wide local excision (WLE).
- 6 local recurrences were found in the WLE group and 0 in the MMS group.
- In individuals with primary DFSP who underwent WLE, complete histological clearance occurred less frequently at the first attempt (81.4%) compared to those who were treated with MMS (86.6%).

Abstract

Background: Dermatofibrosarcoma protuberans (DFSP) is a rare skin cancer. Standard treatment in the United Kingdom (UK) is either surgical wide local excision (WLE) or Mohs micrographic surgery (MMS). It is unclear which approach has the lower recurrence rate.

Objectives: We undertook a retrospective comparative review of DFSP surgical management in the UK National Health Service (NHS) in order to define:

1) current surgical practice for primary and recurrent DFSP
2) local recurrence rates for primary DFSP
3) survival outcomes for DFSP.

Methods: Retrospective clinical case-note review of patients with histologically-confirmed DFSP (January 2004–2014) who have undergone surgical treatment.

Results: Surgical management of 483 primary and 64 recurrent DFSP in 11 plastic surgery and 15 dermatology departments was analysed. Almost 75% of primary DFSP (n=362) were treated with WLE and 20.1% (n=97) with MMS. For recurrent DFSP, 68.7% (n=44) and 23.4% (n=15) underwent WLE and MMS, respectively. Recurrent primary DFSP occurred in 6 patients after WLE and none after MMS. Median follow-up was 4.8 years [IQR 3.5, 5.8] with 8 reported deaths during the follow-up analysis period; one confirmed to be DFSP-related.

Conclusions: WLE was the commonest surgical modality used to treat DFSP across the UK. The local recurrence rate was very low, occurring only after WLE. Although a prospective RCT may provide more definitive outcomes, in the absence of a clearly superior surgical modality, treatment decisions should be based on patient preference, clinical expertise and cost.

Introduction:

Dermatofibrosarcoma protuberans (DFSP) is a rare slow-growing cutaneous sarcoma. Reported annual incidence from large epidemiological studies in the USA and Denmark is 4-5 cases per million population per year[1,2,3]. In England incidence is 2.6 per million[4], likely an underestimate because non-melanoma skin cancers are under-reported[5].

Surgical excision is the only recognised curative treatment for primary DFSP. However, after excision with apparently uninvolved histological margins, local recurrence within or adjacent to the primary site can occur. This is believed to be due to its infiltrative growth pattern and sampling error from standard histological processing,[6] for which the specimen margin evaluated can range from 0.5%[7] to 2%[8]. The amount of tissue visualized depends on the number of sections read. Surgical techniques utilising margin control such as Mohs micrographic surgery (MMS) may reduce the risk of sampling error.

Evidence regarding surgical management of DFSP comprises small case-series that do not enable clinicians or patients to make informed treatment decisions: there are no randomised studies, and little long-term follow-up data. Conventional treatment is wide local excision (WLE) with 1 cm to 5 cm surgical margins of clinically uninvolved skin. The deep margin is defined anatomically and is normally at least to deep fascia. Reported recurrence rates after WLE range from 0 to 60%.[9-16,20,21] MMS limits excision to histologically involved tissue and an undefined surgical margin of uninvolved tissue peripherally and deeply – the size of this is not standardised for DFSP and depends on individual operators. MMS is reported to achieve recurrence rates of 0% to 8.3%.[9,15,17-25] However, these data are based on retrospective and/or non-comparative studies that are heterogeneous in design and subject to bias.[28] The British Society for Dermatological Surgery (BSDS) and European consensus guidelines state that MMS is the preferred treatment for DFSP.[28,29] Two systematic reviews[30,31] suggest that MMS or similar margin control techniques may be associated with lower recurrence rates but found no comparative data confirming that MMS conserves disease-free tissue.[30]

Because of this uncertainty, we have reviewed UK NHS data relating to the surgical management of primary and locally recurrent DFSP over a 10-year period.

Methods

Study Design

A retrospective clinical case-note review of histologically confirmed DFSP between January 1st 2004 and December 31st 2013 was undertaken. UK clinicians were invited to participate via the UK Dermatology Clinical Trials Network (UK DCTN), British Association of Dermatologists (BAD) and the Reconstructive Surgical Trials Network (RSTN). Data were collected locally at individual Trusts by the team of DFSP collaborators. Approval was obtained from NHS Trust Research & Development departments. Clinicopathologic data included: demographic data, clinical history of lesion, tumour site, surgical/ therapeutic/ histopathologic details, post-operative events and available follow-up information (Supplementary Appendix 1). Cases treated with MMS included use of both frozen and paraffin embedded tissue sections. Data were anonymised. Patients who had surgery and any adjuvant or neoadjuvant treatment (chemotherapy or radiotherapy) were included in the overall patient cohort, but excluded from analysis of the surgical outcomes as additional treatment would have had a confounding effect. The statistical analysis protocol was published on the Centre of Evidence Based Dermatology website prior to data analysis, (https://www.nottingham.ac.uk/research/groups/cebd/documents/methodological-resources/dfsp-protocol-final-2017.pdf).

As this was a retrospective study, data on cosmesis, function, patient reported outcome measures (PROMS) were not collected as this information was not systematically recorded in clinical case notes. However, to evaluate the patient perspective, an anonymous survey (Survey Monkey™) was sent to patients with prior history of DFSP via the DFSP Facebook page / www.thedfspnetwork.org [Supplementary Appendix 5].

Outcomes:

Primary outcome: Three year local recurrence rate for primary DFSP, following MMS and WLE.

Secondary outcomes:

- Time to first recurrence (date of surgery to date of histologically confirmed local recurrence)
- Histological clearance (histologic clearance following surgery and of post-operative complication rates)

- Time to metastases (calculated from date of surgery to date of confirmed distant metastases)
- Number of surgical procedures required to achieve adequate histological clearance
- Post-operative complication rate
- Distant recurrence-free survival
- Recurrence free survival

Statistical analysis

Age at diagnosis was calculated from date of diagnostic biopsy or - if not provided – date of surgery or multidisciplinary team discussion (whichever was earliest). The last follow-up was taken as last known clinical review or date of death. Follow-up duration was calculated as time from date of surgery to date of last known clinical review. Contributors were individually contacted for additional information regarding incomplete or unclear data in order to maximise completeness of datasets. Analysis queries were clarified following discussion with a second team member (RM). Demographic and clinicopathologic data were reported for MMS and WLE groups. Means (SDs) or medians (IQRs) were used for continuous data and percentages for categorical data. Analyses were conducted separately for primary and recurrent DFSP. Results have been reported descriptively.

Results

Data were collected from 26 centres (11 plastic surgery and 15 dermatology) with representation from England, Scotland, Wales and Northern Ireland (Supplementary Appendix 2). Clinicopathologic data were provided for 603 patients, of which 56 were excluded because of duplication, treatment outside data collection period or unclear histology or surgical details (Supplementary Appendix 3). Those undergoing procedures other than WLE or MMS, and those who had adjuvant chemotherapy or radiotherapy were excluded from analysis of surgical outcomes.

Demographic, tumour and surgical outcome data for primary and recurrent DFSP are presented in Tables 1 and 2 respectively.

Table 1: Demographic data for primary DFSP cases

Table 2: Demographic data for recurrent DFSP cases

Overall, 74.9% (n=362/483) of primary DFSP and 68.7% (n=44/64) of recurrent DFSP patients underwent WLE compared to 20% (n=97/483) and 23.4% (n=15/64) respectively who underwent MMS. Details of tumours with fibrosarcomatous change are detailed in Supplementary Appendix 4.

Primary DFSP cases (n=483)

Primary outcome: Local recurrence rate at 3 years

For primary DFSP, median follow up duration was 25.5months [IQR6.8,45.7]. Median follow up for WLE cases was 26.7 months [IQR 7.8, 48.2] and 14.2 months [IQR 4.6, 35.6] for MMS. Follow up data were missing for 3% (n=11/362) WLE and 6.2% (n=6/97) MMS cases. There were six recurrences over the period of the data collection (Table 3).

Table 3: Clinicopathological data for six cases of recurrence in the Primary DFSP cohort (all cases treated with WLE).

All cases of recurrence followed WLE compared with zero recurrences in the MMS group. Median follow up for the 6 cases was 2 years [IQR 0.57-3.71].

Secondary outcomes:

a) Time to first recurrence

Mean time to first recurrence (n=6) was 37.2 months (range 9 – 76 months).

b) Histological clearance

Histological clearance following WLE was achieved with the first attempt at curative surgery in 81.4% (n=289/355) of patients; 10.1% had involved margins (n=36/355) and 6.8% (n=24/355) were reported as ‘close’. Data were unclear or missing for the remaining 1.7% (n=6/355). For MMS, 86.6% (n=84/97) DFSP were reported as histologically ‘clear’ at the first surgical attempt, 3.1% (n=3/97) had ‘involved’ or ‘close’ margins**.** Data were unclear for 10.3% (n=10/97). In the WLE group, patients were

less likely to have achieved histological clearance at the first attempt compared to those who had MMS.

c) Number of surgical procedures to achieve adequate histological clearance

Median number of diagnostic procedures performed in both WLE (n=355) and MMS (n=97) groups was 1 [IQR 1,1]. Median number of therapeutic procedures in both of these groups was also 1 [IQR 1,1].

Peripheral clinical margins used for WLE procedures were available for 274 (77.2%) procedures. Median clinical margin was 3cm (n=136); range 0.5 – 5cm [Figure 1]. The number of MMS stages was reported in 72.2% (n=70) cases: median number of stages was 2 (average 1.9; range 1-4). Data for MMS margins used in the first layer was available in 36% (n=35): median margin 10mm (mean 13; range 5-50).

Figure 1. Range of WLE clinical margins used for all DFSP

Pre-operative lesion and post-operative defect sizes for all DFSP groups, where available, are highlighted in Table 4.

Table 4: Median pre-operative lesion size and post-operative defect size for all DFSP cases.

Frozen sections were used in 36% (n=35) and slow Mohs in 32% (n=31) cases. The type of MMS sectioning was unknown for 33% (n=32). All cases with fibrosarcomatous change are detailed in Supplementary Appendix 4.

d) Post-operative complications

Data on post-operative complications were available for 88.2% (n=313/355) and 71.2% (n=69/97) of WLE and MMS cases, respectively. Complications were reported following 15.8% (n=56/355) WLE and 9.3% (n=9/97) MMS procedures. Details of complications were missing for 5.4% (n=3/56) of the WLE group in whom a complication was reported. In the WLE group, 16% (n=9/56) reported more than one complication, compared to 11% (n=1/9) in the MMS group. Most common complications following WLE included poor cosmetic outcome (50% of which required

further surgery), graft failure and infection (Table 5). Reported complications following MMS included poor cosmetic outcome and infection.

Table 5. Reported complications following WLE in primary DFSP

e) Distant recurrence-free survival

There were no reported cases of distant disease recurrence or death during follow-up in this group.

f) Recurrence-free survival

There were no further reported loco-regional recurrences in this group.

Recurrent DFSP cases (n=64)

There were no reported locoregional recurrences after further treatment for recurrent DFSP cases in either WLE or MMS group during the data collection period. Median follow-up duration was 19.8 months [IQR 1.2,.44.4]. Median follow-up for WLE cases was30.8months [IQR 10.2,38.1] and 13.8 months [IQR 0.6, 21.1] for MMS cases. Follow up data were missing for 4.5% (n=2/44) of WLE and 6.7% (n=1/15) of MMS cases.

Secondary Outcomes:

a) Time to subsequent recurrence

There were no further recurrences reported among 64 recurrent DFSP cases treated with WLE or MMS.

b) Histological clearance

Complete clearance was achieved for all DFSP cases treated with MMS (n=14).

c) Number of surgical procedures to achieve adequate histological clearance

Median number of diagnostic and independent therapeutic procedures for the recurrent DFSP tumours undergoing WLE (n=40) was 1 [IQR 1,1] and 2 [IQR 2,3], respectively. For the MMS group (n=14) this was also 1 [IQR 1,1] and 2 [IQR 2,3], respectively. The peripheral clinical margin size used for WLE was available for 87.5% (n=35/40) procedures. Median clinical margin was 3cm (n=15; range 1-5 cm) [Figure 1]. The number of MMS stages was reported in 78.6% (n=11/14) cases; the median number was 2 (mean 1.6; range 1-2). Data for margins used for the first MMS layer was only available in 14.4% (n=2); 10 and 15mm. Data on the

pre and post-operative lesion/defect sizes for the two recurrent groups are shown in Table 4.

d) Post-operative complication rate

Data on post-operative complications was available for 87.5% (n=35/40) and 64.3% (n=9/14) of WLE and MMS procedures respectively. Complications occurred in 35% (n=14/40) WLE and 21.4% (n=3/14) MMS patients. Four patients (28.6%) who had a complication following WLE experienced more than one complication, compared to 33.3% (n=1) patient in the MMS group. The most common complications following WLE were infection, functional impairment and poor cosmetic outcome requiring further surgery. In the MMS group complications included infection (managed with a topical antibiotic) and chronic functional pain.

d) Distant recurrence-free survival

There were no reported cases of distant disease recurrence or death during follow up in this group.

e) Recurrence-free survival

There were no further reported locoregional recurrences in this group.

Evaluation of the Patient Perspective

To evaluate the patient perspective, an anonymous survey (Survey Monkey$^{TM)}$ was sent to patients with prior history of DFSP via the DFSP Facebook page / www.thedfspnetwork.org [Supplementary Appendix 5]. Fifty-two patients reported a history of primary DFSP (March 1995 - June 2014). One-third underwent >3 surgical procedures (44% of all procedures were MMS). Local recurrence occurred in six patients treated with WLE (time to recurrence 1 – 9.5 years). Satisfactory cosmetic outcome was reported in 50% (16/32) treated with WLE and 71% (12/17) with MMS (Chi-square p value 0.17). Half of individuals treated with WLE (16/32) would choose the same procedure again, compared with 94% (15/16) of those treated with MMS (Chi square p value 0.008). Eleven individuals who would not choose WLE again, cited MMS as their preferred alternative option. Amongst this selected group of responders, MMS appeared to be the overall preferred treatment option.

Discussion

To our knowledge, this is the largest DFSP case series reported from the UK describing routine surgical DFSP management of 603 patients over a 10-year period in 26 UK NHS centres. WLE was undertaken in 74.9% (n=362/483) and 68.7% (n=44/64) of primary and recurrent DFSP cases respectively. Median follow-up for the primary cases was 2.2 years with all 6 cases of local recurrence occurring in the WLE group. The difference in local recurrence rates between WLE and MMS was 6 versus 0. The median follow-up was 27 months for WLE versus 14.5 months for MMS for primary DFSP, and 31 months versus 14 months for recurrent DFSP.

Two large population-based studies for DFSP from the USA[1,3] have used cancer registries providing large datasets, but individual case-specific data are lacking. A more recent retrospective review using data from the Netherlands Cancer Registry with linked pathology demonstrated high rates of incomplete surgical excisions.[27] Variations in healthcare systems, costs and accessibility to treatment in different countries may affect external validity of these databases which is the reason for undertaking this multi-centred study which is the largest cohort reported from the UK.

While consensus guidelines for the treatment of DFSP are available[28,29,32,33] significant variations exist between healthcare systems. The US NCCN guidelines recommend WLE with peripheral margins of 2 – 4cm or MMS, with deep margins extending to the level of the investing fascial layer.[31] European guidelines[29] recommend MMS and "related variants" over WLE, with excision of the deep fascia and peripheral safety excision margins of 1 to 1.3 cm, preferably using slow Mohs. If WLE and standard histopathological procedures are used, a larger peripheral safety margin of 3 cm is recommended. Danish guidelines support WLE with 2 – 3cm peripheral margins and deep margins to include the deep fascia, or MMS as first-line treatment in 'appropriate' patients.[32] The British Society for Dermatological Surgery (BSDS) advocates MMS as the preferred treatment for DFSP, but does not offer guidance on initial peripheral margin size or deep margin depth.[28] Our results show that WLE is the commonest treatment for DFSP in the UK NHS. However, since 2011 when the BSDS position statement was published, MMS has been used more frequently; 43.3% (n=42) of all MMS cases were undertaken from 2012 onwards, compared with 25.4% (n=92) managed by WLE. Nonetheless, for both WLE and MMS in the UK, our data show a clear lack of consistency in deployment of these 2 surgical procedures. MMS for DFSP is similar to MMS used for BCC, but there are differences, and it has not been

standardized for DFSP. Although 34.8% (n=39) of MMS procedures in this cohort were performed using frozen sections, paraffin processing is generally recommended due to difficulties in distinguishing DFSP from scarring and reactive fibroblast proliferation. However, there are no comparative quality data for these 2 techniques. The reasons for variation in surgical practice in the UK are unclear.

There were some trends demonstrated in our data which support that previously reported in smaller cohort studies. Head and neck DFSP were more commonly treated by MMS (38% of primary tumours and 44% of recurrent tumours). Moreover, half of tumour recurrences occurred on the head and neck raising a proposal that certain anatomical sites might benefit from margin control prior to reconstruction.

Study limitations

A limitation of retrospective studies is incomplete data, partly due to transfer of patients between different hospitals for diagnosis, treatment and follow-up and varying DFSP management pathways within different geographic areas. Archiving of older case notes limited access to historical records. Initial diagnostic, peri-operative and follow-up information was sometimes lacking. The median follow-up period for WLE was 67.8 and 78.1 months versus 36.2 and 35.1 months for MMS for primary and recurrent DFSP respectively, which will impact on detecting recurrence rates which frequently occur after 2 years. Taken together, all these factors may have resulted in an underestimation of the overall recurrence rate. Nonetheless, our study provides the largest dataset to report surgical management of DFSP in the UK.

Data regarding pre-operative lesion size and post-operative defect size, albeit incomplete, warrants comment; the final defect size for both modalities does not appear to be critically different. While the missing data is in part due to information not being accessible, in many cases it appears not to have been consistently recorded in medical/operative notes at the time of surgery. Without clear documentation of pre- and post-operative, lesion and defect size, and surgical margins used, obtaining accurate and consistent data on tissue conservation is not feasible. The same applies to post-operative function.

The small number of recurrences reported in our series together with short follow-up times did not allow for calculation of distant disease-free and recurrence-free survival. Furthermore the study was underpowered to detect any significant differences between the groups and we have only been able to report the data

descriptively. Finally, there is likely to be selection bias in a retrospective study comparing two different treatments: without randomisation, the relative efficacy of one over the other cannot reliably be determined. The reasons for choosing WLE versus MMS were not explored specifically but are likely to include local availability of MMS, waiting times and lesion-specific factors. In a systematic review, Foroozan et al[31] made a weak recommendation in favour of MMS or similar techniques with surgical margin control, but also highlighted the need for future randomised controlled trials (RCTs). However, development of sufficiently powered RCTs pose significant challenges for rare, largely non-life limiting disease with low recurrence rates such as DFSP and are unlikely to attract competitive funding. In the absence of any clearly superior surgical modality, treatment decisions should be based on patient preference, expertise of the treating team, and cost. Knowledge of the cost of WLE compared to MMS to the UK NHS for DFSP is lacking. There are significant cost differences dependent on setting e.g. local anaesthetic day-case costs versus general anaesthetic procedures with overnight stay and a robust health economic analysis is essential. In terms of establishing patient preferences, evaluation of both surgical options using validated patient reported outcome measure tools and development of an Option Grid™ decision aid could help both clinicians and patients in the decision-making process.

Cooperation between the UK Dermatology Clinical Trials Network (UK DCTN), the Reconstructive Surgical Trials Network (RSTN) and the National Cancer Research Institute (NCRI) Non-melanoma Skin Cancer Subgroup enabled this review to be undertaken. The development of UK consensus guidelines for the management of DFSP and other primary skin sarcomas has been approved and is scheduled for development during 2021-2.

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References

1. Kreicher KL, Kurlander DE, Gittleman HR et al. Incidence and Survival of Primary Dermatofibrosarcoma Protuberans in the United States. *Dermatol Surg*. 2016 Jan;42 Suppl 1:S24-31.
2. Akram J, Wooler G, Lock-Andersen J. Dermatofibrosarcoma protuberans: clinical series, national Danish incidence data and suggested guidelines. *J Plast Surg Hand Surg*. 2014 Feb;48(1):67-73.
3. Criscione VD, Weinstock MA. Descriptive epidemiology of dermatofibrosarcoma protuberans in the United States, 1973 to 2002. *J Am Acad Dermatol*. 2007 Jun;56(6):968-73.
4. Personal correspondence from Public Health England, May 2014.
5. April 2013 Non-melanoma skin cancer in England, Scotland, Northern Ireland, and Ireland. NCIN Data Briefing. http://www.ncin.org.uk/publications/data_briefings/non_melanoma_skin_cancer_in_england_scotland_northern_ireland_and_ireland (last accessed 19th March 2019)
6. Ratner D, Thomas CO, Johnson TM et al. Mohs micrographic surgery for the treatment of dermatofibrosarcoma protuberans. Results of a multiinstitutional series with an analysis of the extent of microscopic spread. *J Am Acad Dermatol*. [Comparative Study Multicenter Study]. 1997 Oct;37(4):600-13.
7. Tolkachjov SN, Brodland DG, Coldiron BM et al. Understanding Mohs Micrographic Surgery: A Review and Practical Guide for the Nondermatologist. *Mayo Clin Proc*. 2017;92(8):1261-12
8. Van Delft LCJ, Nelemans PJ, van Loo E, Abdul Hamid M and Kelleners-Smeets NWJ. The illusion of conventional histological resection margin control. *Br J Dermatol*. 2019 May; 180(5): 1240–1241.
9. Gloster HM, Jr., Harris KR, Roenigk RK. A comparison between Mohs micrographic surgery and wide surgical excision for the treatment of dermatofibrosarcoma protuberans. *J Am Acad Dermatol*. [Comparative Study Review]. 1996 Jul;35(1):82-7.
10. Rutgers EJ, Kroon BB, Albus-Lutter CE, Gortzak E. Dermatofibrosarcoma protuberans: treatment and prognosis. *Eur J Surg Oncol*. [Review]. 1992 Jun;18(3):241-8.

11. Smola MG, Soyer HP, Scharnagl E. Surgical treatment of dermatofibrosarcoma protuberans. A retrospective study of 20 cases with review of literature. *Eur J Surg Oncol*. [Review]. 1991 Oct;17(5):447-53.
12. Mark RJ, Bailet JW, Tran LM et al. Dermatofibrosarcoma protuberans of the head and neck. A report of 16 cases. *Arch Otolaryngol Head Neck Surg*. [Review]. 1993 Aug;119(8):891-6.
13. Chang CK, Jacobs IA, Salti GI. Outcomes of surgery for dermatofibrosarcoma protuberans. *Eur J Surg Oncol*. 2004 Apr;30(3):341-5.
14. DuBay D, Cimmino V, Lowe L et al. Low recurrence rate after surgery for dermatofibrosarcoma protuberans: a multidisciplinary approach from a single institution. *Cancer*. 2004;100(5):1008-1016.
15. Lowe GC, Onajin O, Baum CL et al. Treatment of Dermatofibrosarcoma Protuberans With Long-Term Follow-up: The Mayo Clinic Experience. *Dermatol Surg*. 2017 Jan;43(1):98-106.
16. Kokkinos C, Sorkin T, Powell B. To Mohs or not to Mohs. *J Plast Reconstr Aesthet Surg.* 2014 Jan;67(1):23-6.
17. Snow SN, Gordon EM, Larson PO et al. Dermatofibrosarcoma protuberans: a report on 29 patients treated by Mohs micrographic surgery with long-term follow-up and review of the literature. *Cancer*. 2004 Jul 1;101(1):28-38.
18. Galimberti G, Montano AP, Kowalczuk A et al. Outcomes in 11 patients with dermatofibrosarcoma protuberans treated with Mohs micrographic surgery. *Int J Dermatol*. 2012 Jan;51(1):89-93.
19. Roh MR, Bae B, Chung KY. Mohs' micrographic surgery for dermatofibrosarcoma protuberans. *Clin Exp Dermatol*. 2010 Dec;35(8):849-52.
20. Meguerditchian AN, Wang J, Lema B et al. Wide excision or Mohs micrographic surgery for the treatment of primary dermatofibrosarcoma protuberans. *Am J Clin Oncol*. [Comparative Study Evaluation Studies]. 2010 Jun;33(3):300-3.
21. Paradisi A, Abeni D, Rusciani A et al. Dermatofibrosarcoma protuberans: wide local excision vs. Mohs micrographic surgery. *Cancer Treat Rev*. [Comparative Study Research Support, Non-U.S. Gov't Review]. 2008 Dec;34(8):728-36.
22. Hancox JG, Kelley B, Greenway HT, Jr. Treatment of dermatofibroma sarcoma protuberans using modified Mohs micrographic surgery: no recurrences and smaller defects. *Dermatol Surg*. 2008 Jun;34(6):780-4.

23. Nelson RA, Arlette JP. Mohs micrographic surgery and dermatofibrosarcoma protuberans: a multidisciplinary approach in 44 patients. *Ann Plast Surg*. [Case Reports Evaluation Studies]. 2008 Jun;60(6):667-72.
24. Ah-Weng A, Marsden JR, Sanders DS, Waters R. Dermatofibrosarcoma protuberans treated by micrographic surgery. *Br J Cancer*. [Comparative StudyReview]. 2002 Dec 2;87(12):1386-9.
25. Dawes KW, Hanke CW. Dermatofibrosarcoma protuberans treated with Mohs micrographic surgery: cure rates and surgical margins. *Dermatol Surg*. [Case Reports Comparative Study]. 1996 Jun; 22(6):530-4.
26. Matin RN, Acland KM and Williams HC. Is Mohs micrographic surgery more effective than wide local excision for treatment of dermatofibrosarcoma protuberans in reducing risk of local recurrence? A Critically Appraised Topic. *Brit Jour Dermatol.* 2012 Jul;167(1):6-9
27. van Lee CB, Kan WC, Gran S, Mooyaart A, Mureau MAM, Williams HC, Matin R, van den Bos R, Hollestein LM. Dermatofibrosarcoma Protuberans Re-excision and Recurrence Rates in the Netherlands Between 1989 and 2016. *Acta Derm Venereol*. 2019 Nov 1;99(12):1160-1165.
28. https://www.bsds.org.uk/imagelib/pdfs/BSDS_position_statement_for_DFSP_-_Dec_2011.pdf (last accessed 19th March 2019)
29. Saiag P, Grob JJ, Lebbe C et al. Diagnosis and treatment of dermatofibrosarcoma protuberans. European consensus-based interdisciplinary guideline. *Eur J Cancer.* 2015 Nov;51(17):2604-8.
30. Pallure V, Dupin N, Guillot B. Surgical treatment of Darier-Ferrand dermatofibrosarcoma: a systematic review. *Dermatol Surg*. [Research Support, Non-U.S. Gov't Review]. 2013 Oct;39(10):1417-33.
31. Foroozan M, Sei JF, Amini M et al. Efficacy of Mohs micrographic surgery for the treatment of dermatofibrosarcoma protuberans: systematic review. *Arch Dermatol*. [Research Support, Non-U.S. Gov't Review]. 2012 Sep;148(9):1055-63.
32. Nahhas AF, Scarbrough CA, Trotter S. A Review of the Global Guidelines on Surgical Margins for Nonmelanoma Skin Cancers. *J Clin Aesthet* Dermatol. 2017;10(4):37–46.
33. NCCN Clinical Practice Guidelines in Oncology; Dermatofibrosarcoma Protuberans. Version 1.2019 — August 31, 2018.
Available from the NCCN website: https://www.nccn.org (last accessed 19th March 2019)