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REVIEW ARTICLE

TOOTH WEAR CHARTS AS RAPID HUMAN AGE-GROUP ASSESSMENT METHODS: A REVIEW

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ABSTRACT

Forensic odontologists use age estimation in forensic medicine for identification purposes of deceased victims and missing persons. Various methods have been proposed for age assessment. A tooth wear chart is one method used for initial age assessment, with both the Miles chart and Broth well chart being the most used methods. The age assessment should not be limited to one particular technique. Different, more accurate methods and repetitive measurements should be employed in most cases. This article presents a review of the validity and the efficacy of age assessment by the Miles and Brothwell tooth wear charts.

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 (Willems, 2001). 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 tooth development and differences in eruption times vary according to inherent biological variability, more controlled by genes than by environmental factors. Together, therefore, they provide a relatively accurate indication of chronological age (Maled *et al*., 2014). Schour and Massler (1941), using data obtained by (Logan and Kronfeld, 1933), compiled two charts schematically showing the development of the human dentition. The information, presented in tables, has been extensively used over the years and has proved to be reasonably accurate in spite of the medically compromised and small sample size.

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The data were derived from 25 post-mortem specimens of which 19 were under two years of age. More specific and detailed techniques of age estimation have been published (Gustafson, 1950; Hunt and Gleiser, 1955; Demirjian *et al*., 1973; Moorrees *et al*., 1963; Anderson *et al*., 1976). However, these methods involve time-consuming and cost-inefficient procedures following tooth extraction. Preparation of microscopic sections of teeth or radiographic examination is time consuming and also require ethical approval in many cases. The age assessment of individuals over 28 years of age is more challenging (Brooks, 1955). Morphological techniques (Gustafson, 1950), or radiology techniques (Solheim, 1993; Kvaal *et al*., 1995), 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.

Age Assessment by Tooth Wear

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. 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 ofage. They are accepted as being influenced by certain kinds of food, the method of mastication, existence of

artificial teeth, gender, geographic location, environmental conditions and par function (Reeder, 1953; Telang *et al*., 2014). Most of the schemes which assess age by tooth wear, first assemble the skulls or jaws of a group of young children and adults of 'known age' determined from eruption patterns(Miles, 1962). Many studies have reported on age assessment by wear scores (Hojo, 1954; Murphy, 1959), and a considerable number used the Miles method (Miles, 1958; Nowell, 1978; Brothwell, 1981; Kieser *et al*., 1983; Johnson, 1976). The lack of an appropriate known-age reference cohorts, from which to age past populations, is one of the biggest problems in dental wear ageing (Millard and Gowland, 2002), and tooth wear patterns assessed in one population should not be used to evaluate age in another population or era (Nowell, 1978; Brothwell, 1981; Kieser *et al*., 1983). Millard and Gowland (2002), using a version of the Miles' method reported older ages than traditional methods, especially in individuals showing substantial degrees of tooth wear.

The Brothwell Method

Kim *et al*.(2000), held that scoring tooth wear was an accurate method for placing subjects into two age groups. Brothwell's method, based firmly on the Miles chart, constrained age assessment to four 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. Many studies attempted to evaluate the application of the Brothwell chart as aninitial screening method and as such is mostly a validation of the Miles method of age assessment, on which Brothwell based his chart (Santini *et al*., 2017; Alayan *et al*., 2017). In a recent study (Alayan *et al*., 2017), Cohen's weighted kappa (Cohen, 1968), was used, rather than the Bland-Altman test or *t*-test, to calculate the inter-rater agreement statistic between two sets of scores of the recorded age at death *versus* estimated age from Brothwell chart. This takes into account disagreement between the two raters, but not the degree of variance. This is especially relevant when the rating is done on categorized or ranked order information rather than continuous information. Close matching was always achieved in the recent study(Alayan *et al*., 2017),with an 88%agreement deemed to be very good. The preponderance of skulls were allocated either to the correct age group or a lower adjacent group, but never to a non-adjacent group. The weighted kappa score was 0.877, indicative of a 'verygood' the strength of agreement being (Alayan *et al*., 2017).

It has been contended that the accuracy of age estimation was increased if skulls were categorized into age groups rather than given a 'specific age'(Johnson, 1976; Kim *et al*., 2000).The agreements between the actual age and the estimated age can be placed into ten-year groups with reasonably high sensitivity. For this reason, in the recent study (Alayan *et al*., 2017), the skulls were allocated to the correct age group or an adjacent lower age group, not a higher age group. Furthermore, the original Brothwell chart (Brothwell, 1981), used age groups stated as "about 17 -25; 25- 35; 35 – 45; and "above" 45. This created the possibility of having 26-year-olds and 36-year-olds being placed in two different groups. To avoid this, age groups were changed to be 17–25 years, 26–35 years, 36–45 years and > 45 years (Alayan *et al*., 2017).

The Miles Method

In understanding the Brothwell chart, it is necessary to have a full appreciation of the principals of the Miles method of age assessment on which it is based. The Miles method relies on obtaining a "known age" group of subjects ranging from 6 years to 18 or 19 years as assessed by tooth eruption. In the recent study (Alayan *et al*., 2017), the functional period of the first molar (M1), from the time of eruption at about six years, to the end of twelve years in function, is recorded and compared with tooth wear in the second molar (M2) after six years in function, i.e. at 18 years of age. In this way, the data from the 'known age' group is projected forward for another six years to extend the period of what could be regarded as a reasonably confident age estimation, up to the age of 24 years. This provided a basis on which M1 wear, up to 18 years, could be compared to 12 years of M2 wear and up to six years of the third molar (M3) wear and as the baseline group on which the ages of other specimens could be assessed (Alayan *et al*., 2017; Santini *et al*., 2017). Using this method, Miles produced an age assessment chart based on tooth wear patterns. Miles accepted the limitations in the generality of his chart and stated that tooth wear patterns appraised in one population should not be used to assess age in another population or era. This opinion has been accepted by others (Nowell, 1978; Brothwell, 1981; Kieser *et al*., 1983). Brothwell (1981), however, draw attention to the fact that the rates of wear in earlier British populations did not appear to have changed much from Neolithic to Medieval times, the implication being that tooth eruption times did not meaningfully alter over this extensive period. He concluded that his chart would provide roughly correct for all these periods.

Factors Affecting Tooth Wear Methods

The age of eruption of permanent teeth in humans is also a key concern in age assessment. In support of the consistency over time, of the age at eruption of permanent teeth, Helm *et al*.(1979), showed that the age at eruption of permanent teeth was similar, as was the rate of attrition of the first and second molars, in medieval Danishskulls compared with contemporary Danish children. What is more, it is interesting to note that, despite the small sample used by Schour and Massler (1941), compared to the broad cross-section sample of Blenkin and Taylor (2012), the atlas style charts, relating to the age of eruption of permanent teeth, produced by both these authors, and others, are verysimilar. The conclusion to be drawn from these reports is that establishing a "known age" group of subjects evaluated by tooth eruption does not have noteworthy shortcomings. The ethnic, geographical and temporal diversity of the Miles' Anglo-Saxon sample and the nineteenth Chinese sample is evident and offers the tentative hypothesis that a non-refined food-type is the primary cause of tooth wear, though the many other possible causes must not be ruled out. This statement should be considered on the understanding that tooth wear patterns have been shown to vary in type and degree, in any one population, and between populations. Sexual dimorphism has also been reported (Lavelle, 1970; Molnar, 1971). That a good relationship existed between tooth attrition patterns and the type of food given is highlighted in a report on

five groups of hunter-gatherers and five groups of agriculturalists (Smith, 1984). Hunter-gatherers, whose food was rough, showed worn, almost flat, molar surfaces. In populations, whose food was based on wheat or corn, wear patterns changed, and the worn molar surfaces tended to be more oblique. Contrary to this and in support of the use of the Brothwell chart within different populations and eras, Lovejoy(1985), reported that tooth wear patterns from the Libben American Indian population were similar to that provided by Murphy (1959), for Australian Aborigines. The results of the recent study (Alayan *et al*., 2017), compare favorably with other recent age-at-death assessment studies in spite of the miscellany between the Miles sample and the Chinse skulls. Using dental panoramic tomograms of living patients of both sexes with documented ages, 18 to 77 years and data treated by regression analysis, the error was +/- 2.55 years (Durić *et al*., 2005).In studies using dental stone casts, the estimation of an individual's age were within +/-3 to 5 years in 42-62% of the studies subjects (Kim *et al*., 2000), within +/- 5 years of the actual ages in about 64-70% of subjects(Yun *et al*., 2007; Telang *et al*., 2014), and within +/- 3 years of actual age in 50% of subjects (Telang *et al*., 2014). In the study by Millard and Gowland (2002), they used statistical probability methods to assess age by wear. Their method produced older ages than traditional methods, especially in the older age groups. This may be due to ethnic or genetic variations, or eating habits, as they pointed out that their results in this respect were especially noted in individuals showing heavy degrees of tooth wear patterns.

Conclusion

It can be concluded that age estimation using tooth wear patterns is considered to be fairly accurate in young individuals up to 40 years old, but the accuracy decreases with age, because of difficulty in assessing levels of tooth wear in older people. It is not proposed that the Brothwell chart can be used without awareness being given to the population in question, nor is it recommended as a replacement for other well-established age assessment methods. Instead it should be viewed as a non-time consuming, user-friendly initial screening method appropriate for the evaluation of large case numbers. The Brothwell chart can, with caution, be used to arrive at a reasonable estimation of age groups in the stated Chinese population, and can be used with caution, as an initial method of age assessment, allowing for easier and more rapid data collection with no loss of overall accuracy.

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