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A simplified three-dimensional volume measurement technique in keloid scars: Validity and reliability

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Summary *Introduction:* Effective treatment of keloid scars is important because patients are often confronted with major cosmetic, psychological, and social consequences. Three-dimensional (3D) imaging has been reported for the evaluation of keloid treatment. These techniques were complex to use in clinical practice. In this study, the validity and reliability of a simplified 3D volume measurement technique are defined.
Methods: Thirty-three scars were simulated using deformable modeling compound. The volume of the compound is calculated using the weight and density of the modeling compound, and it is compared with the 3D volume measurement.
Results: The mean simulated keloid volume was 2.884 cc. The correlation was very high ($r = 0.999$), but there was a significant mean difference of 0.252 cc ($p < 0.001$). This was corrected using a formula, *actual volume = 1.072 × measured volume*. This formula was validated using a new data set of 33 simulated scars. There was a nonsignificant mean difference of 0.010 cc ($p = 0.731$).

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Conclusion: This 3D measurement technique combined with the correcting formula is valid and reliable to be used in practice for the evaluation of keloid scar treatment.

Introduction

Keloid scars, or keloids, are pathological scars as a result of dermal injury, and they exhibit exuberant, indefinite growth of collagen during wound healing.[1] Every year, 15 million patients in the developed world acquire these pathological scars.[2] Keloids often cause symptoms such as hypersensitivity, pruritus, or pain.[3] Patients are often affected with major cosmetic, psychological, and social consequences.[3] Effective treatment and prevention of keloids are therefore important in clinical practice.

Various methods are available to evaluate the outcome of keloid treatment. The first objective method ever reported is the clinical evaluation using the Vancouver Scar Scale dating from 1990.[4] In 2004, another assessment scale was introduced in which patients' ratings were included: the Patient and Observer Scar Assessment Scale (POSAS).[5] These assessment scales are both validated tools to evaluate scars, but both tools have inter-rater variations with a minimal correlation.[6–8] An objective method in which volume is measured is the use of impression material, which has been described in 2000.[9] However, this technique has been shown to be not exact enough to measure keloid volumes, because the material deformed the keloid and the negative impression had to be filled with liquid to measure the volume. In 2003, Har-Shai et al. used >99.5% polysiloxane high-precision impression material for more precision.[10] Another method is the use of ultrasound to measure keloid thickness; however, this technique is limited to the assessment of the cross-sectional depth, and it is not able to measure volume.[11]

In 2007, Taylor et al. reported a new technique to measure keloid volume using a three-dimensional (3D) imaging.[12] 3D imaging was first used for the assessment of craniofacial morphology.[13–16] For volume measurements, the technique was used to evaluate lipofilling[17] and esthetic breast surgery.[18–20] However, 3D imaging has shown some downsides. In breast volume measurements, the mean error is 4.0–6.9%, depending on the volume. 3D breast imaging has higher volume errors in higher volumes.[18] Eder et al. reported a slightly higher deviation of 1.63% in 3D volume measurement versus 1.10% in magnetic resonance imaging (MRI)-scan volume measurements.[21] In keloids, Ardehali et al. validated the 3D volume measurement in 2007.[3] After validation, they used this technique in practice to evaluate keloid therapy with steroid injections. They reported a Pearson's correlation coefficient of 0.998 (p-value of <0.0001) and a relationship between the actual and 3D-measured volume of 1.0766 ($\pm$0.0110); the actual volume of a keloid was 1.0766, which is smaller than the 3D-measured volume.

For this study, we developed a technique to measure keloid scar volumes, which is easier in use than the technique described by Ardehali et al.[3] This study aims to define the validity and reliability of this technique. We also wanted to define the impact of volume in the accuracy of the 3D volume measurements using this simplified technique. Our goal was to increase the use of the 3D volume measurements in clinical practice for the evaluation of keloids.

Methods

Objective determination of keloid volume

Thirty-three scars were simulated using deformable modeling compound. The density of this deformable modeling compound was determined using water shift in a graduated 5 cc cylinder and the measured mass in 10 random objects. The mass was measured under laboratory conditions using a scale accurate to 1.0 mg. The density of the deformable modeling compound was 1.25 g/cm^3 ($\pm$0.02).

The mass of each simulated keloid was measured before application to the sternum of a subject. The application was performed in a similar way in each simulated keloid. The deformable compound was applied with latex gloves. All measurements were performed in a room with climate control. The actual volume of each simulated scar was calculated using the formula, $Mass = Density \times Volume$.

3D imaging system

The Vectra XT 3D imaging system (Canfield Imaging Systems, Fairfield, NJ, USA) was used to obtain 3D images (Figure 1). The camera determines points in three dimensions by a triangular position of six color digital

Figure 1 Canfield vectra XT camera setup.