## F27 The Correlated, Non-Independent Nature of the Human Dentition: Why the Product Rule Cannot Be Used

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This goal of this presentation is to show that the human dentition has correlated, non-independent features which render the use of the product rule invalid as a means of determining dental uniqueness.

This presentation will impact the forensic science community by demonstrating how the use of the product rule is an improper means to statistically analyze the human dentition.

One of the fundamental principles of the bitemark analysis assumes that the human dentition is unique. However, there are very few published studies that explore this issue. One oft-cited paper that attempted to prove the uniqueness of the dentition was published in

In this work, the product rule was used to determine that the number of possible combinations of human tooth positions in the lower

jaw alone is on the order of $6.08 \times 10^{12}$. This study ignored the possibilities of biological correlation and also assumed a uniform distribution of tooth position to make this claim.

The questions are thus: Are the features of the dentition correlated? Are they uniformly distributed? Do the biological features of the human dentition demand more nuanced approaches than the product rule?

Two data sets of the human mandible were randomly collected. HSIRB exemption was approved for each set. One set consisted of 172 3D laser scanned models. The second set consisted of 344 2D models that were scanned on a flatbed scanner. Landmark points were first measured on the dentitions. The center position of each tooth and the angle the tooth made in a horizontal plane was calculated. The 2D or 3D nature of the source was immaterial as the information extracted was independent of the third dimension. The arches were oriented such that the distal of the canines touched a baseline and a perpendicular line was drawn from the baseline to the mesial of the right central incisor. This resulted in a set of three measurements per tooth, *x* and *y* coordinates measured with a resolution of +-1 mm and angles measured to +-5 degrees. The data distribution was then recorded.

Two simulation tests were performed to examine the effects of correlation and non-uniform distribution. The first simulation used was a permutation test. In this procedure, a simulated data set was created using the original tooth measurements, but randomly assigning measurements to specimens using a random number generator. The *x*, *y* and angle measurements were permuted independently. This procedure preserves the distributions of individual measurements, so that histograms of the individual measurements (*x*, *y* position or angle values) are identical to the histograms seen in the original data. However, the permutation test as used here destroys all the *correlation* between measurements that was present in the original data. So the permutation test allows one to see how important correlation is in the data set. This simulation was repeated 1,000 times.

The second simulation used was a Monte Carlo simulation that assumed uniform distributions of all measurements over the observed measurement ranges, which is the assumption made implicitly in Rawson's model. To generate such a simulation, the range of possible tooth positions was calculated from the empirical observations in the datasets. Then simulated specimens were assigned measurements *randomly distributed* over the observed range with no correlation between measurements. As in the permutation test, the simulation was repeated 1,000 times.

Results show that the features of the human dentition are highly correlated and show a non-uniform distribution.

Conclusions indicate that the use of the product rule is an invalid means of describing the human dentition and should be avoided. **References:**

1. Rawson RD, Ommen RK, Kinard G, Johnson J, Yfantis A. Statistical evidence for the individuality of the human dentition. J Forensic Sci 1984;29(1):245-53.

**Bitemarks, Bitemark Research, Dental Uniqueness**

 ** Presenting Author*