

Tooth Color Measurement Reproducibility and Examiner Reliability Using Digital Imaging

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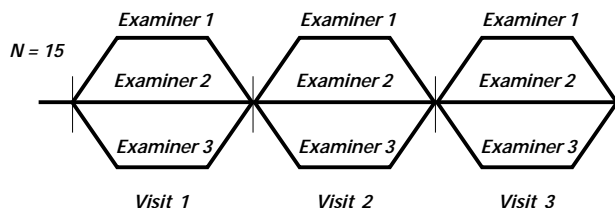


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ABSTRACT

Objective: This research evaluated the measurement reproducibility and inter-examiner reliability of a digital imaging system used clinically to measure tooth color. **Methods:** Digital images of the anterior teeth were collected from 15 adults using a standard method involving a chin rest, high resolution digital camera, and fixed lighting conditions. Using a 3-period crossover randomization, images were collected by 3 different examiners. All 3 imaging examiners collected images again at 2 subsequent visits within a two-day period, in order to introduce subject repositioning as part of the reproducibility assessment. L*a*b* tooth color was measured from each digital image. Intra-class correlations (ICC) and 95% confidence intervals (95% CI) were calculated using a 0-1 scale, where 0 represented no agreement and 1 represented perfect agreement. **Results:** Each examiner exhibited measurement reproducibility for b* (yellowness) across visits, with ICC ranging from 0.975-0.980. Similar reproducibility was demonstrated for L* (lightness) and a* (redness), with ICC ranging from 0.959-0.982, depending on examiner and color parameter. For each examiner, 95% CI lower bounds for the ICC of b*, L* and a* ranged from 0.920-0.965. Inter-examiner reliability was similarly high, with ICC ranging from 0.987-0.993 for b*, 0.981-0.990 for L*, and 0.986-0.992 for a* depending on visit. Between-examiner 95% CI lower bounds for the ICC of b*, L* and a* ranged from 0.962-0.986. **Conclusion: Clinical measurement of tooth color from digital images was highly reproducible across visits, and highly reliable across examiners, with intra-class correlations exceeding 0.95.**

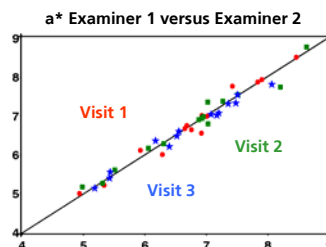
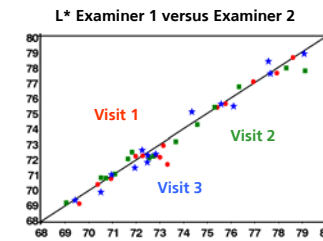
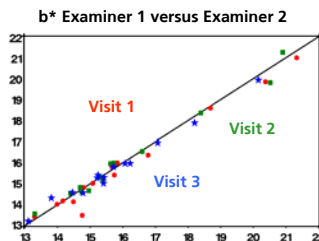
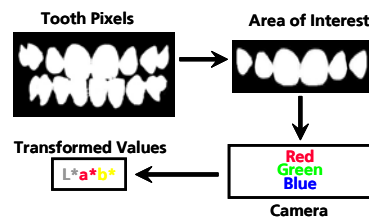
STUDY DESIGN



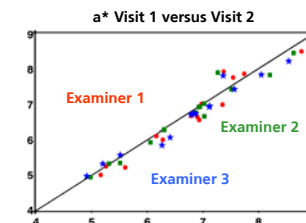
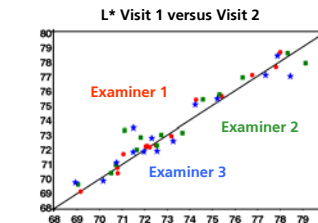
A crossover design was used with 3 examiners, 3 periods, 6 sequences, and measured at 3 separate visits (9 total measurements per adult volunteer).

MATERIALS AND METHODS

Digital Image Analysis Color Measurement



RESULTS



Measurement Reproducibility Intra-Class Correlation (95% CI)

	Visit 1	Visit 2	Visit 3
L*	0.982 (0.965, 1)	0.960 (0.923, 1)	0.965 (0.931, 1)
a*	0.959 (0.920, 1)	0.967 (0.934, 1)	0.965 (0.932, 1)
b*	0.975 (0.944, 1)	0.977 (0.955, 1)	0.980 (0.959, 1)

The following formula was used:

$$\text{Intra-Class Correlation} = \frac{\sigma_B^2}{\sigma_B^2 + \sigma_W^2 + \sigma_E^2}$$

where σ_B^2 = between-subject variance, σ_W^2 = within-subject variance, σ_E^2 = error variance. This measure ranges from 0 to 1, where 0 represents no association and 1 represents perfect agreement. Variances were estimated using analysis of variance (ANOVA) methods. 95% confidence intervals were also calculated.

Inter-Examiner (Operator) Reliability Intra-Class Correlation (95% CI)

	Visit 1	Visit 2	Visit 3
L*	0.981 (0.962, 1)	0.988 (0.976, 1)	0.990 (0.979, 1)
a*	0.986 (0.972, 1)	0.988 (0.975, 1)	0.992 (0.984, 1)
b*	0.987 (0.973, 1)	0.993 (0.985, 1)	0.993 (0.986, 1)

CONCLUSION

Clinical measurement of tooth color from digital images was highly reproducible across visits, and highly reliable across examiners, with intra-class correlations exceeding 0.95.