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For this article Margriet van Eikema Hommes carried out research into the art technical history of the decoration program of the galleries in the Royal Palace Amsterdam while the author of the present thesis contributed with insight into the present physical condition of the paintings as well as their conservation and restoration history.

Eikema Hommes, Margriet van, and Esther van Duijn. "Restauratie behandelingen aan de Nachtelijke Samenzwering van Claudius Civilis in het Schakerbos van Flinck en Ovens." Appendix to "Een doek van geene beteekenis', De nachtelijke samenswering van Claudius Civilis in het Schakerbos van Govert Flinck en Jürgen Ovens technisch onderzocht," by Margriet van Eikema Hommes and Emilie Froment. *Oud Holland* 124/2-3 (2011): 141-170.

For this article Margriet van Eikema Hommes carried out research into the art technical history of the painting by Ovens and Flinck. The author of the present thesis contributed to the publication with information about the material and technical characteristics of the painting and influence of past restoration campaigns on the present physical condition. Data about the recent restoration treatment of the painting is also part of the participation of the author of the present thesis to the article.

Summary

The Consequences of Wax-Resin Linings for the Present Appearance and Conservation of Seventeenth Century Netherlandish Paintings on Canvas

Background information

This thesis explores the conditions under which and the extent to which wax-resin linings may have altered the surface appearance of seventeenth century Netherlandish paintings. The lining of paintings is a restoration treatment meant to consolidate weakened canvas. In the Netherlands from the mid-nineteenth century, the traditional method for lining paintings involved the use of an adhesive based on a mixture of beeswax and natural resin, hence the term “wax-resin linings”. Considered until the 1970’s as an overall cure, wax-resin lining has been systematically applied to paintings. Practically, the technique involves the adhesion of a new canvas to the verso of the original and the impregnation of the whole painting’s structure with the wax-resin adhesive. The melting of the adhesive was achieved using hot hand held irons as a heat source.

Early in the history of wax-resin linings, documents refer to undesirable consequences of the technique, amongst which colour change of paintings is regularly reported. Nonetheless, the technique was broadly implemented until the 1970s. From the middle of the twentieth century, with the development of codes for conservation practice that viewed the drawbacks of the method as increasingly problematic, the attitude towards wax-resin lining began to change and alternative techniques for the structural treatment of paintings were developed.

Relevancy of the research

Most paintings preserved currently in the Netherlands were wax-resin lined. For example, it is estimated that 95% of paintings from the Dutch Golden Age were subjected to this technique. To date, however, there remains limited scientific research investigating the influence of wax-resin linings for the conservation of these paintings. In order to fill this gap of knowledge the present thesis examined colour change of ground layers in seventeenth century Netherlandish paintings on canvas. This focus was chosen due to the painting technique used in these works, where the ground is often left visible to be used as a middle tone or was slightly glazed to manage smooth transition between shadows and highlights. A change in tone of the ground, therefore, significantly alters the overall aesthetical character of the paintings, leading to misinterpretation of the works. Further colour change is caused by the penetration of the lining adhesive into paintings’ structure. Colour change is therefore a clear sign that physical characteristics of the paint film have been fundamentally modified and therefore may require a specific conservation approach.

Goals of the research

By clarifying the conditions under which wax-resin linings may have altered the appearance of seventeenth century Netherlandish paintings, this research aimed to enable paintings conservators to recognize and understand visual changes caused by this treatment, as well as anticipating conservation problems. In addition, results of the research would provide new evidence for consideration by conservators and art historians for estimating the original appearance of the paintings, and the impact of visual changes caused by their physical history.

Hypothesis

Material evidence found in the paintings by Jacob Jordaens (1593-1678) in the Royal Palace Amsterdam provided the basis for the research hypothesis. Technical examination revealed that though the four paintings by the Flemish painter had aged in the same conditions and received similar restoration treatments, including wax-resin linings, they are today in very different physical condition. Differing degrees of darkness, which in some cases compromised an accurate reading of the depiction, was particularly striking. Technical examination also highlighted the use of various ground types that differ in both the number of layers and material composition. Interestingly, some testimonies from experienced practitioners, report that colour change of paintings after wax-resin lining may be dependent on the composition of the ground. The correlation between material evidence and documentary sources supported the hypothesis put forward in the present study that the visual consequences of wax-resin linings in seventeenth century Netherlandish canvas paintings is related to the original preparation technique. Previous studies that have addressed this question include work completed in the 1980s by the National Gallery, London, and in 2010 by the Van Gogh Museum, Amsterdam. These studies provided a basis on which to develop the present research by providing information about experimental samples and methods for colour measurements.

Research methodology

The present study takes into consideration three main factors. Firstly, the material and physical characteristics of ground layers for canvas paintings produced in the Netherlands during the seventeenth century. Secondly, the physical modifications that may become manifest in these ground layers as a consequence of natural ageing and/or restoration treatments before wax-resin was implemented. And finally, the different methods for wax-resin lining used by paintings conservators in the Netherlands from the mid-nineteenth century until the 1970s. In order to examine the influence of each of these factors, the research methodology included technical examination of seventeenth Netherlandish canvas paintings, study of historic documents, practical experiments on reconstructions and instrumental analyses.

Central to the research's approach was the study of visual phenomena observed on reconstructions which were manufactured using materials and techniques based on material evidence from paintings selected for their relevance to the research. These included works by Jacob Jordaens, including the four paintings produced in the 1660s for Amsterdam's city hall (today's Royal Palace Amsterdam) and *Susanna and the Two Elders*, 1653, National Gallery of Denmark. In addition, the list comprised paintings by Gerard van Honthorst (1592-1656) and Theodor van Thulden (1606-1678) created in 1648-1651 for the Oranjezaal as well as *The Night Watch*, 1642, by Rembrandt in the Rijksmuseum, Amsterdam. Ground recipes found in documentary sources from the period and results of technical research from other paintings were also incorporated.

The materials selected for the manufacturing of reconstructions included nine different pigment types: chalk, lead white, raw umber, yellow iron oxide, red iron oxide, tile red, charcoal black, quartz sand and two types of clay. Two types of binding media were also used - namely linseed oil and animal glue. Pigments were used either independently or in mixtures of various ratios.

The degree to which the ground layers obliterate the darkened underlying canvas support (hiding power) was hypothesised to be a key parameter in the colour change of ground layers. In order

to investigate the influence of grounds' hiding power on colour change after impregnation, compositions were applied in different thicknesses onto canvas support. In addition, a pilot-study included the systematic application of different thicknesses onto opacity charts. The lining procedure used on reconstructions resulted from research into historical practices, though it occasionally had to be altered in order to minimize variables.

Colour measurements were recorded with a spectrophotometer. The CIELAB colour space was used and colour differences were calculated using the 1976 CIELAB colour difference equation. The colour data gathered was evaluated holistically and took into account results from measurements of ground samples on opacity charts. In addition, cross-sections of paint samples taken from the reconstructions were also analysed using light microscopy, providing further insight into the impact of layer thickness. Results were then compared with physical characteristics of real paintings in order to test their validity.

Results

Results from the experiments showed that wax-resin impregnation caused colour change in several of the ground reconstructions tested. Comparative colour measurements of the reconstructions showed that, in most of the cases, the L*, a* and b* values of the grounds decreased after impregnation indicating that the colour of grounds became darker and cooler in hue. Study of the results of colour measurements showed that the extent of change was influenced by the type of binding medium and inorganic components as well as the proportion of the latter. Furthermore, results of the hiding power study showed that all grounds types that underwent colour change after impregnation had poor hiding power, supporting the hypothesis that the hiding power of the ground affects colour change. The change in hue of the reconstructions toward cooler tones was considered an additional sign for the influence of the hiding power as this might be due to a turbid medium effect that typically occurs when a light toned thin paint covers a darker and warmer layer underneath.

Colour measurements of ground reconstructions showed that the glue-bound grounds changed colour more significantly than oil-bound grounds. It was assumed that the increased absorbency of these grounds compared with grounds composed of linseed oil caused this difference in colour change. The filling in of the voids inherently present in the glue-bound ground with wax-resin resulted in changes of refractive index and surface texture. These two phenomena were assumed to have exacerbated the colour change measured in the animal glue-bound grounds compared with the oil-bound grounds into which the wax-resin did not penetrate.

Of the ground reconstructions bound in animal glue, the one composed of chalk changed most significantly after wax-resin impregnation. This reconstruction is the only case where the change in hue was towards a more yellow and red colour. Of the ground reconstructions bound in linseed oil, those composed of either chalk or ball clay measured the most significantly altered after treatment, followed by the lead white and Maas river clay containing grounds which changed only slightly, while the grounds composed of either red iron oxide, yellow iron oxide, raw umber or charcoal black did not undergo change.

Research also found that the ratio of chalk to either yellow iron oxide, raw umber, lead white or yellow iron oxide and raw umber used in combination, was a significant factor in the colour change of oil-bound ground layers composed of pigment mixtures. Colour measurements showed that, in general, the higher the concentration of chalk the more significant the colour change. Furthermore, the results suggested that the impact of the inclusion of chalk on the

degree of colour change was dependent on the pigment that it was mixed with, for example no colour change was measured in ground reconstructions composed of chalk and raw umber. The hiding power study supported these results as trends indicated that the higher the proportion of chalk the more poorly the ground hid the substrate it was applied on. The minimum proportion of chalk at which colour change was measured varied depending on the other components in the ground. Colour measurements also showed that the inclusion of 10% raw umber to the ground composed of lead white and chalk prevented colour change completely, as no colour difference was measured even when the proportions of chalk were 50 and 70%.

Each quartz containing oil-bound ground reconstruction showed substantial colour change following wax-resin impregnation. The colour change in grounds of this type was amongst the most significant of all oil-bound grounds tested. Trends indicated that the higher the concentration of quartz the greater the colour change of the grounds after impregnation. Although the inclusion of 3% yellow iron oxide tended to reduce this effect, the colour change of the grounds remained significant. The hiding power study indicated that the higher the concentration of quartz, the poorer the hiding power, supporting the influence of hiding power on the colour change of the reconstructions.

Research also found that the influence of thickness varied according to the kinds and proportion of the inorganic components in the ground. For example, the ground composed of chalk in animal glue changed colour more significantly when applied thinly. Similar trends were found for the oil-bound grounds composed of either ball clay or lead white, 98% chalk mixed with either yellow iron oxide or combinations of yellow iron oxide and raw umber in equal amounts, as well as 80% chalk with lead white. On the contrary, layer thickness did not influence the degree of colour change of oil-bound ground composed of lead white and raw umber (even with 70% chalk). Finally, the quartz and ball clay containing oil-bound grounds changed colour to a similar extent regardless of the thickness of application.

The hiding power study showed that layer thickness considerably influenced the hiding power of certain grounds under investigation. A general trend was that the thinner the ground the less hiding it was, therefore supporting results of colour measurements from the reconstructions on canvas support. An exception was the ground composed of chalk and yellow iron oxide in linseed oil for which colour measurements were not decisive.

Evaluation

Results of colour measurements of ground reconstructions rarely showed an exact match with the grounds of historical paintings. Though the composition of the reconstructions was based on material evidence found in seventeenth century Netherlandish paintings, factors that differentiate the reconstructions from the real paintings were significant and precluded inferences about the original colour of the ground of paintings before lining.

Instead, analysis of the research findings enabled the identification of trends that can predict the likelihood that paintings with certain ground characteristics have been visually altered by wax-resin impregnation. For future research it would be very interesting to broaden the type of grounds investigated. For example: lead white containing oil-bound grounds with varying pigment mixtures and proportions of chalk, red grounds and double grounds.

The research also showed that the “abraded look” of the surface of a ground could be a phenomenon resulting from wax-resin impregnation.

It now appears that the presence of adhesive in the canvas structure resulting in the darkening of the support is a cause for the alteration of the appearance of paintings. Correction of this effect could involve extracting wax-resin from the painting's structure, assuming that this treatment might reveal the original colour of the priming. Past research on that topic has not been decisive and questions remain as to whether a full extraction would really return the painting to pre-lining colour, and if such an approach may expose paintings to high risks of delamination.

Key to the interpretation of visual phenomena was the correlation of colour measurements of ground reconstructions on canvas support with measurements of the same grounds applied on opacity charts. This allowed analysis of the influence of ground layers hiding power regarding the degree of colour change. Whether colour change in oil-bound ground is only due to the original hiding power of these ground types or whether this property was changed by the impregnation of wax-resin in the ground was not clarified. Therefore, the characterisation of the degree of wax-resin impregnation in oil-bound grounds is an area for future research. This question coupled with the porosity of oil-bound grounds is very relevant since their porosity is suspected to increase with ageing resulting in favourable conditions for colour change. This research could be carried out by a systematic comparative study of both lined and unlined paintings.

Conclusion

Paintings conservators world-wide are often confronted with the conservation of paintings that have been wax-resin lined and are treating such paintings despite a lack of scientific research on the overall consequences of the technique for present conservation. The present study is only a start in a broader field of research into the impact of the physical modification of the wax-resin adhesive on the conservation of paintings today. More insight based on scientific research is therefore essential and timely. Research into the effects of wax-resin linings includes numerous lines of study, each of which have a high level of significance for paintings conservation, conservation history and art history. In order to maximize the benefits for different fields of interest, it is crucial to investigate these lines in an integrated and concerted manner. While new knowledge is required, one should not forget that significant aspects have already been investigated, especially with regard to the history of the technique. This information is, however, spread between various institutes and the creation of a place of reference for the conservation of wax-resin lined paintings could help to remedy this. It would centralize and coordinate existing information on the history and conservation of wax-resin lined paintings, as well as create new knowledge integrated with past research. The creation of such a centre in the Conservation-Restoration department at the University of Amsterdam is not only relevant because of the history of wax-resin linings that is tightly connected with the Netherlands but also due to the fundamental role of the University in carrying out scientific research and supporting the sharing and dissemination of knowledge.

Nederlandse samenvatting

De gevolgen van was-hars bedoeking voor de huidige uiterlijk en conservering van 17de eeuwse Nederlandse schilderijen op doek

Achtergrond informatie

Dit proefschrift onderzoekt de omstandigheden waaronder, en de mate waarin, was-hars bedoekingen het oppervlakte-beeld van zeventiende-eeuwse Nederlandse schilderijen kan hebben veranderd. Het bedoeken van schilderijen is een restauratiemethode bedoeld om verzwakt schilderdoek te consolideren. In Nederland hield, vanaf het midden van de negentiende eeuw, de traditionele methode van het bedoeken van schilderijen in dat er gebruik werd gemaakt van een specie op basis van een mengsel van bijenwas en natuurlijk hars, vandaar de term “was-hars bedoeking”. Omdat was-hars bedoeken tot de zeventigerjaren werd beschouwd als een behandeling voor totale verbetering, werd het systematisch op schilderijen toegepast. Praktisch gesproken houdt de techniek in dat een nieuw doek wordt toegevoegd aan de achterzijde van het origineel en dat de gehele structuur geïmpregneerd wordt met het was-hars mengsel. Het smelten van de specie werd bereikt door het gebruik van hete handstrijkijzers.

Reeds vroeg in de geschiedenis van het was-hars bedoeken, verwijzen documenten naar de ongewenste gevolgen van deze techniek, met name de kleurverandering van schilderijen werd regelmatig benoemd. Niettemin werd de techniek alom toegepast tot de zeventigerjaren. Vanaf het midden van de twintigste eeuw, met het opkomen van de gedragsregels voor conservering, begon men de methode als problematisch te zien en begon de houding tegenover de was-hars bedoeking te veranderen, alternatieve technieken voor structurele behandelingen van schilderijen werden ontwikkeld.

Het belang van het onderzoek

De meeste schilderijen die op dit moment in Nederland bewaard zijn gebleven zijn bedoekt met was en hars. De schatting is dat bijvoorbeeld 95% van de schilderijen uit de Gouden Eeuw op deze manier zijn behandeld. Er bestond tot nu toe echter weinig wetenschappelijk onderzoek naar de invloed van was-hars bedoekingen op de conservering van deze schilderijen. Om dit gemis aan kennis aan te vullen wordt in dit proefschrift de kleurverandering onderzocht van de gronderingen van zeventiende-eeuwse Nederlandse schildrijen op doek. Deze invalshoek werd gekozen vanwege de gebruikte schildertechnieken in deze werken waarbij de grondering vaak zichtbaar werd gelaten om te worden gebruikt als middentoon, of door een dunne glacering aan te brengen om zo de vloeiende overgang te verkrijgen van schaduw naar hooglichten. Een verandering in kleurschakering van de ondergrond verandert daarmee in belangrijke mate het esthetisch karakter van de schildering hetgeen kan leiden tot misverstanden bij de interpretatie van het werk. De verandering van kleurtoon van de grondering, wordt veroorzaakt door het binnendringen van de bedoekingsspecie in de ondergrond van het schilderij. Kleurverandering is daarom een duidelijke aanwijzing dat materiele kenmerken van de verflaag fundamenteel zijn veranderd waardoor wellicht een specifieke conserveringsbenadering vereist is.

Doelstellingen

Was-hars bedoeking kan het beeld van de zeventiende-eeuwse Nederlandse schilderijen hebben veranderd. Dit onderzoek is erop gericht, middels het verklaren van de omstandigheden waaronder dit gebeurde, om schilderijrestauratoren in staat te stellen de visuele veranderingen te herkennen en te begrijpen als wel hen in staat te stellen om beter op conserveringsproblemen in te kunnen spelen. Daarbij, de onderzoeksresultaten zouden voor restauratoren en kunsthistorici nieuwe input kunnen leveren om zowel een inschatting te kunnen maken van het originele beeld van de schilderijen alsook ook de impact te kunnen bepalen van de visuele veranderingen als gevolg van hun fysieke geschiedenis.

Hypothese

De basis voor de onderzoekshypothese werd gevonden in concrete aanwijzingen in de schilderijen van Jacob Jordaans (1593-1678) in het Koninklijk Paleis te Amsterdam. Technisch onderzoek wees uit dat, hoewel de vier schilderijen van de Vlaamse schilder waren verouderd onder dezelfde omstandigheden en dezelfde restauratiebehandelingen hadden ondergaan (inclusief was-hars bedoeking), zij zich nu in geheel verschillende materiele conditie bevinden. Wat bijzonder opviel waren de verschillende gradaties van verdonkering wat in sommige gevallen een juiste interpretatie van de afbeelding verhinderde. Technisch onderzoek onderkende het gebruik van verschillende type gronderingen die verschillen in zowel het aantal lagen als in samenstelling. Interessant is te noemen dat enkele ervaren restauratoren hebben beschreven dat kleurverandering in schilderijen na was-hars bedoeking mogelijk afhankelijk kan zijn van de compositie van de grondering. De samenhang tussen feitelijk bewijsmateriaal en geschreven bronnen ondersteunt in deze studie de naar voren gebrachte hypothese dat de visuele gevolgen van een was-hars bedoeking van zeventiende-eeuwse Nederlandse schilderijen op doek is gerelateerd aan de originele gronderingstechniek. Eerdere studies die zich bezig hielden met deze vraag betreft het onderzoek door de National Gallery, Londen, in de tachtiger jaren en die van 2010 door het Van Gogh Museum, Amsterdam. Deze studies vormden een basis voor de ontwikkeling van het huidige onderzoek door informatie te verschaffen over proefmonsters en methodes voor kleurmeting.

Onderzoeksmethodologie

De huidige studie neemt drie hoofdfactoren in overweging. Ten eerste, de materiele en fysieke kenmerken van gronderingslagen voor schilderijen op doek, gemaakt in de Nederlanden in de zeventiende-eeuw. Ten tweede, materiële veranderingen die manifest kunnen worden in deze gronderingslagen als gevolg van natuurlijke veroudering en/of restauratiebehandelingen voordat was-hars gebruikt werd. Ten slotte, de verschillende was-hars bedoekingsmethodes die gebruikt werden door Nederlandse schilderijrestauratoren vanaf het midden van de negentiende-eeuw tot de zeventiger jaren. Om de invloed van ieder van de factoren te kunnen bestuderen, omvatte de onderzoeksmethode het technisch onderzoek van zeventiende-eeuwse Nederlandse schilderijen op doek, de studie van historische documenten, praktische experimenten uitgevoerd op reconstructies en analytisch onderzoek met behulp van natuurwetenschappelijk onderzoeksmateriaal.

Centraal in de onderzoeksbenadering stond de bestudering van visuele verschijnselen die waargenomen werden op reconstructies die gemaakt waren met materialen en technieken

gebaseerd op concreet bewijs van de schilderijen, geselecteerd vanwege hun relevantie voor het onderzoek. Dit betroffen werken van Jacob Jordaens, inclusief de vier schilderijen die hij in 1660 maakte voor het Amsterdamse Stadhuis (het huidige Koninklijk Paleis) en *Susanna en de Twee Ouderlingen* uit 1653 (National Gallery, Denemarken). Daarnaast omvatte de lijst schilderijen van Gerard van Honthorst (1592-1656) en Theodor van Thulden (1606-1678), gemaakt van 1648 tot 1651 voor de Oranjezaal, als ook *De Nachtwacht* uit 1642, door Rembrandt van Rijn (Rijksmuseum, Amsterdam). Recepten voor gronderingen die in documenten gevonden werden uit die periode en resultaten van technisch onderzoek van andere schilderijen werden ook gebruikt.

De gekozen materialen voor het maken van de reconstructies betroffen negen verschillende pigmenten: kalk, loodwit, omber, gele ijzeroxide, rood ijzer oxide, pannen rood, houtskool zwart, kwarts zand en twee types klei. Ook werden twee soorten bindmiddel gebruikt – namelijk lijnzaadolie en dierlijke lijm. De pigmenten werden, puur of gemengd in verschillende percentages, gebruikt. De grondering doet de verdonkering van het doek teniet (dekkraft). De hypothese is dat de mate waarin dat gebeurt een hoofdrol speelt in de kleurverandering van de onderliggende lagen. Teneinde de invloed te onderzoeken van de dekkraft van gronderingen op kleurverandering na impregnatie, werden verschillende samenstellingen in diverse diktes op het doek aangebracht.

Daarnaast, een pilotstudie betrof de systematische toepassing van verschillende diktes op opaciteitskaarten.

De toegepaste bedoekingsmethode op reconstructies kwam voort uit onderzoek naar de historische praktijk, hoewel deze af en toe moest worden aangepast om variabelen te minimaliseren.

Kleurmetingen werden vastgelegd met een spectrofotometer. Het CIELAB kleurmodel werd gebruikt en kleurverschillen werden berekend met de 1976 CIELAB kleurnormen. De verzamelde kleur-data werden geëvalueerd op holistische wijze en meegenomen bij metingen van gronderingmonsters opaciteitskaarten. Tevens werden dwarsdoorsnedes van verfmonsters van de reconstructies geanalyseerd met behulp van lichtmicroscopie waarmee nog meer inzicht werd verkregen in de invloed van de laagdikte. Om hun deugdelijkheid te testen werden de resultaten vervolgens vergeleken met de fysieke karakteristieken van de echte schilderijen.

Resultaten

Resultaten van de experimenten lieten zien dat het impregneren met was-hars kleurveranderingen veroorzaakte in een aantal geteste reconstructies. Vergelijkende kleurmetingen van de reconstructies lieten zien dat, in de meeste gevallen, de L^* , a^* en b^* waarden van de gronderingen na het impregneren afnamen, hetgeen er op wijst dat de kleur van de gronderingen donkerder en koeler van tint werden. Studie van de resultaten van de kleurmetingen liet zien dat de mate van verandering werd beïnvloed door het type bindmiddel en de anorganische componenten, als ook de relatieve proporties van de laatste. Verder, resultaten van de studie van de dekkraft lieten zien dat alle soorten grondering-types die kleurverandering ondergingen na het impregneren een slechte dekkraft bezaten. Dit versterkte de hypothese dat de dekkraft van de grondering kleurverandering beïnvloedt. De verandering in toon van de reconstructies naar een koelere toon werd beschouwd als een extra teken van de invloed van de dekkraft aangezien dit te wijten kan zijn aan een *turbid medium effect* dat typisch plaatsvindt

wanneer een licht gekleurde dunne verflaag een meer donkere en warmere laag daaronder bedekt.

Kleurmetingen van de gronderingsreconstructies lieten zien dat de lijm-gebonden grondering meer van kleur veranderde dan de olie-gebonden grondering. De veronderstelling was dat het sterkere absorptievermogen van deze grondering vergeleken met de grondering van lijnzaadolie, dit verschil in kleurverandering veroorzaakte. Het opvullen van de vides, inherent aan de lijm-gebonden grondering met was-hars, resulteerde in veranderingen in de brekingsindex en de oppervlaktestructuur. Men veronderstelde dat deze twee fenomenen de kleurveranderingen in de dierlijke lijm-gebonden grondering duidelijk versterkte, vergeleken met de olie-gebonden grondering waarin de was-hars niet doordrong.

Van de reconstructies gebonden in dierlijke lijm veranderde diegene het meest na de was-hars impregnatie die uit kalk bestond. Deze reconstructie is de enige waar de kleurverandering in tint naar een meer gele en rode kleur ging. Van de reconstructie gebonden in lijnzaadolie veranderden diegenen na de behandeling, die bestonden uit kalk of *ball clay* het meest significant. Daarna volgden loodwit en Maasklei waarvan de grondering slechts licht veranderde terwijl de grondering die bestond uit rood ijzeroxide, geel ijzeroxide, rauwe omber en houtskool zwart in het geheel niet veranderden.

Onderzoek toonde eveneens aan dat de ratio van kalk in geel ijzeroxide, rauwe omber of loodwit, of in de combinatie van geel ijzeroxide en rauwe omber, een belangrijke factor was in de kleurverandering van de oliegebonden grondering samengesteld uit pigmentmengsels. Kleurmetingen lieten zien dat, in het algemeen, hoe hoger de concentratie van kalk hoe sterker de kleurverandering. Daarbij kwam dat de resultaten suggereren dat de invloed van kalk op de mate van kleurverandering afhankelijk is van het pigment waarmee het gemengd wordt, zo vond er bijvoorbeeld geen kleurverandering plaats in de gronderingsreconstructies die bestond uit kalk en rauwe omber. De studie van de dekkraft ondersteunde deze resultaten aangezien trends aangaven dat hoe hoger het aandeel kalk hoe minder de grondering het substraat verborg waarop het was toegepast. Het minimum aandeel van kalk waarbij kleurverandering werd gemeten varieerde afhankelijk van de andere componenten in de grondering. Kleurmetingen lieten ook zien dat wanneer de grondering, bestaande uit loodwit en kalk, en voor 10% bestond uit rauwe omber er in het geheel geen kleurverandering plaatsvond. Er werd zelfs geen kleurverandering gemeten als het aandeel kalk 50 tot 70% was.

Elk oliegebonden reconstructie die kwarts bevatte liet substantiële kleurverandering zien na een was-hars impregnatie. De kleurverandering in dit type grondering behoorde tot de meest significante van alle geteste oliegebonden gronderingen. Trends gaven aan dat hoe hoger de kwartsconcentratie hoe groter de kleurverandering was na impregnatie. Hoewel de toevoeging van 3% geel ijzeroxide dit effect neigde te reduceren bleef de kleurverandering van de grondering significant. De studie van de dekkraft gaf aan dat hoe hoger de kwartsconcentratie was hoe minder de dekkraft waarmee de invloed van de dekkraft op de kleurverandering van reconstructies bevestigd werd.

Onderzoek toonde ook aan dat de invloed van de dikte varieerde, afhankelijk van de soorten en proporties van de anorganische componenten in de grondering. Bijvoorbeeld, de grondering bestaande uit kalk in dierlijke lijm deed de kleur meer significant veranderen wanneer het dun werd toegepast. Vergelijkbare trends werden gevonden ten aanzien van oliegebonden

gronderingen die bestaan uit a) *ball clay* of loodwit, b) 98% kalk gemengd met of geel ijzeroxide of combinaties van geel ijzeroxide en rauwe omber in gelijke porties, c) 80% kalk met loodwit. Aan de andere kant, de dikte van de laag had geen invloed op de mate van kleurverandering bij de oliegebonden grondering die bestond uit loodwit en rauwe omber (zelfs met 70% kalk). Tenslotte, de grondering die kwarts en *ball clay* bevatte veranderde in gelijke mate van kleur ongeacht de dikte van de toepassing.

De studie van de dekkkracht toonde aan dat de dikte van de laag de dekkkracht van bepaalde onderzochte gronderingen aanzienlijk beïnvloedde. Een algemene trend was dat hoe dunner de grondering was hoe minder dekkend hij was, waarmee de resultaten van kleurmetingen bij de reconstructies op schilderdoek werden ondersteund. Een uitzondering was de grondering die bestond uit kalk en geel ijzeroxide in lijnzaadolie waarbij de kleurmetingen niet eenduidig waren.

Evaluatie

De resultaten van kleurmetingen van gronderingsreconstructies toonden zelden een exacte match met de grondering van historische schilderijen. Hoewel de compositie van de reconstructie was gebaseerd op feitelijk bewijs gevonden in de zeventiende-eeuwse Nederlandse schilderijen, waren er significante factoren die de reconstructies onderscheidden van de echte schilderijen en die conclusies uitsloten over de originele kleur van de grondering voor het bedoekingsproces.

In plaats daarvan, de analyse van de onderzoeksbevindingen maakte de identificatie mogelijk van trends die de waarschijnlijkheid kunnen voorspellen dat schilderijen met een bepaalde gronderings-karakteristiek visueel zijn veranderd bij de impregnatie van de was-hars bedoeking. Het zou voor toekomstig onderzoek erg interessant zijn om het type grondering dat wordt onderzocht te verbreden. Bijvoorbeeld, oliegebonden grondering die loodwit bevat combineren met verschillende pigmentmengsels en proporties van kalk, rode grondering en dubbele grondering. Het onderzoek liet ook zien dat de aangetaste aanblik van de oppervlakte van de grondering een verschijnsel kan zijn die voortkomt uit de was-hars impregnatie.

Het lijkt er nu op dat de aanwezigheid van lijm in de doekstructuur, die verantwoordelijk is voor het donkerder worden van de drager, oorzaak is van de visuele aantasting van het beeld van het schilderij. Correctie van dit effect zou het onttrekken kunnen inhouden van de was-hars uit de structuur van het schilderij, tenminste ervan uitgaande dat deze behandeling de originele kleur van de grondering zou kunnen onthullen. Onderzoek uit het verleden van dit onderwerp is niet beslissend geweest en de vraag blijft of een volledige onttrekking de kleur van het schilderij van voor de was-hars behandeling zou terugbrengen. Ook is er de vraag of een dergelijke behandeling de schilderijen zou kunnen blootstellen aan het hoge risico van delaminatie.

Sleutel bij de interpretatie van visuele fenomenen was de correlatie van kleurmetingen van gronderingsreconstructies op doek met metingen van diezelfde gronderingen toegepast op opaciteits-kaarten. Dit stelde ons in staat een analyse te maken van de invloed van de dekkkracht van de grondlaag op de mate van kleurverandering. De vraag of de kleurverandering in oliegebonden gronderingen alleen te wijten is aan de originele dekkkracht van dit type grondering of dat deze eigenschap werd veranderd door de impregnatie van was-hars, kon niet worden opgehelderd. Daarom zijn de diverse kenmerken van de mate van was-hars impregnatie in oliegebonden grondering een belangrijk gebied van toekomstig onderzoek. Deze vraag, gekoppeld aan de poreusheid van oliegebonden grondering, is zeer belangrijk aangezien verondersteld wordt dat deze poreusheid toeneemt bij het ouder worden wat op zich weer

gunstige condities schept ten aanzien van kleurverandering. Dit onderzoek zou kunnen worden uitgevoerd door een systematische vergelijkende studie van zowel bedoekte als onbedoekte schilderijen.

Conclusie

Wereldwijd worden schilderijrestauratoren vaak geconfronteerd met het restaureren van schilderijen die met was-hars zijn behandeld, en deze schilderijen behandelen ondanks een gebrek aan wetenschappelijke onderbouwing met betrekking tot de algemene consequenties van die techniek voor de huidige conservering. De huidige studie is slechts een begin van een breder onderzoeksveld naar de invloed van de fysieke verandering van was-hars lijm op de tegenwoordige restauratie van schilderijen. Het is daarom essentieel, en ook het goede moment, om inzichten te verkrijgen gebaseerd op wetenschappelijk onderzoek. Onderzoek naar de effecten van was-hars bedoekingen omvat diverse studiegebieden die ieder op zich van groot belang zijn voor schilderijenrestauratie, restauratiegeschiedenis en kunstgeschiedenis.

Teneinde de voordelen voor de verschillende gebieden te maximaliseren is het cruciaal deze gebieden te onderzoeken op een geïntegreerde en gecoördineerde wijze. Hoewel nieuwe kennis en inzichten vereist zijn moet niet worden vergeten dat belangrijke onderdelen reeds zijn onderzocht met name waar het gaat om de geschiedenis van de techniek. Deze informatie is echter verspreid over verschillende instituten en het opzetten van een gespecialiseerd centrum voor de restauratie van was-hars bedoeking van schilderijen zou dit kunnen verhelpen. Het zou bestaande kennis met betrekking tot de geschiedenis en restauratie van was-hars bedoekte schilderijen centraliseren en coördineren, alsook nieuwe kennis met reeds verricht onderzoek integreren. De oprichting van een dergelijk centrum bij de afdeling Conservering-en- Restauratie van de Universiteit van Amsterdam is niet alleen relevant vanwege de geschiedenis van was-hars bedoeking die nauw verbonden is met Nederland maar is ook van belang vanwege de fundamentele rol die de Universiteit speelt bij het uitvoeren van wetenschappelijk onderzoek en het ondersteunen, delen en verspreiden van deze kennis.

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