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Digital image processing: How to retouch your clinical photographs

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Before the widespread use of computers, before scanners and digital cameras were used by orthodontists, there was one crucial moment that determined whether a clinical picture would be good or not, and that was when we pressed the shutter release button. After that, there was not much we could do. Poor image quality could be the result of any number of factors, including amount of lighting (too dark, too washed-out, flash did not go off), color balance (too red, too green), alignment (skewed to the left), cropping (way off to the right), background showing (cheek retractors, fingers holding retractors, badly painted fingernails on fingers holding retractors), dust on the lens, food or plaque on teeth and brackets, saliva bubbles, etc. Fortunately, all of these problems can now be fixed, provided one is moderately proficient in the use of image manipulation software. Images taken directly with a digital camera and those produced by scanning a photograph or slide can now be "corrected" in very imaginative ways and appear original and unmodified to an unsuspecting audience. As an example, look at Fig 1. Can you tell what has been changed in this photograph? In the paragraphs that follow you will see how we can modify our clinical photographs either to remove flaws or to transform them into fictitious computer images. Please note that proper scientific conduct dictates that we should always report whether our images have been computer enhanced or modified.

Many software packages can be used for image manipulation. Examples include Adobe Photoshop, Adobe PhotoDeluxe, Ulead PhotoImpact, MGI PhotoSuite, Jasc Paint Shop Pro, Picture Window by Digital Light & Color, and Corel Photo-Paint. In the present paper we are going to use Adobe Photoshop 5.0 LE (Limited Edition) as an example. This program was selected because it is comprehensive enough to allow us to accomplish almost everything we would like to do, it has an acceptable learning curve, and, like some of the other available imaging programs, it will accept Photoshop plug-ins (add-on mini programs and filters used to extend or simplify corrective functions). Photoshop LE is a scaled-down version of Photoshop 5.5, which is currently one of the most widely used professional image software programs on the market. Photoshop LE is available for Windows PCs and Macs and is often included with the purchase of a scanner or other computer hardware. Most of the procedures described below can be accomplished using other software. The general approach should be similar, but the specific commands or tool names may differ.

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ALIGN AND CROP

If your image is not properly aligned, or contains more information than you need, correction is very easy. Fig 2 shows a scanned slide photograph with large unnecessary black areas and an excessively slanted occlusal plane. There are at least two ways to rotate an image in Photoshop. One is to use the Image-Rotate Canvas menu command. This has the Arbitrary... option with which you can enter the number of degrees to rotate the image clockwise or counter-clockwise. Unless you want to rotate a number of images by exactly the same amount, this method may not be very useful because you can seldom estimate the required number of degrees with any accuracy. The second method allows rotating with the mouse and gives immediate feedback on the process. To rotate in this way you must first select the entire image. Use Select-All to accomplish this. Next, select Edit-Transform-Rotate and position the mouse close to one of the corners of the image. The mouse pointer turns into a small semicircular arrow. Drag the mouse to rotate the image. Each time you let go of the mouse button, Photoshop repaints a draft version of the image so that you can make sure the change is satisfactory. You can also move the image up or down and left or right by dragging it with the mouse from any point in the center of the image. When you are satisfied, hit the Enter key. Use the Select-None command to de-select the image. The rotated photograph is shown in Fig 3. Notice that the corners of the picture have rotated out of view and will be lost when the image is saved. This does not happen if you use Image-Rotate Canvas. Instead, the image is enlarged to accommodate the rotation. The new areas that have come into view are filled with white, the default background color.

Cropping involves cutting and throwing away the peripheral parts of the image and keeping only the cen-

Fig 1. A computer modified image. Can you tell which areas have been modified? (The original image is in Fig 9).

Fig 2. A rather disappointing photograph. The image needs rotation and cropping.

tral portion that is of interest. Photoshop, like most imaging programs, has a special Crop tool. Select it from the Tools toolbox. If it is not visible, click and hold on the Marquee tool, or press the C key on the keyboard. Then use the mouse and drag on the image to select the area that you want to keep. You can resize or move the selected area using the small resize handles at the corners. Once you are satisfied, hit the Enter key to perform the crop (Fig 4). Note that in order to keep a reasonable part of the image, we had to include some white areas at the corners. The more rotation is needed, the larger these areas will be. These white areas can be corrected later by using some of the techniques discussed below. Nevertheless, always rotate first and crop next—not the other way around—to keep white areas to a minimum.

Fig 3. After rotation. Occlusal plane is now horizontal. The corners of the image have rotated out of view and are lost once the image is saved.

Fig 4. After cropping. Note that some areas of the image are white because cropping included parts of the rotated image that were not present in the original.

ADJUST FOR BRIGHTNESS, CONTRAST, AND COLOR

If the image does not look right with regard to brightness and contrast, it can be easily adjusted with the Brightness and Contrast controls. Such simple adjustments are not always enough because they affect all of the pixels in the image in a uniform way. Most of the time, the image needs different adjustments for the very bright, the very dark, and the intermediate range pixels. To understand this very important aspect of image enhancement we need to look at the histogram of the image.

Histogram

Fig 5 shows a photograph that appears too dark. Image-Adjust Levels opens a dialog box that displays a histogram of the pixel brightness levels in the image. The histogram shows how many pixels are present in the image at each of the brightness levels. Let's assume

that the image is a grayscale image (no color). Pixels in such an image can range from black (zero brightness) to white (full brightness). These values are coded in number format ranging from 0 (black) to 255 (white). Gray colors take values in between these extremes. Therefore, there are potentially 256 different brightness levels in an image. This peculiar number derives from the 8 bits (1 byte) that are used to hold the different brightness levels.[1] The image histogram shows how many pixels there are for each brightness level.

Observe that the histogram in Fig 5 is skewed to the left (low values), indicating that most pixels in the image are dark. Also, the histogram does not extend along the whole range of brightness values, but is concentrated in the middle gray part. Thus, although the image contains areas that should be very bright (the highlights of the flash on the teeth) and other areas that should be very dark (the dark spaces between upper and lower teeth), there are no pixels that have very high or very low brightness levels. In these cases we say that the tonal range is small. To improve the image we need to expand the tonal range to cover the area from white to black. We do this by moving the triangular sliders that are situated beneath the histogram. The white slider is moved until it is positioned at the right tail of the histogram and the black slider is moved to the left tail. Then the middle slider is adjusted until the image appears to have the correct brightness.

Fig 6 shows the corrected photograph and the new histogram. Notice that now the histogram covers the whole tonal range. It contains gaps because it was expanded from a smaller histogram. Gaps are larger in the dark areas where more expansion was required in order to make the image brighter. The middle slider that was used to adjust brightness is similar to the Gamma Correction control that is found in many image processing programs. Gamma correction is a simpler procedure that can effectively improve contrast but cannot change the tonal range because it affects only the mid-range tones.

Histogram manipulation is a very powerful technique for diagnosing and correcting image problems. Apart from overall brightness and contrast adjustments, it can also be used for correcting color. In color images it is possible to adjust the histogram for each of the three primary colors (red, green and blue) separately. This gives a more detailed control on color balance and tint than simpler Hue, Saturation, Tint, and Color Balance tools.

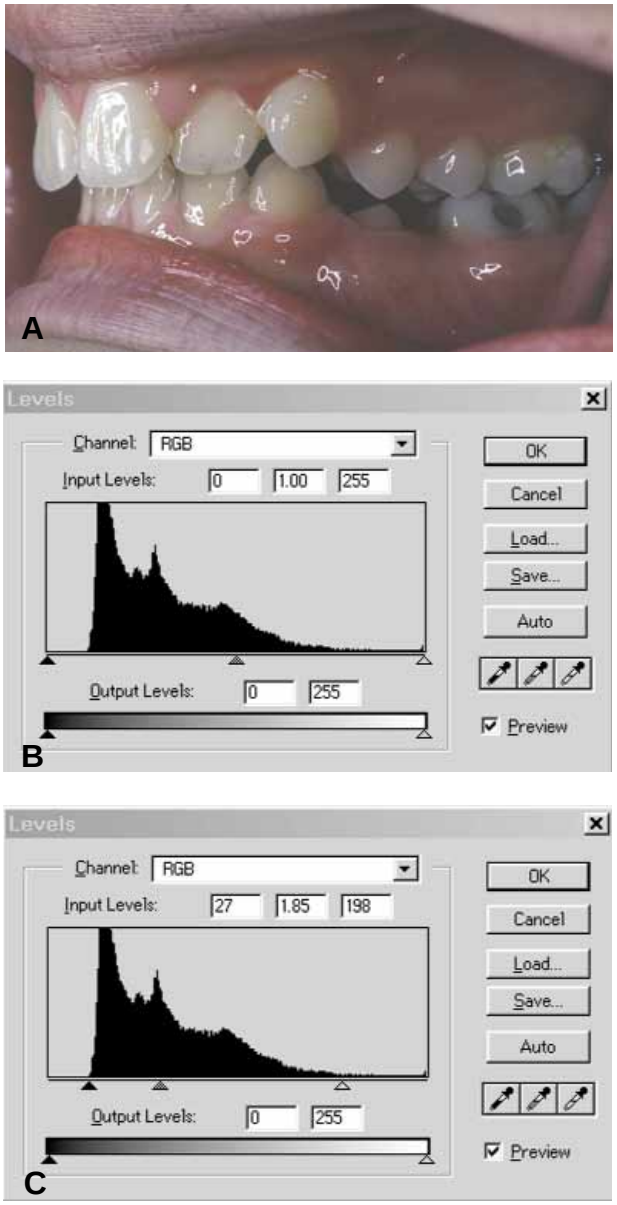

Fig 5. A, A photograph that looks too dark. **B**,The histogram as displayed by Photoshop. **C**,The histogram after adjusting the sliders beneath. The white and black slider should be positioned at the end points of the histogram. The mid-level slider can be adjusted until the overall brightness of the image looks good.

REMOVE SCRATCHES AND DUST

Scratches and dust are especially apparent on scanned slides because of the high resolution used in scanning. Thus, slides should be carefully cleaned before they are scanned. Adobe Photoshop comes with a special filter that removes these defects quite satisfactorily. Select Filter-Noise-Dust & Scratches and slowly increase the Radius slider until the defects disappear. Because this filter produces a kind of blurring

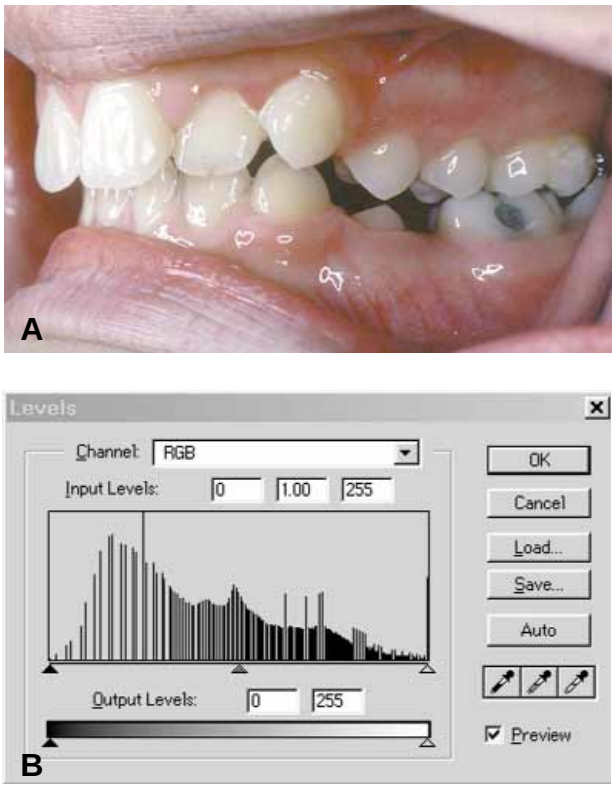

Fig 6. A, The corrected photograph of Fig 5. **B,** The corresponding histogram.

of the image, it is best to apply the filter only to the regions of the image that contain scratches and dust. To control the area being affected, use the Marquee or Lasso tool to select the area around each defect. Keep the Shift key pressed to select multiple areas, as shown in Fig 7. Use the Dust & Scratches filter with the smallest Radius setting that will still remove the defects. Small defects such as these can also be removed very effectively without affecting resolution by using the Clone tool, as will be discussed below.

REMOVE LARGE AREAS (CHEEK RETRACTORS, TEETH, CARIES, ETC)

Removing large areas of the image without leaving obvious marks is not as easy as removing small defects. The area covered by the unwanted object has to be filled with a realistic looking substitute. It is not sufficient to paint over a cheek retractor with a uniform pink color; the texture of the lips must be recreated. There are a number of tools and methods to accomplish this. Each is explained separately below, although they are usually used in combination to produce the desired result.

Fig 7. Small areas selected around dust on the image. The image was scanned from a slide. Multiple areas were selected by using Lasso and keeping the Shift key depressed.

Smudge tool

This tool can be likened to smudging wet colors in a painting with one's finger. The Smudge tool works by dragging the mouse from one area of the image to another. The colors are smeared over to the destination area. Smudge could be used to cover the white areas that were left over in Fig 4 by "pushing" the colors from the interior of the image towards the white corners. The direction of mouse movement is very important when using Smudge because it determines the direction in which the colors are pushed. The brush size and shape are also important. You will probably prefer a brush with a soft edge so that no obvious hard edges are left over.

Rubber Stamp tool (Clone tool)

The Clone tool is probably the most valuable tool available. It exists in all image-processing programs under various names. Basically, cloning tools allow you to duplicate (clone) selected pixels and replace the original pixels. To use this tool you first have to specify the source area on the image. Option-click (Macintosh) or Alt-click (Windows) to set the source point. Then drag the mouse to the destination part of the image. The Clone tool will copy the pixels from the source area and paint them on the destination area. By selecting the appropriate brush size and using it judiciously, you can quickly remove scratches, defects, and

Fig 8. Fig 4 after using Clone, together with some copying and pasting. Compare with the original photograph in Fig 2.

Fig 9. The original image that was used to create the image in Fig 1. Note the peg-shaped lateral incisor, metal cheek retractors, fillings on the centrals, and the rotated molar. There were also dust specks because this image was scanned from a slide.

dust with micro-surgical precision. You simply clone over the defect with pixels from the immediately adjacent area. Using the immediately adjacent area usually produces a better match than selecting pixels from other parts of the image. By copying the data from one area of an image to another, you replace existing data. You can make many improvements with this feature including extending the background to adjacent areas to cover blank spots caused by rotating an image, covering blemishes by cloning the adjacent area over them, copying a tooth to replace an extraction, "painting" a lip on top of a cheek retractor, and much more.

A brush with a soft edge is, again, a good choice. Generally, use a soft-edged brush when cloning, unless you are cloning a hard edge or are close to an adjacent hard edge. Thus, if you were removing a blemish in the middle of the lip, you would use a soft-edged brush but if you were cloning the edge of a lip, you would use either a hard-edged brush or a very small soft-edged brush. The reason for this is that soft-edged brushes scatter copied pixels to the surrounding area to hide the edges, while a hard-edged brush contains the pixels within the confines of the brush. When covering a cheek retractor, the soft-edged brush works well because you are cloning not only the lip but surrounding cheek area as well. The effective area of the cloning tool can be limited and controlled by first selecting the area to be cloned using Lasso or Marquee.

It is usually a good practice to magnify the area to be worked on as much as possible before applying cloning and other tools. Magnification increases the accuracy and ease of the correction. When the image is later viewed at normal size, minor errors created during the correction become almost insignificant.

The white areas in Fig 4, which were left over after rotating and cropping Fig 2, were covered primarily with the cloning tool. Some copying and pasting was also performed to get a more natural result, as shown in Fig 8.

Copy and Paste

This method is similar to using the Rubber Stamp tool but, instead of replacing individual pixels to duplicate a part of the image, we copy and paste a whole area in one step. Use Marquee or Lasso to select the desired part of the image. Magnetic Lasso is a good choice if you wish to select an area that is well demarcated from the background. Magnetic Lasso tries to automatically set the selection outline to follow sharp edges. Once an area is selected, it is usually a good idea to make the edges of the selection semitransparent so that it will blend smoothly with the rest of the image when pasted. To do this use Select-Feather. Specify the number of pixels to feather based on the size of the selection. The best value can usually be found by trial and error. Feathering can also be specified beforehand for each of the selection tools (Marquee or Lasso) by opening the tool's options. After feathering, use Edit-Copy to copy the selection to the clipboard. Then, use Edit-Paste to paste it on the image. Photoshop will paste the selection as a new layer on the image.

USE LAYERS

Layers can be likened to transparent sheets that are overlaid on the image. It is possible to paint on these sheets, edit them, and move them around without affecting the underlying image. This gives tremendous power to experiment before committing yourself to the final image. For example, assume that we want to add

Fig 10. The image after removing dust and the cheek retractors.

Fig 11. The image after building up the peg lateral and removing the central incisor restorations

some text on a clinical slide. Without the use of layers, the text would be painted permanently on the image. If the result was not satisfactory, it would be very difficult to erase the text, move it, or switch to another font. Using layers, we paint the text on a layer and place the layer on the image. It is very easy to move the layer or to delete it completely and try again without affecting the rest of the image. Also, multiple layers can be used and different effects can be tested by making each layer in turn visible or invisible. Layers provide a very quick and effective way to save and display a series of potential facial changes without altering the basic image permanently. Simply save each of the layers as a separate file and retrieve them as needed.

If an image contains layers it can only be saved in a Photoshop file format. To save such an image in other formats (eg, JPG or TIF), you first have to merge all layers into one with the Layer-Flatten Image command.

SAMPLE CORRECTIONS

We will close this discussion on the capabilities of image manipulation programs by describing how the image in Fig 1 was created. The original image is shown in Fig 9. This image was scanned from a slide and it had some dust specks. These dust specks were removed first by using the Dust & Scratches filter as described above (Fig 7). The metal cheek retractors were removed by using Smudge and working along the direction of the mucobuccal fold. This was effective for the left retractor (right side on the image) where a large part of the mucobuccal fold was visible and could be smudged toward the retractor. To remove the right cheek retractor, Rubber Stamp was used to copy the mucobuccal fold from the patient's left side. The tool's option was set to Clone (Non-Aligned) and the same part of the image was copied over the right cheek retractor to cover it completely. Then Smudge was used to touch up on some areas and blend them together. Rubber Stamp was used as a final touch to copy some lip texture where the cheek retractor crossed the lips. The result can be seen in Fig 10.

The peg lateral was built up by copying the left lateral on top of it. First, the left lateral was selected by using Magnetic Lasso. This tool did a good job of selecting the lateral along its edges. Next, the selection was enlarged, using Select-Modify-Enlarge, to include some gingiva around the tooth. Then it was feathered by 2 pixels and copied. After pasting on a new layer, it was flipped horizontally using Edit-Transform-Flip Horizontal and moved over the right lateral using Move. Because the space between the canine and the central is smaller than the pasted lateral, the lateral was slightly reduced in size, by using the Edit-Transform-Scale. Some pixels were also deleted along the periphery of the selection (with the Eraser), especially on the labial side where a highlight from the lip had been inadvertently copied along with the tooth. Finally, the incisor was made slightly darker by adjusting the middle slider of the Levels dialog box, as described in the histogram section above. All of these actions were done on the layer that contained the lateral incisor and did not affect the underlying image. This made it much easier to correct mistakes.

The fillings on the mesial of the central incisors were removed by using Smudge and Rubber Stamp (Clone). At this stage, the image appears as shown in Fig 11.

The molar was corrected in a manner similar to the correction of the lateral incisor. First the molar was selected by using Lasso and copied to a new layer. The selection extended beyond the molar toward the palatal

side so that the area would cover the rotated and palatally displaced molar when it was moved buccally. Next it was rotated by using Edit-Transform-Rotate and the mouse. Unwanted pixels at the edge of the selection were erased with the Eraser. The only problem was the mesial part of the amalgam that was still visible next to the premolar. This was covered by copying part of the second premolar of the opposite side. The final result is in Fig 1.

The reader should note that there are a number of alternate ways to accomplish tasks with digital imaging software. You, the software operator, must select the tools that will best accomplish the desired end result under a specific set of conditions.

A CAUTION: In order to preserve your original file and to avoid re-scanning or starting from scratch any time a mistake is made, make it a habit to save your image under a new file name after each satisfactory series of corrections. Make your next few corrections on the new image and save again under another new file name, and so forth. This approach will make it possible to try several alteration techniques or alterations without having to repeat a lot of detailed work. Also, if the computer crashes (as sometimes happens when working with memory-hungry applications and very large images) or power is interrupted, you will have the latest image saved and you won't lose hours of valuable work.

CONCLUSION

Image manipulation programs can be used to enhance our clinical pictures in a variety of ways. Aligning, cropping, color correction, and brightness and contrast adjustments are the most common uses and require a minimum of expertise. Some more advanced applications and examples were also demonstrated.

References

1. Swartz ML. Managing digital images. Am J Orthod Dentofacial Orthop 2000;118:354-8.

The use of computers, computer programs, and other computerized equipment to assist in the orthodontic practice will be reported under this section of the American Journal of Orthodontics and Dentofacial Orthopedics. Manuscripts, comments, and reprint requests, unless otherwise noted, may be submitted to Dr Martin Abelson, 14720 N Shotgun Pl, Tuscson, AZ 85737.

CONTRIBUTORS WANTED!

The possibilities for computers are limitless, as is our job. Our research team is the world of clinicians who try new ideas and concepts. To grow, we must share. If you do not have time to write a formal paper, submit an outline with all pertinent facts and findings. We will complete the job.

MA, DH, & RS.