Journal of Forensic and Legal Medicine 34 (2015) 145–150

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original communication

Ballistics ordnance gelatine – How different concentrations, temperatures and curing times affect calibration results

Nicholas R. Maiden [a,*], Wesley Fisk [a], Christian Wachsberger [b], Roger W. Byard [a]

[a] The University of Adelaide, Discipline of Anatomy and Pathology, Frome Rd, Adelaide, South Australia, 5005, Australia
[b] Defence Science and Technology Organisation, PO Box 1500, Edinburgh, South Australia, 5111, Australia

ARTICLE INFO

Article history:
Received 21 November 2014
Received in revised form
1 March 2015
Accepted 29 May 2015
Available online 6 June 2015

Keywords:
Ordnance gelatine
Calibration
FBI formulation
NATO formulation
Bloom
Penetration depth

ABSTRACT

A study was undertaken to determine whether different concentrations of ordnance gelatine, water types, temperatures and curing times would have an effect on projectile penetration of a gelatine tissue surrogate. Both Federal Bureau of Investigation (FBI) and North Atlantic Treaty Organization (NATO) specified gelatines were compared against the FBI calibration standard.

10% w/w and 20% w/w concentrations of gelatine with Bloom numbers of 250 and 285 were prepared and cured at variable temperatures (3–20 °C) for 21 hours–3 weeks. Each block was shot on four occasions on the same range using steel calibre 4.5 mm BBs fired from a Daisy® air rifle at the required standard velocity of 180 ± 4.5 m/s, to ascertain the mean penetration depth.

The results showed no significant difference in mean penetration depth using the three different water types ($p > 0.05$). Temperature changes and curing times did affect penetration depth. At 10 °C, mean penetration depth with 20% gelatine 285 Bloom for the two water types tested was 49.7 ± 1.5 mm after 21 h curing time, whereas the same formulation at 20 °C using two different water types was 79.1 ± 2.1 mm after 100 h curing time ($p < 0.001$).

Neither of the NATO 20% concentrations of gelatine at 10 °C or a 20% concentration of 285 Bloom gelatine at 10 °C met the same calibration standard as the FBI recommended 10% formulation at 4 °C. A 20% concentration of 285 Bloom at 20 °C met the same calibration/penetration criteria as a 10% concentration of 250 Bloom at 4 °C after 100 h of curing, therefore matching the FBI calibration standard for a soft tissue simulant for wound ballistics research. These results demonstrate significant variability in simulant properties. Failure to standardise ballistic simulants may invalidate experimental results.

1. Introduction

Ballistics ordnance gelatine is the most widely accepted simulant for wound ballistics research. However, it is homogeneous and cannot replicate the heterogeneous nature of human tissue. Therefore at best, it can only be considered a soft tissue simulant.[1–3]

A series of experiments were conducted using different ordnance gelatine concentrations, water types, temperatures and curing times to see how BB penetration results might be affected in both FBI and NATO specified ordnance gelatine.

2. Materials and methods

A series of tests with both 10% w/w and 20% w/w concentrations of differing Bloom strength ordnance gelatine was undertaken. The gelatine was prepared in accordance with standard methods.[4–7] As there is no calibration method mentioned in the NATO Standard for 20% ordnance gelatine,[18] the same calibration method recommended by Fackler and Malinowski[8] for 10% ordnance gelatine and accepted by the FBI, has been applied to 20% ordnance gelatine in order to compare results.

Gelita® Type 'A' gelatine powder with a Bloom number of 250 and Croda® Type 'A' gelatine powder with a Bloom number of 285 were used. Propionic acid (mould inhibitant) was added at the usual ratio of 5 ml per 1000 g of finished product. The powders were hand mixed with three different types of water namely tap water, reverse osmosis (RO) water and de-ionized water. The gelatine mixtures were hydrated at room temperature for

* Corresponding author. Discipline of Anatomy and Pathology, Level 3 Medical School North Building, The University of Adelaide, Frome Road, Adelaide 5005, Australia. Tel.: +61 447710921; fax: +61 8 8303 5384.
E-mail address: Nicholas.Maiden@adelaide.edu.au (N.R. Maiden).

http://dx.doi.org/10.1016/j.jflm.2015.05.019
1752-928X/

approximately 4–6 h before being melted in a temperature controlled, stainless steel water jacketed bath at a temperature not exceeding 40 °C. This melting process took approximately 10–12 h. The gelatine solution was then poured into plastic containers measuring 210 mm in diameter, 150 mm in depth, and sealed with plastic wrap to prevent dehydration. The containers were placed into a commercial grade climate controlled refrigerator at temperatures of between 3-4 °C and the gelatine allowed to cure for varying periods of 21 h, 100 h and 3 weeks. The solidified gelatine blocks were subsequently removed from the refrigerator and their temperatures checked with a laboratory grade thermometer. A number of blocks were also conditioned for 72 h in 10° and 20 °C climate-controlled environments until the entire block reached the required temperature. Each block was shot on four occasions from a range of 3 m using Crosman® 'Copperhead' brand steel calibre 4.5 mm BBs fired from a Daisy® brand air rifle. Each shot was fired towards the centre of the gelatine block, but a short distance apart, to ensure none of the permanent cavities crossed paths. The penetration depth of each shot was measured from the anterior surface of the gelatine block using a stainless steel probe that was inserted into the permanent cavity until it touched the BB. The probe was marked and withdrawn from the block. The total penetration distance was then measured from the probe using a vernier gauge. The mean penetration distance was established from the combined values of the four shots for each set of tests. An Ohler® model 35P chronograph was used to measure the mean velocity of the BBs fired from the air rifle. Six pumps of the air rifle were found to achieve the required velocity of 180 m/s ± 4.5m/s.[8]

Statistical analyses of the energy results were conducted using Graphpad Prism 5.02 for Windows, (Graphpad Software, San Diego California USA). Values were expressed as mean and standard error of the mean. Test results for all ordnance gelatine formulations were compared using one way ANOVA with statistical significance set at $p < 0.05$ and inter-individual comparisons made using Bonneferoni's *post hoc* test.

3. Results

3.1. 10% ordnance gelatine at 4 °C 250 bloom (FBI standard)

3.1.1. 21 Hours curing time

The mean penetration depth of 10% gelatine at 4 °C 250 Bloom using RO water (N = 4) was 106.9 ± 1.9 mm. The mean penetration depth for the same formulation using tap water (N = 4) was 113.7 ± 2.6 mm ($p > 0.05$), and for de-ionized water was 112.0 ± 2.8 mm ($p > 0.05$).

The overall mean penetration depth for the three water types was 110.9 ± 3.5 mm.

3.1.2. 100 Hours curing time

The mean penetration depth of 10% gelatine at 4 °C 250 Bloom using tap water (N = 4) was 104.8 ± 2.0 mm. The mean penetration depth for the same formulation using de-ionized water (N = 4) was 107.3 ± 3.0 mm ($p > 0.05$).

The overall mean penetration depth for the two water types was 106.1 ± 1.8 mm.

3.1.3. 3 Weeks curing time

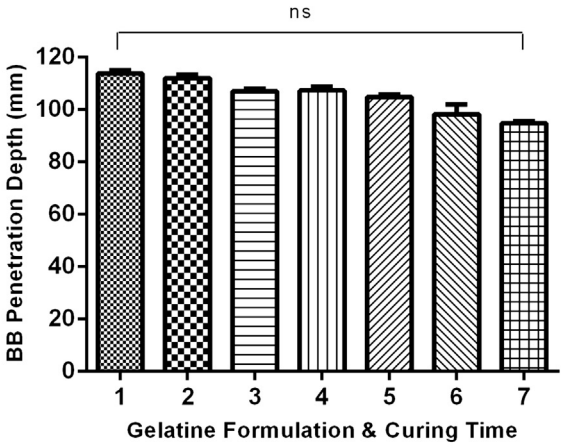
The mean penetration depth of 10% gelatine at 4 °C 250 Bloom using de-ionized water (N = 3) was 98.2 ± 6.6 mm. The mean penetration depth for the same formulation at 3 °C using de-ionized water (N = 3) was 94.6 ± 1.4 mm ($p > 0.05$).

The BB penetration results for all 10% gelatine at 4 °C and 3 °C 250 Bloom formulations after their respective curing times are shown in Fig. 1.

3.2. 20% ordnance gelatine at 10 °C 250 bloom (NATO standard)

3.2.1. 21 Hours curing time

The mean penetration depth of 20% gelatine at 10 °C 250 Bloom using RO water (N = 4) was 48.6 ± 6.3 mm.



1. 10% gelatine at 4°C 250 Bloom using tap water after 21 hours curing time
2. 10% gelatine at 4°C 250 Bloom using de-ionized water after 21 hours curing time
3. 10% gelatine at 4°C 250 Bloom using RO water after 21 hours curing time
4. 10% gelatine at 4°C 250 Bloom using de-ionized water after 100 hours curing time
5. 10% gelatine at 4°C 250 Bloom using tap water after 100 hours curing time
6. 10% gelatine at 4°C 250 Bloom using de-ionized water after 3 weeks curing time
7. 10% gelatine at 3°C 250 Bloom using de-ionized water after 3 weeks curing time

Fig. 1. Mean BB penetration depth for 10% ordnance gelatine at 4 °C 250 Bloom using three different water types and curing times. In addition, the same formulation at 3 °C was tested to compare the results. ns = not significant.