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A. J. Gwinnett
S.U.N.Y. at Stony Brook

L. Gorelick
S.U.N.Y. at Stony Brook

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EVIDENCE FOR THE USE OF A DIAMOND DRILL FOR BEAD MAKING IN SRI-LANKA C.700-1000 A.D.

A.J. Gwinnett* and L. Gorelick

School of Dental Medicine
Health Science Center
S.U.N.Y. at Stony Brook
Stony Brook, N.Y. 11794

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Abstract

The use of a diamond splinter turned by a bow drill to drill the quartz beads in present day Cambay, India has been documented. A group of Cambay beads were made available for study. They were compared with a similar group of quartz beads excavated in Mantai, Sri-Lanka. These were dated stratigraphically c.700-1000 A.D. Silicone impressions were made of the drill holes from selected beads from both Cambay and Mantai. These were examined by means of scanning electron microscopy. The pattern of drilling was the same, suggesting that the technique of drilling with a diamond splinter and bow drill was an ancient one. This has not been previously reported.

KEY WORDS: Beads, drilling, diamond, scanning electron microscopy.

*Address for correspondence:
School of Dental Medicine
Oral Biology and Pathology Dept.
S.U.N.Y. at Stony Brook
Stony Brook, NY 11794 Phone No.: (516) 246-2879

Introduction

Possehl[3] documented the step-by-step procedures used to make agate and chalcedony beads in present day Cambay, India. He showed that while electrification was used by the Cambay craftsmen for the various steps in manufacture, such as shaping and polishing, a totally different technique, one that concerns us here, was used for drilling. The method of drilling shown by Possehl was that of an ancient type of bow drill which produced alternating clockwise and counter-clockwise rotation of the wooden spindle, into which was hafted a tiny diamond splinter. Possehl observed that a single spherical bead of chalcedony, about 0.5cm in diameter was perforated in about 20 seconds. The earliest published[4] observation of this method was in 1851 A.D.

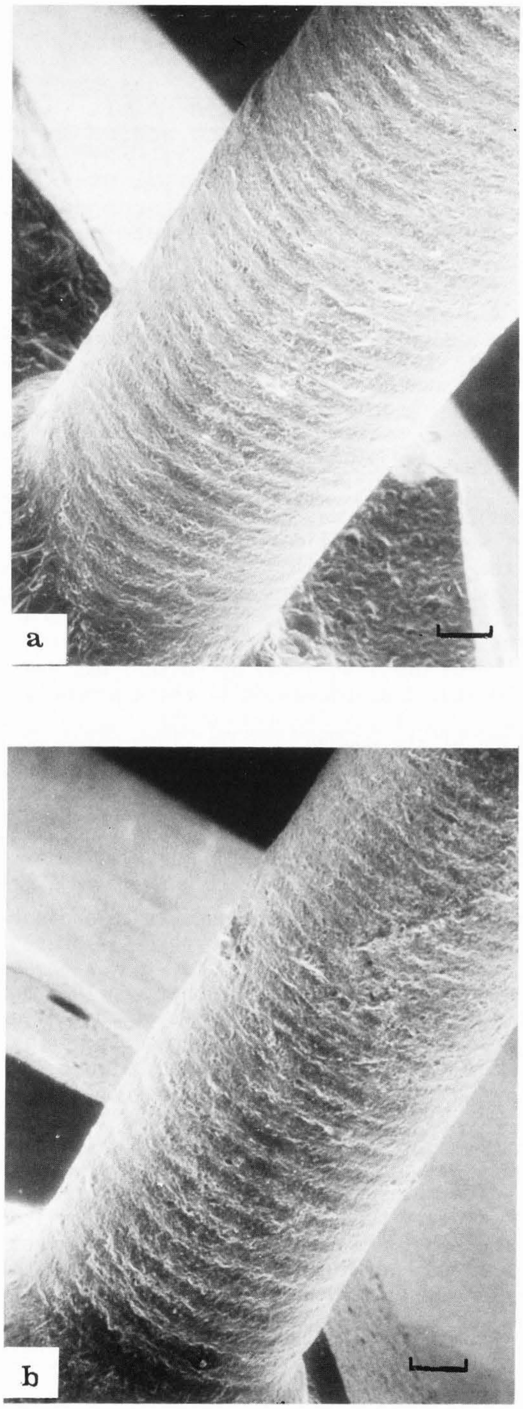
We hypothesized that because a bow drill was being used, the technique was an ancient one. An opportunity to test the hypothesis presented itself when we were invited to study a group of beads excavated in Sri-Lanka between 1981 and 1984 by Professor John Carswell of the University of Chicago. The beads were found in a stratified context in Mantai and dated c.700-1000 A.D.

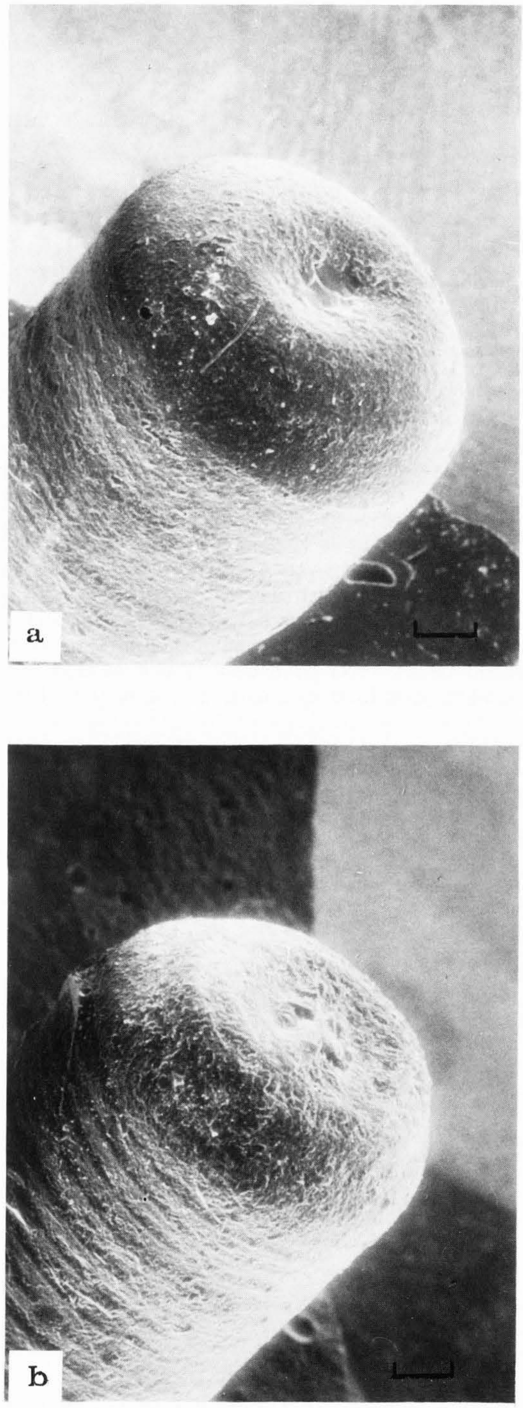
Materials and Methods

The method that we used has been previously reported and published.[1] In summary, silicone impressions were made of selected beads from the Cambay and Mantai samples. Beads that were incompletely drilled were preferred because the marks created by the leading edge of the drill could be observed and they provide the most discriminating information. The impressions were mounted on aluminum stubs with conductive cement and coated with a conductive layer of gold in a Ladd water cooled sputtering device. The coated samples were then examined in an Amray scanning electron microscope. Observations were recorded photographically.

Results

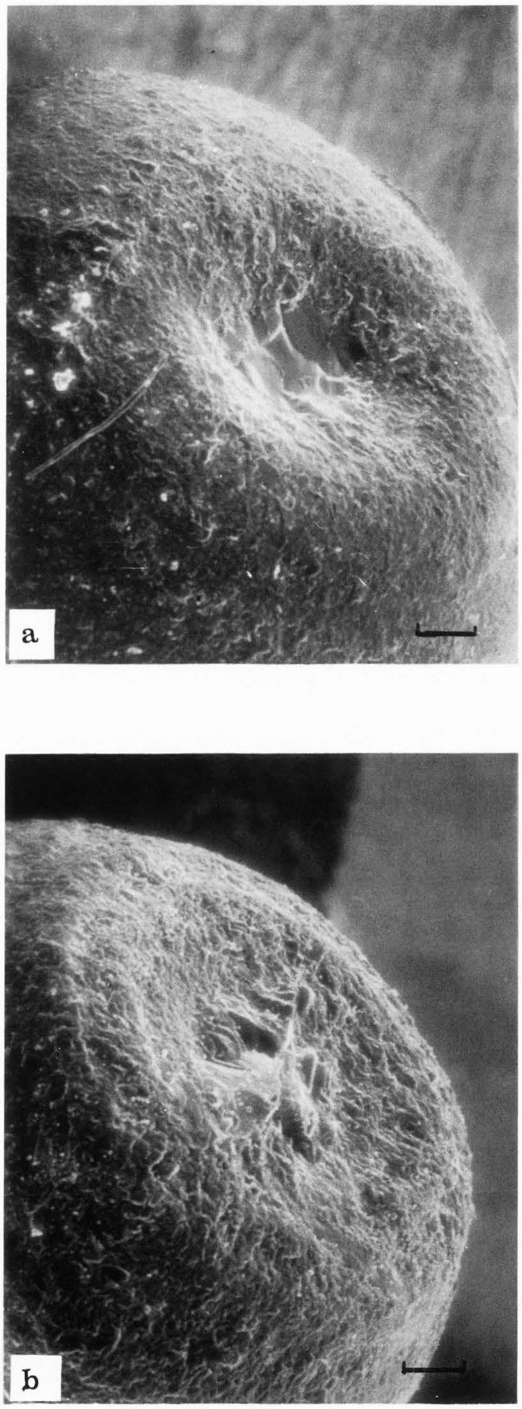
The pattern revealed by the photomicrographs in both the Cambay and Mantai beads were the



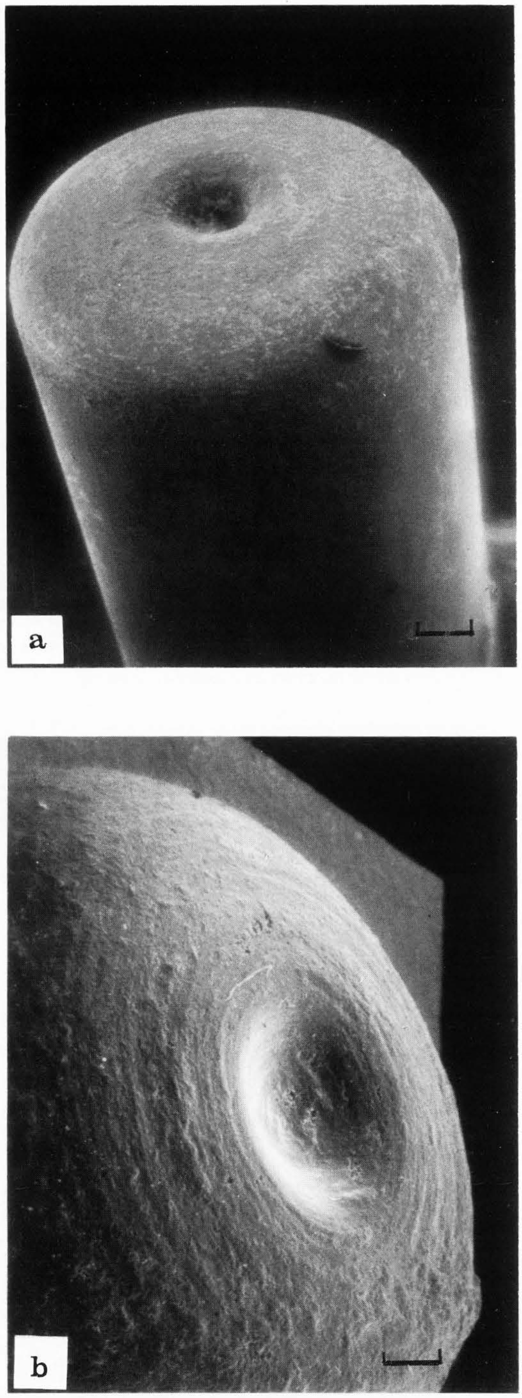


Figs. 1a & 1b. The shapes of the drill holes, here turned inside out by the impression technique, were quite parallel with regular concentric grooves on the side walls. Note the striking similarity here between a Cambay bead (a) and one from Mantai (b). Bar = 250 μm.

Figs. 2a & 2b. The leading edge of these drill holes show a central area in which a chonchoidal fracture pattern can be noted. (a) is a bead from Cambay and (b) a bead from Mantai. Bar = 250 μm.



Figs. 3a & 3b. While a difference in fracture pattern can be observed in Cambay (a) and Mantai (b) beads, the characteristic is unmistakably conchoidal and typical of agate from which the beads were made. Bar = 125 μm.



Figs. 4a & 4b. Using a copper rod and a slurry of emery produces a characteristic leading edge when drilling hard stones such as agate. In these impressions, the central depression would be an elevation in the substrate. It is relatively smooth and represents the site of preferred wear in the drill itself. Bar = 500 μm and 250 μm respectively.

same. The shapes of the drill holes were quite parallel and the side walls contained a series of regular concentric grooves (Figs. 1a & 1b). The pattern on the bottom of the drill holes produced by the leading edge of the drill, was that of a slight rounding with a central depression in which a conchoidal fracture pattern (Figs. 2a & 2b and Figs. 3a & 3b) was observed. These characteristics were clearly different from those produced by other ancient techniques. For example, when a copper drill was used with a loose abrasive (Figs. 4a & 4b), the wear pattern on the leading edge had a central depression that was relatively smooth as if macerated and finer abrasive began to act as a polishing agent. A chipped flint drill could not penetrate quartz.

Discussion

Intriguing questions are raised by our findings, e.g., where did the ancient diamond drills come from, how widespread was the technique in the ancient Far East and how old is the technique? This last question is particularly relevant due to a reference by Pliny[2] as to the existence of natural diamonds in a splinter form, as well as, in typical crystal form and his reference to diamond particles used for engraving Roman gem stones.

Conclusion

While our evidence for the use of a diamond splinter drill in Mantai c.700-1000 A.D. is substantial, further research is needed to determine the pattern created by splinter drills harder than quartz, but less hard than diamond such as corundum.

Acknowledgements

The authors are indebted to Professor Gregory Possehl, University Museum, Philadelphia, and Professor John Carswell, The David and Alfred Smart Gallery, University of Chicago for providing the artefacts for study.

References

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Discussion with Reviewers

A.S. Pooley: Please give more detail on the method of replication, cleaning of the artefact, material used, special precaution needed, setting time, difficulty of extraction, stability of the impression under the SEM.
Authors: For complete details we suggest reading our article, Ancient Seals and Modern Science published in Expedition, 20, 1978, 38-47. Summarily, the method involves the cleaning of the drill hole with a wooden toothpick and compressed air. A dental impressioning material of polyvinyl siloxane is used to reproduce the detail of the hole. A small amount of this mixed low viscosity material is teased into the drill hole with a thin toothpick and allowed to set, usually within 5 minutes. We have not experienced any significant difficulties in withdrawing this elastic material even from drill holes less than 1mm in diameter. The conductively coated material has proven stable under the electron beam.

A.S. Pooley: While outside the realm of the paper and possibly elsewhere, I am curious: How is the diamond hafted or held in the wooden rod, what prevents more wear on the wood than the diamond? Does the drill tip get hot with such a high rate of drilling (1.5cm per minute through agate)?
Authors: Possehl (text reference 3), states that an umbrella spoke is inserted in a wooden rod. The diamond splinters are then held in the umbrella spoke. No more elaboration was given by Possehl. One must assume the generation of heat and some of this was dissipated by a continuous water feed to the drilling site.

R.J. Koestler: How many samples have you examined?
Authors: This preliminary report is based on seven beads from Cambay and seven from Mantai.

R.J. Koestler: Have you found patterns other than the ones reported? If so, what percentage of those found typified the type focused on in this paper?
Authors: No other patterns were found.

R.J. Koestler: Have you examined the patterns made by hollow core copper tools that had diamond fragments embedded in the tube face?
Authors: We have examined the patterns made by contemporary tubular drills with bonded diamond fragments and they are totally different.

R.J. Koestler: What other tools have you worked with to attempt to duplicate this pattern?
Authors: We have conducted a functional analysis using solid copper, bronze, iron and wooden rods in conjunction with various abrasives. We have also used contemporary, bonded abrasive drills including diamond as well as tungsten carbide drills. The pattern was only reproduced when we used hafted diamond splinters.

V. Griffiths: Are both beads (i.e. Cambay and Mantai samples) of agate or are the two bead materials different in any way which is important to the observed artifacts?
Authors: Some of the beads were agate and some were quartz. We found no difference in the pattern of drilling on these two substrates.

V. Griffiths: It does seem that the conchoidal

fracture patterns shown in the central areas of Figs. 3a & 3b are not characteristic of diamond drilling per se but may be, for example a result of frictional heat-induced fractures if the drilling is performed dry (no lubrication or cooling) with a tool other than diamond, e.g. another piece of agate. Perhaps this could be tested in the laboratory. Comment should be made.
Authors: This is a very interesting question. We are presently undertaking our own experimental duplication and our preliminary findings show that the fracture pattern only occurs when drilling with two diamond splinters hafted side by side. Such a set up has been described to us by Professor Possehl. We have not tried using agate as a drill and our experience is presently confined to the use of knapped flint which has a similar hardness on the Mohs scale. Flint will not penetrate agate or quartz.

V. Griffiths: What is the material drilled in Figs. 4a & 4b? Is it similar to material used as beads in Figs. 1a & 1b?
Authors: Yes, the agate material used experimentally was similar to the beads.

V. Griffiths: If the depression in the leading edge shown in Fig. 4 arises because of wear of the copper rod itself, why is there a depression in the leading edge in Figs. 2a, 2b, 3a, and 3b? Does the depression in the latter figures imply diamond wear or something about the way a diamond chip was held in the tool or that diamond was not used?
Authors: This is another most perceptive question. The depression and fracture pattern was only reproduced by us experimentally when two diamond splinters were hafted side by side. Our work is continuing into this intriguing phenomenon.