Treatment of vitiligo
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A systematic review of autologous transplantation methods in vitiligo

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ABSTRACT

Objective: A systematic review of the effectiveness, safety and applicability of autologous transplantation methods in vitiligo.

Data Sources: Computerized searches of bibliographical databases, a complementary manual literature search and contacts with researchers and pharmaceutical firms.

Study selection: Predefined selection criteria were applied to all studies found.

Data Extraction: Two investigators independently assessed the articles for inclusion. When there was a disagreement, a third investigator was consulted.

Results: Sixty-three studies were found, of which 16 reported on minigrafting, 13 on split-thickness skin grafting, 15 on grafting of epidermal blisters, 17 on grafting of cultured melanocytes and 2 on grafting of noncultured epidermal suspension. Of these, 39 patient series were included. The highest mean success rates were achieved with split-thickness skin grafting (87%; 95% Confidence Interval [CI], 82% to 91%) and epidermal blister grafting (87%; 95% CI, 83% to 90%). The mean success rate of 5 culturing techniques varied from 13% to 53%. However, in 4 of the 5 culturing methods fewer than 20 patients were studied. Minigrafting had the highest rates of adverse effects, but was shown to be the easiest, fastest, and least expensive method.

Conclusions: Because no controlled trials were included, treatment recommendations should be formulated with caution. Split-thickness skin or epidermal blister grafting can be recommended as the most effective and safest techniques. No definite conclusions can be drawn about the effectiveness of culturing techniques, because only a small number of patients have been studied. The choice of method also depends on certain disease characteristics and the availability of specialized personnel and equipment.
INTRODUCTION

Vitiligo is a common hypopigmentary disorder occurring in about 0.5% of the world’s population, regardless of age, sex and skin color. The disorder is primarily treated by medical therapies. However, these therapies are not successful in every patient. In those patients who do respond, complete repigmentation is only rarely achieved. Certain areas, such as lips, nipples, genitals, eyelids, and distal extremities are common areas that are known to respond poorly\textsuperscript{1,2}.

Several methods of autologous transplantation of melanocytes have been developed to repigment lesions that are stable and those that are refractory to medical therapies. Autologous skin grafts can be obtained from the uninvolved skin using several techniques\textsuperscript{3-5}. When using the minigrafting (or punch grafting) technique, 1 to 2 mm full thickness punch grafts are harvested from normally pigmented donor sites and are then transplanted to depigmented acceptor sites from which similar punch grafts have been removed. Epidermal blister grafting involves the formation of epidermal blisters by application of a negative pressure to the normally pigmented skin. Two days before transplantation, blistering of the depigmented lesion is induced using liquid nitrogen or topical psoralen and UV-A therapy. After blister formation, the depigmented epithelium is removed and the roofs of the pigmented donor blisters are transplanted to the denuded lesional areas. Split-thickness skin grafting involves removal of the depigmented epithelium by superficial dermabrasion or dermatome. A thin split-thickness skin graft is then harvested from a normally pigmented donor area with a dermatome and placed into the denuded achromatic area. Transplants composed of cultured autologous epidermis or pure melanocytes have been made possible by the development of techniques used to grow melanocytes in vitro. When enough melanocytes are acquired, they are transplanted into the previously denuded recipient skin. A more simplified method includes transplanting noncultured melanocytes from a shave biopsy specimen of occipital skin, into a liquid nitrogen-induced blister at the acceptor site.

Current treatment recommendations for choosing a transplantation method are based on data from a limited number of studies\textsuperscript{1-5} and on personal and institutional preferences\textsuperscript{6-9}. A literature search revealed no systematic review of transplantation methods in vitiligo, so we conducted such a review. Effectiveness, safety, and the practical and economical aspects of each of the described techniques were analyzed to support evidence-based recommendations for daily clinical practice\textsuperscript{10-12}.  

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METHODS

DATA SOURCES

The computerized bibliographical databases MEDLINE (National Library of Medicine, Bethesda, Md, USA) and EMBASE (Elsevier Science BV, Amsterdam, The Netherlands) were screened for clinical trials from January 1966 to December 1997 (last update 15 December 1997). No language restrictions were applied. As main keywords (including analogues and derivatives) we used “vitiligo”, “surgery”, “skin transplantation” and “transplantation autologous”. Other sources were abstract books of symposia and congresses, dissertations, textbooks, monographs, reviews, editorials, letters to the editor, free/rapid communications and the reference lists from all the articles retrieved. Also we contacted 21 leading authorities in the field of vitiligo and 9 pharmaceutical companies to provide us with any additional published and unpublished data.

STUDY SELECTION: INCLUSION AND EXCLUSION CRITERIA

Two investigators (M.D.N. and W.W.) independently assessed the articles on patient series for inclusion and exclusion. When there was a disagreement, a third investigator (P.M.M.B) was consulted.

We included clinical trials on minigrafting, split-thickness skin grafting, grafting of epidermal blisters, grafting of cultured melanocytes and grafting of noncultured epidermal suspension performed in patients with vitiligo. Excluded were double publications (reports of the same study published in different journals or languages), studies describing combination with another (experimental) technique, methodological studies, studies reporting on fewer than 3 patients and studies with insufficient data on effectiveness. The exclusion criterion “methodological study” was used for studies describing only the technique. In case of double publications, only the most detailed publication was selected.

DATA EXTRACTION

Analysis Based on Patient Series

Because no randomized controlled trials (RCTs) were found, analysis was needed on the available patient series. Because comparative trials can contain a description of at least 2 patient series, the total number of patient series could exceed the total number of studies included. Success rates were presented as sample size-weighted averages, which were calculated for each modality by dividing the total number of patients achieving more than
75% repigmentation by the total number of patients in the included series. The 95% confidence intervals (95% CIs) of these averages were calculated with the computer program Confidence Interval Analysis for MS-DOS by means of the exact method (version 1.0, 1989, M.J. Gardner and D.G. Altman, British Medical Journal, London)\(^1\).

**Adverse Effects**

The treatment duration (range and mean values) was also determined for each treatment modality. Treatment-specific adverse effects were estimated by dividing the number of patients experiencing adverse effects by the total number of patients in the included series. For each study, sample size-weighted averages for these frequencies and their 95% CIs were calculated with the same software used for the calculation of the success rates. “Imperfect color matching” as an adverse effect of the acceptor site was defined as the occurrence of hyperpigmentation and/or hypopigmentation of the grafts giving a variegated appearance of the pigment in the treated area.

**Other Factors Relevant for Choice of Transplantation Method**

Because every grafting method has its specific advantages and disadvantages, other aspects of treatment were included, such as clinical types treated, maximal treatable lesion size per session, required size of the donor skin, duration of the procedure and need for special equipment or personnel.

**RESULTS**

**Literature Search.**

In total, 63 studies were obtained, of which 42 could be identified in the databases (Table 1). The mean hit rate of the databases was 67%, with a range of 33% to 100%. Fifteen of the 21 leading authorities and 7 of the 9 pharmaceutical firms contacted replied and provided us with relevant references. No study required a third reviewer to resolve disagreements about selection.

The number of studies ranged from 2 to 17 for the 5 different modalities. Most studies reported on results with grafting of cultured melanocytes (27% [17/63]). No RCTs were found. One Korean study on epidermal blister grafting was not yet available when the manuscript was submitted\(^1\).
A total of 64 patient series could be identified, varying from 2 to 17 series among the different modalities. After application of the exclusion criteria, 25 series were excluded. A total of 39 (61%) series could be included\(^{15-53}\), reporting on the results in 1035 patients.

The reasons for exclusion are summarized in Table 1. In cases with more than one exclusion criterion, only the most important one is listed.

**Effectiveness.**

The highest success rates were achieved with split-thickness skin grafting (87%; 95% CI, 82% to 91%) and epidermal blister grafting (87%; 95% CI, 83% to 90%) (Figure 1). The lowest success rate was reported with grafting of noncultured epidermal suspension (31%; 95% CI, 11% to 59%). However, of the latter, a total of only 16 patients were studied.

Figure 2 shows the effectiveness of different transplantation methods using cell-culturing techniques. Studies using the same culture medium were combined. Studies A, B and E described in vitro culturing techniques of epidermis containing both keratinocytes and melanocytes (“co-cultures”). In study E, only 1 publication was included reporting the results in 15 patients. In study B only 4 patients were treated. Study A was associated with the highest percentage of patients with more than 75% repigmentation (53%; 95% CI, 27% to 78%) in a total of 15 patients. Studies C and D used melanocytes alone in the cultures. However, with study C, only 1 publication was found to report the results of 18

### Table 1. Results of the Literature search and Reasons for Exclusion of Patient Series

<table>
<thead>
<tr>
<th>Method</th>
<th>Minigrafting</th>
<th>Split-Thickness Grafting</th>
<th>Grafting Epidermal Blister</th>
<th>Grafting Cultured Grafting Epidermis/Melanocytes</th>
<th>Grafting Noncultured Epidermis</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of studies found</td>
<td>16</td>
<td>13</td>
<td>15</td>
<td>17</td>
<td>2</td>
<td>63</td>
</tr>
<tr>
<td>No. found through databases</td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>13</td>
<td>1</td>
<td>42</td>
</tr>
<tr>
<td>(Hit rate for databases, %)</td>
<td>(44)</td>
<td>(69)</td>
<td>(80)</td>
<td>(76)</td>
<td>(50)</td>
<td>(67)</td>
</tr>
<tr>
<td>No. of patients series identified</td>
<td>17</td>
<td>13</td>
<td>15</td>
<td>17</td>
<td>2</td>
<td>64</td>
</tr>
<tr>
<td>Included</td>
<td>9 (56)</td>
<td>8 (62)</td>
<td>10 (67)</td>
<td>10 (59)</td>
<td>2 (100)</td>
<td>39 (61)</td>
</tr>
<tr>
<td>Excluded</td>
<td>8 (44)</td>
<td>5 (38)</td>
<td>5 (33)</td>
<td>7 (41)</td>
<td>0</td>
<td>25 (39)</td>
</tr>
</tbody>
</table>

Reasons for exclusion of patient series, No.

- Double publication: 0
- Combined with another (experimental) technique: 0
- Methodological study: 0
- Series of fewer than 3 patients: 0
- Inadequate or insufficient data on effectiveness: 0


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\(^{15-53}\)
CHAPTER 3.3

Figure 1: Effectiveness of autologous noncultured transplantation methods in vitiligo. Analysis was based on patient series (sample size-weighted averages and 95% confidence intervals in brackets)

Figure 2: Effectiveness of autologous cultured transplantation methods in vitiligo. Analysis based on patient series (sample size-weighted averages and 95% confidence intervals in brackets)

patients. Study D reported a mean success percentage of 48% (95% CI, 39% to 56%) in a total of 130 patients.

Adverse effects.

Of the 39 included series, 35 (90%) reported adverse effects (Table 2). Scar formation at the donor site, considered to be the most undesirable adverse effect, was most frequently reported with minigrafting (40%; 95% CI, 34% to 47%), followed by split-thickness skin grafting (12%; 95% CI, 7% to 16%). No scar formation was observed with the other techniques. Hyperpigmentation at the donor site was mostly reported with epidermal blister grafting (28%; 95% CI, 23% to 33%). In patients receiving noncultured epidermal suspension grafts, no adverse effects were reported at the donor sites.

At the acceptor sites, a cobblestone appearance of the grafts was a specific adverse effect of the minigrafting technique and occurred in 27% of the cases (95% CI, 21% to 33%). Milia and partial loss of grafts were the 2 most common adverse effects with split-thickness skin grafting (13%; 95% CI, 8% to 18% and 11%; 95% CI, 7% to 15% respectively). In all 5 techniques, imperfect color matching occurred in less than 10% of the cases. Thick margins of the grafts occurred exclusively in split-thickness skin grafting (in 5% of the cases; 95% CI, 2% to 9%). Scar formation and infection were less common adverse effects (< 3% each) at the acceptor sites.

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### Table 2. Proportion of Patients with Adverse Effects

<table>
<thead>
<tr>
<th>Method</th>
<th>Minigrafting</th>
<th>Split-Thickness Skin Grafting</th>
<th>Grafting Epidermal Blisters</th>
<th>Grafting Cultured Epidermis/Melanocytes</th>
<th>Grafting Noncultured Epidermal Suspension</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of included series (total No. of patients)</td>
<td>9 (258)</td>
<td>8 (232)</td>
<td>10 (347)</td>
<td>10 (182)</td>
<td>2 (16)</td>
</tr>
<tr>
<td>Range of observation period in months</td>
<td>3-24</td>
<td>2-36</td>
<td>2-36</td>
<td>2-30</td>
<td>3-4</td>
</tr>
<tr>
<td>Series with adverse effects reported</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(No. of patients involved)</td>
<td>8 (218)</td>
<td>6 (198)</td>
<td>10 (347)</td>
<td>9 (167)</td>
<td>2 (16)</td>
</tr>
<tr>
<td>Adverse effects at donor site *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Koebner phenomenon</td>
<td>4 (2) [1-5]</td>
<td>0</td>
<td>7 (2) [1-4]</td>
<td>1 (1) [0-3]</td>
<td>0</td>
</tr>
<tr>
<td>- Hypopigmentation</td>
<td>0</td>
<td>31 (16) [11-21]</td>
<td>0</td>
<td>1 (1) [0-3]</td>
<td>0</td>
</tr>
<tr>
<td>- Hyperpigmentation</td>
<td>0</td>
<td>2 (1) [0-4]</td>
<td>98 (28) [24-33]</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>- Scar/keloid formation</td>
<td>88 (40) [34-47]</td>
<td>24 (12) [8-17]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>- Infection</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Adverse effects at acceptor site *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Partial loss of graft(s)</td>
<td>13 (6) [3-9]</td>
<td>22 (11) [7-15]</td>
<td>0</td>
<td>1 (1) [0-3]</td>
<td>0</td>
</tr>
<tr>
<td>- Cobblestoning</td>
<td>59 (27) [21-33]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>- Sinking pits</td>
<td>15 (7) [4-10]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>- Thick margins</td>
<td>0</td>
<td>10 (5) [2-9]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>- Milia</td>
<td>0</td>
<td>26 (13) [8-18]</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>- Imperfect colour matching</td>
<td>20 (9) [5-13]</td>
<td>8 (4) [1-7]</td>
<td>24 (7) [4-10]</td>
<td>13 (8) [4-13]</td>
<td>0</td>
</tr>
<tr>
<td>- Scar/keloid formation</td>
<td>2 (1) [0-3]</td>
<td>0</td>
<td>3 (1) [0-3]</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>- Infection</td>
<td>2 (1) [0-3]</td>
<td>4 (2) [1-5]</td>
<td>3 (1) [0-3]</td>
<td>1 (1) [0-3]</td>
<td>0</td>
</tr>
</tbody>
</table>

* Data are reported as number of patients with percentage of sample size-weighted averages in parentheses and 95 CIs in brackets.

### Other Factors Relevant for Choice of Transplantation Method.

Table 3 shows that all clinical types of vitiligo have been treated with these techniques. Most experience was gained with generalized vitiligo (40% [415/1035]), followed by segmental vitiligo (18% [190/1035]).

Areas commonly resistant to medical therapies have also been treated with these transplantation methods, including lips, nipples, eyelids, genitals and fingers. The best results have been reported with minigrafting, split-thickness skin grafting and grafting of epidermal blisters. Little or no experience has been gained with culturing techniques or grafting of noncultured epidermal suspension. With grafting of cultured melanocytes lesions of up to 500 cm² could be treated, using relatively smaller donor areas (1-10 cm²).

The total duration of the grafting procedure varied greatly between the techniques used.
Table 3. Other factors relevant for the choice of transplantation method

<table>
<thead>
<tr>
<th></th>
<th>Minigrafting</th>
<th>Split-Thickness Skin Grafting</th>
<th>Grafting Epidermal Blisters</th>
<th>Grafting Cultured Epidermis/Melanocytes</th>
<th>Grafting Noncultured Epidermal Suspension</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of included series</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>(Total No. of patients)</td>
<td>(258)</td>
<td>(232)</td>
<td>(347)</td>
<td>(182)</td>
<td>(16)</td>
</tr>
<tr>
<td>Types of vitiligo studied</td>
<td>gen (117), seg (69), foc (72)</td>
<td>gen (32), seg (22), foc (28) unknown (150)</td>
<td>gen (115), seg (89) foc (143)</td>
<td>gen (151), seg (7), foc (3) unknown (21)</td>
<td>gen (0), seg (3), foc (8)</td>
</tr>
<tr>
<td>(all stable) *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficult areas treated</td>
<td>lip (14/14)</td>
<td>lip (2/2)</td>
<td>lip (9/11)</td>
<td>lip (0)</td>
<td>lip (0)</td>
</tr>
<tr>
<td>with good response</td>
<td>nipples (0)</td>
<td>nipples (0)</td>
<td>nipples (1/1)</td>
<td>nipples (0)</td>
<td>nipples (0)</td>
</tr>
<tr>
<td>(No./total)</td>
<td>eyelids (1/1)</td>
<td>eyelids (9/7)</td>
<td>eyelids (16/16)</td>
<td>eyelids (1/2)</td>
<td>eyelids (0)</td>
</tr>
<tr>
<td></td>
<td>genital (penis) (1/1)</td>
<td>genital (scrotum) (0/1)</td>
<td>genital (vulva) (1/1)</td>
<td>genital (penis) (1/1)</td>
<td>genital (0)</td>
</tr>
<tr>
<td></td>
<td>fingers (12/12)</td>
<td>fingers (7/10)</td>
<td>fingers (19/45)</td>
<td>fingers (0/2)</td>
<td>fingers (0/2)</td>
</tr>
<tr>
<td>Size treated area per session, cm² †</td>
<td>0.5-132</td>
<td>1-190</td>
<td>3.6-200</td>
<td>1-500</td>
<td>4-50</td>
</tr>
<tr>
<td>Size donor area required per session, cm² †</td>
<td>6 (100 grafts)</td>
<td>1-190</td>
<td>3.6-200</td>
<td>1-10</td>
<td>1-12 (occipital skin)</td>
</tr>
<tr>
<td>Duration of blister formation (donor site)</td>
<td>NA</td>
<td>NA</td>
<td>30 min-3 h</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Duration of incubation in trypsin</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>18 h</td>
</tr>
<tr>
<td>Duration of culturing period</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>10 days-8 weeks</td>
<td>NA</td>
</tr>
<tr>
<td>Duration of grafting procedure</td>
<td>45 min for 50 cm² (about 100 minigrafts)</td>
<td>15 min-120 min for 2.5-200 cm²</td>
<td>liquid nitrogen: 1-3 days dermabrasion: 15-30 min local 8-MOP: 3 days-2wks suction blister: 30 min-3 h grafting: 15-30 min</td>
<td>liquid nitrogen: 1-3 days dermabrasion: 15-30 min suction blister: 30 min-3 h grafting: 45-60 min</td>
<td>35-60 min</td>
</tr>
<tr>
<td>Immobilization period plus wound dressing, days †</td>
<td>10-14</td>
<td>2-14</td>
<td>4-14</td>
<td>5-14</td>
<td>8-12</td>
</tr>
<tr>
<td>Equipment required</td>
<td>biopsy punches, dermatome, dermabrader</td>
<td>suction blister apparatus</td>
<td>laboratory</td>
<td>laboratory</td>
<td>laboratory</td>
</tr>
<tr>
<td>Specialized personnel required</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

* Gen indicates generalized; seg, segmental; foc, focal; † Values expressed as ranges; NA indicates not applicable.

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The shortest duration was with minigrafting (45 minutes for 50 cm²) and split-skin grafting (120 minutes for 200 cm²). Blister formation took from 30 minutes to 3 hours, whereas the grafting procedure itself took about half an hour. Culturing periods varied between 10 days and 8 weeks, depending on the number of cells needed. The total procedure for grafting the noncultured epidermal cell suspension took about 2 days.

Minigrafting seems to be the easiest and least expensive method, since it does not require special equipment, personnel or a laboratory. For split-thickness skin grafting, a dermatome and dermabrader set are required. For grafting of epidermal blisters, a suction apparatus is essential. Transplantation of cultured melanocytes requires specialized personnel and laboratory facilities.

COMMENT

A review of the available literature was performed to assess the effectiveness, safety and applicability of different forms of autologous transplantation methods in vitiligo. The results indicated that the highest success rates were achieved with split-thickness skin grafting and epidermal blister grafting. Minigrafting caused the highest proportion of adverse effects at the donor- and acceptor site. On the other hand minigrafting was the easiest, fastest and least expensive transplantation method.

The data presented here should be interpreted with caution. As there were no comparative studies, only average success and adverse-effect rates could be studied, which only allows for indirect comparison. Furthermore, of the 9 different studies on grafting techniques, 5 reported on fewer than 20 patients, 4 of these on culturing techniques (studies A, B, C and E) and 1 on grafting of noncultured epidermal suspension. Because of the low numbers of patients studied, conclusions about effectiveness and safety of these therapies must be drawn carefully.

Despite our attempts to obtain all relevant studies we cannot exclude the possibility that publication bias has interfered with our data. Some leading authorities provided us with unpublished articles already accepted for publication.

In all studies, patients fulfilled certain selection criteria before they were admitted for transplantation. Their conditions had been refractory to treatment for at least 6 to 12 months and had stabilized for at least 1 to 2 years. Patients with a tendency for scar or keloid formation and patients younger than 12 years old were excluded. We agree with
existing guidelines\textsuperscript{1-5} that patients should first meet the above-mentioned selection criteria before transplantation can be applied, however, these criteria have not been used consistently by all investigators. Moreover, the definition of “stabilized disease” differed among the studies. For example, the disease was considered stable when there were no new lesions or when old lesions had not grown in “2 years” according to Savant\textsuperscript{18} and “in 6 months” according to Boersma et al.\textsuperscript{20}. Not all authors used the minigrafting test to select stable cases\textsuperscript{55,56}. These differences in selection procedure may explain some of the variation in treatment outcome. When vitiligo is still active, there is a higher risk for treatment failure and for the development of the Koebner phenomenon at the donor site\textsuperscript{34}. We therefore propose the use of a more uniform scoring system of disease activity based on the results of the minigrafting test\textsuperscript{55,56} as an objective parameter to select stable cases and on the patient’s history\textsuperscript{57}.

Variations in the method of assessing repigmentation grade may have also influenced treatment outcome. One study used “digital image analysis” to assess repigmentation grade more accurately\textsuperscript{20}.

In this review, the effectiveness of only mono-therapies is summarized. However, the combination of 2 techniques may increase the repigmentation grade. Falabella et al.\textsuperscript{58} have shown that the minigrafting method can be used as an effective additional procedure to restore completely the depigmented lesions (up to 100% repigmentation), when after epidermal blister grafting or grafting of cultured cells residual achromatic areas are still present.

Among the noncultured transplantation methods, split-thickness skin grafting and epidermal blister grafting were shown to be the most effective methods. The relatively lower success rate achieved with minigrafting can be explained by variations in the size of pigment spread of the punch grafts. Racial factors and skin type may play an important role in this matter\textsuperscript{16,18,19}. Postoperative radiation therapy may improve the repigmentation grade in minigrafting. A facial tanner or a sunbed\textsuperscript{20}, psoralen and UV-A or sunlight\textsuperscript{21}, or sunlight alone\textsuperscript{45}, can be used as UV sources. Just as it has been shown in epidermal blister grafting that pigment spreading can be enhanced by pre-operative radiation therapy of the donor sites using psoralen and UV-A\textsuperscript{41}, this modification may be useful with minigrafting.

The question arises whether the repigmentation induced by grafting methods is permanent. Since transplantation of melanocytes does not treat the underlying cause in vitiligo, reactivation of the disease may lead to a secondary failure of the treated skin and to the development of the Koebner phenomenon at the donor sites. Follow-up studies
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are therefore needed to address this issue.

Analysis of adverse-effect profiles indicate that minigrafting had the highest proportion of patients with adverse effects at the donor and acceptor sites. The risks of minigrafting are well known and are generally acceptable\(^3\)\(^5\). A cobblestone appearance may resolve spontaneously but can also be prevented by punching the holes much deeper at the acceptor area and by using more superficial donor grafts\(^18\)\(^20\). However, superficial scar formation at the donor sites still remains the main limitation of this method.

Adverse effects have also been encountered in many patients undergoing split-thickness skin grafting. Milia, however, are temporary phenomena and thick margins can be treated with repeated dermabrasion\(^26\). Scar formation at the donor sites can be prevented by using a very thin graft\(^28\), and the risk of graft loss can be minimized by adequate postoperative care (immobilization of the treated area)\(^31\).

In all techniques, imperfect color matching of the grafts was caused by hypopigmentation and/or hyperpigmentation. Hypopigmentation of the grafts can be explained by reactivation of the disease\(^21\) or, as in culturing techniques, by insufficient concentration of grafted melanocytes\(^45\). Hyperpigmentation of the grafts may be related to overstimulation of melanocytes by growth factors or cytokines during the reepithelialization phase\(^52\). To minimize hyperpigmentation, any form of postoperative radiation therapy should be halted when sufficient color matching is achieved.

Grafting of cultured autologous melanocytes was originally a promising procedure to repigment large achromic areas using relatively small donor areas. However, culturing methods are still in a developmental stage since relatively low numbers of patients have been studied. There is also concern regarding the tumorigenic risks of culturing techniques because certain culture media contain tumor promoters and grafted areas are postoperatively treated with UV radiation\(^48\)\(^59\). To date, melanoma has not been reported in patients treated with these techniques. Nevertheless, we do not recommend the supplementation of culture media with tumor promoters and the prolonged use of postoperative UV therapy.

Because no randomized controlled trials were included in our analysis and because of the low numbers of patients in some modalities, the following treatment recommendations in this study should be viewed with caution. Among the noncultured transplantation methods, split-thickness skin and epidermal blister grafting can be recommended as the most effective techniques. No definite conclusions can be drawn with regards to the effectiveness of culturing techniques, since only small numbers of patients were studied.
Most adverse effects of grafting techniques are temporary and can be easily prevented or treated. The choice of transplantation method also depends on certain disease characteristics (i.e. size and localization of the lesions) and the availability of specialized personnel and equipment. Further studies involving a statistically significant number of patients are required to substantiate our treatment recommendations.

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A complete list of all studies identified is available on request from the authors.