ORIGINAL ARTICLE

Validation of the efficacy of age assessment by the Brothwell tooth wear chart, using skulls of known age at death

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Abstract

Objective: The present study aims to validate the efficacy of age assessment by the Brothwell tooth wear chart, uniquely using skulls of recorded known age at death. **Materials and Methods:** Fifty Chinese skulls, of known age recorded at death, ranging from 16 to 62 years, were used. All the skulls were anonymized laid out, numbered 1–50, and using randomized tables. A 70-mm, ×3 magnification glass with light (Rolson, Ruscombe, Twyford, Berkshire, United Kingdom) was used to evaluate tooth wear patterns, and the age assessed using newly devised "age calculator" based on the Brothwell Chart. **Results:** The recorded age at death versus the estimated age derived from the Brothwell chart was statistically compared the weighted kappa score = 0.877, suggestive of a "very good" strength of agreement. **Conclusion:** The Brothwell chart, based on tooth wear, can be used as a consistent method of age assessment, allowing for easier and more rapid data collection with no loss of overall accuracy.

Key words: Age estimation, Brothwell chart, forensic odontology, forensic science, tooth wear

Introduction

Age estimation is critical in forensic medicine for identification purposes of deceased victims and missing persons and in the context of felonies and accidents. Various methods have been proposed for age assessment.[1] Chronological age estimation in children based on dental maturation may be divided into those using the atlas approach and those using scoring systems and can be obtained with relative accuracy, based on the order and time of tooth eruption from infancy to about 21 years of age. Tooth mineralization stages are much less affected by variation in nutritional and endocrine status and developing teeth and therefore provide a relatively accurate indication of chronological age, and that difference in eruption times varies according to inherent biological variability, more controlled by genes than by environmental factors.[2]

Schour and Massler[3] used data obtained by Logan and Kronfeld[4] compiled two charts showing schematically, the development of the human dentition. The information in tables has been extensively used over the years and has proved to be relatively accurate in spite of the medically compromised

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small sample size which was derived from 25 postmortem specimens of which 19 were under 2 years of age.

More precise and detailed techniques of age estimation have been published.[5-9] However, these methods involve time-consuming and cost-inefficient techniques after tooth extraction and preparation of microscopic sections of teeth or time-consuming radiographic observation following obtaining ethical approval.

The age assessment of individuals of 28 years and older is more challenging.[10] Morphological techniques[5] or radiology techniques[11,12] are based on the measurement of regressive changes in teeth including factors such as the loss of periodontal attachment, the apposition of cementum at the root apex, the amount of apical resorption, and the transparency of the root. Again, their weakness is in the time-consuming nature of data collection.

Tooth wear patterns have been used for many years as an age estimation scheme, in spite of early acceptance that tooth wear patterns are not solely a function of age, being significantly influenced by certain kinds of food, the method of mastication, existence of artificial teeth, gender, geographic location, environmental conditions, and parafunction.[13,14] Most of the schemes, which assess age by tooth wear, first compile a group of young children and adults of "known age" determined from eruption patterns.[15]

Many studies have reported on age assessment by wear scores,[16-18] and a considerable number used the Miles method.[19-23]

The lack of a suitable known-age reference cohorts from which to age past populations is one of the biggest problems in dental wear aging,[24] and tooth wear patterns appraised in one population should not be used to assess age in another population or era.[20-22] Millard and Gowland,[24] using a version of the Miles method, reported older ages than traditional methods, especially in individuals showing heavy degrees of tooth wear patterns.

Kim *et al*.[25] opined that scoring tooth wear was a very accurately method for placing subjects into two age groups. Brothwell's method, based firmly on Miles, constrained age assessment to three age groups, rather than the continuum as used by Miles. The Brothwell chart is user-friendly and quick to use. It, however, requires the data to be validated against skulls of recorded known age and not against those whose "known age" has been extrapolated forward from a cohort assessed by tooth eruption.

Aim

The aim of this study is to validate the efficacy of age assessment by the Brothwell tooth wear chart, using skulls of known age at death.

Materials and Methods

Preliminary study: Intra- and inter-observer reliability

Intra- and inter-observer reliability was first assessed in the following way.

For intra-observer reliability, ten mandibles showing different wear patterns and not used in the main study were chosen by a university staff member not involved in data collection. The museum identification marks were obscured by wrapping the mandible in tin foil so that only the occlusal surfaces of the teeth were visible. Using randomized tables, the mandibles were then placed on the examination table ordered from 1 to 10.

The wear patterns on the mandibular first and second molars were recorded using the Brothwell chart. This was designated as Sequence A. After a period of 3 weeks, the same skulls were arranged using randomized tables, in a different sequence, designated as Sequence B. Wear patterns for Sequence A and B were then compared. This was repeated until a high agreement was achieved between sequences. Inter-observer reliability was assessed in a similar manner.

Ten different skulls were chosen by a university staff member not involved in data collection. This time the wear patterns on mandibular first and second molars were recorded by two observers, the author plus one other. The two sets of scores were then compared. Three weeks later, the same skulls were arranged in a different sequence using the randomized tables, and scores were taken. Scores recorded by the two observers were repeated until a high level of agreement was achieved between sequences.

Main Study: Validation the efficacy of age assessment by the Brothwell chart

An independent colleague randomly chose fifty mandibles from Chinese skulls of known age from the Turner Collection, Anatomy Section, Department of Biomedical Sciences in the College of Medicine, University of Edinburgh. The age at death of each of the Chinese skulls was known, having been recorded at the time of acquisition. The age range was from 16 to 62 years. In attestation of this, the collector stated that "the age of each individual was noted at death and the age, sex, and nationality are beyond doubt."[26]

All the skulls had an identification mark placed at the time of deposition of the skulls in the museum, and this matched the recorded date at death. A colleague obscured all these identification marks on the skulls by wrapping the mandible in tin foil so that only the teeth occlusal surfaces were visible. The skulls were then laid out, numbered 1–50, using randomized tables. The mandibular teeth were cleaned with nonalcoholic material to make sure that all details of wear were clear. A handheld 70-mm Magnifying Glass with Light, ×3 magnification (Rolson, Ruscombe, Twyford, Berkshire, United Kingdom), was used to evaluate tooth wear patterns.

A newly devised "age calculator" was used, based on the Brothwell Chart. This "tool" consists of:

1. One blank record card [Figure 1] for each of the 50 teeth. On this card, the sequence number was recorded as well as the (eventual) estimated age
   There are diagrams of two blank teeth (occlusal surfaces) on which the tooth wear patterns are drawn. On the right side, there is an aid to show the colors used to illustrate the patterns and spaces for the skull number and actual age, to be filled in at the end of the exercise. During the assessment, these are blank
2. A transparent sheet, with a vertical red line, can be placed over the completed record card. In the illustration [Figure 2], the red line has been aligned with M1
3. The Brothwell chart was put between the record card and the transparent sheet. This is moved horizontally until the registered wear pattern on the record card corresponds with a similar pattern on the Brothwell chart.

In the original Brothwell chart, patterns for M3 are also given. M3 was not used in this study.

The wear patterns of M1 and M2 for each tooth are recorded on the record card in the appropriate boxes. The transparent sheet is overlaid and the chart inserted between the two. The chart is moved until the recorded pattern corresponded with a similar pattern on the Brothwell chart. When there was doubt about the tooth wear patterns, the age was always assessed upward. This process was repeated for M2. Only after all the 50 records were complete, the skull number and actual age were filled in the record card by the colleague.

Statistical analysis

"Weighted kappa," quantifying inter- and intra-rater agreements, was calculated using GraphPad QuickCalcs website: http://www.graphpad.com/quickcalcs/kappa1/cfm.

Results

Table 1 gives the results of the intra- and inter-observer reliability for both the first molar tooth (M1) and the second molar tooth (M2) together with weighted kappa score showing the strength of agreement. This was deemed to be "very good" for both teeth.

Table 2 shows the recorded age at death versus the estimated age derived from the Brothwell chart. The number of observed agreements was 44 (88.00% of the observations); the number of agreements expected by chance was 15.6 (31.28% of the observations). The weighted kappa score = 0.877, suggestive of "very good" strength of agreement.

Discussion

Many previous studies of adult age assessment by tooth wear have used materials in which age has been assessed indirectly and not from authenticated records. Essentially, the current study is a validation of the Miles method, on which Brothwell based his chart. Miles estimated the age of each skull by reference to a group of younger skulls whose age was determined from tooth eruption information. The current study differs in that a substantial number of skulls, of confirmed known age, were used. They were then blindly assessed for age using the Brothwell tooth wear chart.

Weighted kappa was used to calculate the inter-rater agreement statistic between two measurements as weighted kappa determines the agreement when the rating is done on categorized or ranked order information rather than continued information. Close matching was always achieved. Skulls were always allocated either to the correct age group (most cases) or an adjacent group but never to a group nonadjacent.

The strength of agreement between the actual age group and estimated age group was considered to be good. It has been argued that the accuracy of age estimation was increased[23,25] if skulls were categorized into age groups rather than given a "specific age," and the above results are in general agreement with this.

In spite of these promising results, forensic odontologists should not restrict assessments to one particular technique. It

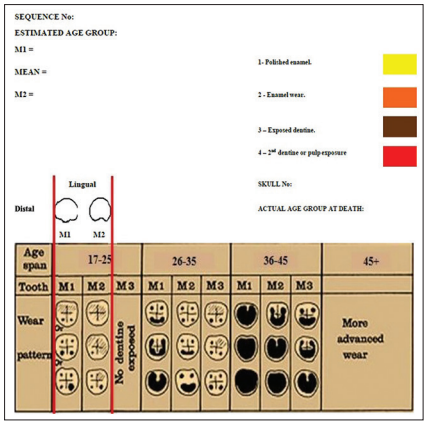

Figure 1: Calculator with blank record card and Brothwell Chart

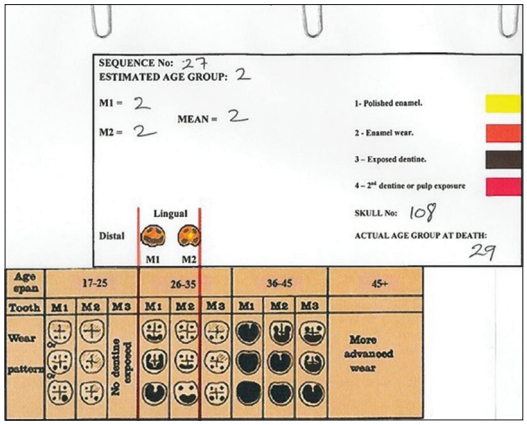

Figure 2: Calculator with completed record card (Brothwell Chart)

Table 1: Intra- and inter-observer reliability

Items	Intra-observer reliability		Inter-observer reliability	
	M1 (%)	M2 (%)	M1 (%)	M2 (%)
Number of observed agreements	8 (80.0)	9 (90.0)	8 (80.0)	8 (80.0)
Number of agreements expected by chance	2.6 (26.0)	3.1 (31.0)	3.5 (35.0)	3.2 (32.0)
Weighted kappa score	0.851	0.909	0.804	0.836

The strength of agreement was deemed to be "very good"

Table 2: Recorded age at death versus estimated age from Brothwell chart

Recorded age at death	Estimated age				
	Group 1 (17-25 years)	Group 2 (26-35 years)	Group 3 (36-45 years)	Group 4 (>45 years)	Total
Group 1 (17-25 years)	7	1	0	0	8
Group 2 (26-35 years)	0	21	3	0	24
Group 3 (36-45 years)	0	0	10	0	10
Group 4 (>45 years)	0	0	2	6	8
Total	7	22	15	6	50

is advisable to employ the different techniques and repetitive measurements. The Brothwell chart should be viewed as a non-time-consuming, user-friendly screening method well suited for assessments of a vast number of cases.

Conclusion

The intra- and inter-observer reliability testing indicated that tooth wear assessment at different periods and between the various assessors was precise to the extent that it could be used in age assessment methods.

The Brothwell chart, based on tooth wear, can be used as a reasonable method of age assessment, allowing for easier and more rapid data collection with no loss of overall accuracy.

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Conflicts of interest
There are no conflicts of interest.

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