Application of Cryogenic Treatment to Enhance the Property of a Bone Saw Blade

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Abstract: Bone saw blade is one of the important instruments and commonly used in the osteotomy. Healing following bone surgery may be delayed or even prevented if the bone cells are severely injured by thermal necrosis resulting from frictional heat generated during surgical preparation. A bone saw blade used in surgical osteotomy can be enhanced to increase edge life and wear resistance, which successfully reduce cutting time and produce less mechanical heat generation. As a result, reduced heat exposure and risk of cell damage, improved tissue care, less risk of metalosis can be achieved. Thus, this issue is very significant, valuable and practical to orthopedic surgeons. Cryogenic treatment can improve the material properties by decreasing the residual stress, stabilizing dimensional accuracy and even increasing the life of the tools. The purpose of this study is to investigate the feasibility and effect of cryogenic treatment on the performance of a bone saw blade in terms of different testing methods (such as evaluating cutting efficiency, tool life test and observing the wear pattern of a bone saw blade). Experimental results demonstrated that the performance of cryo-treated bone saw blades is much better than the untreated ones. The cryo-treated bone saw blades showed the decrease of 9.76% cutting time and 65.95% wear rate from the cutting efficiency and tool life test respectively, when compared with the untreated ones. In addition, the wear pattern of the cryo-treated bone saw blades is less severe compared with the untreated ones by observing the tips of bone saw blades. The above-mentioned benefits verify that cryogenic treatment can enhance the performance of a bone saw blade.

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1. Introduction

A broad range of orthopaedic surgery operations involves osteotomy (cutting bones) as a preparation for attaching prosthetic devices. Bone cutting causes an increase in bone temperature, and a temperature above 47℃ is critical because it causes thermal bone necrosis [1-5]. Healing following bone surgery may be delayed or even prevented if the bone cells are severely injured by thermal necrosis resulting from frictional heat generated during surgical preparation. A bone saw blade used in surgical osteotomy can be enhanced to increase edge life and wear resistance, which successfully reduce cutting time and produce less mechanical heat generation.

As a result, reduced heat exposure and risk of cell damage, improved tissue care, less risk of metalosis can be achieved. Thus, this issue is very significant, valuable and practical to orthopedic surgeons [6-11].

Cryogenic treatment can improve the material properties by decreasing the residual stress, stabilizing dimensional accuracy and even increasing the wear resistance (life) of the tools. It has been widely used in tools, cutting, mold and other industries [12-21].

The purpose of this study is to investigate the feasibility and effect of cryogenic treatment on the performance of a bone saw blade in terms of different testing methods (such as evaluating cutting efficiency, tool life test and observing the wear pattern of a bone saw blade).

2. Experimental

2.1 Experimental Materials

Commercial bone saws blades provided by K&W company (model: SB-81827) were used as received. This type of bone saw blades is similar to STRYKER 2108-182, which is widely used in osteotomy. The material for the SB-81827 bone saw blade is 420 type of stainless steel. By the metal analyzer (SPECTROMAXx), the chemical composition can be obtained and shown in Table 1. There is no difference on the appearance of bone saw blades with cryogenic treatment and as received, as shown in Figure 1 and Figure 2. Testing materials are the artificial bone materials of the type 0060 Generic bone of SYNBONE Company (as shown in Figure 3). The material is in solid foam with 400mm length and an external diameter of 25mm, and the hollow diameter is 9mm.

Table 1 Chemical composition of a 420 stainless steel as received.

Composition	C	Mn	P	S	Cr	Fe
Percentage (%)	0.351	0.51	0.023	0.0058	14.56	Balance

Figure 1 A commercial bone saw blade (SB-81827).

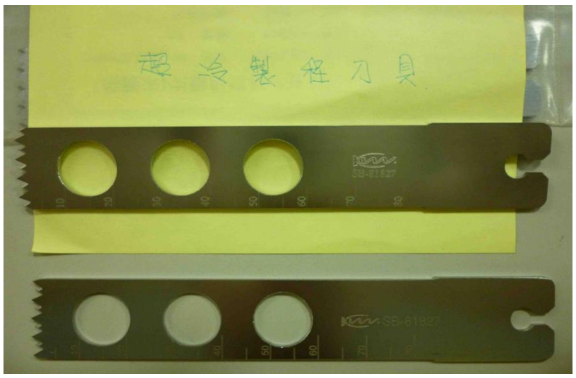
Figure 2 A commercial bone saw blade (SB-81827) with cryogenic treatment.

Figure 3 SYNBONE 0060 Generic bone.

2.2 Experimental Equipment

(1) Cryogenic Treatment

The LS-100 cryogenic treatment processing system was utilized in this study. This system mainly includes cryogenic processor LS-100 and liquid nitrogen conveyer system, as shown in Figure 4. This apparatus adopts the heat absorption method of heat flows, and the system can nearly be totally isolated without heat dissipation through the vacuum heat insulation. In addition, this system is equipped with a precise micro-processor computer and thermocouples, which can control the heating and cooling rates accurately. The bone saw blades were put into the chamber in which the samples were cooled down to around -300℉ at a slow rate and soaked at the same temperature for a period of time and slowly heated back to room temperature.

Figure 4 LS-100 Cryogenic Processor.

(2) Cutting Apparatus

Bone saw blade testing machine is in-house designed by the K&W company, and is equipped with the adjustable motor which was set up as 2000 rpm (shown in Figure 5). The artificial bone material was affixed to testing machine and a bone saw blade was situated at the machine as shown in Figure 6.


5(a)

5(b)

Figure 5 A bone saw blade cutting test machine (a) whole picture (b) adjustable motor.

6(a)

6(b)

Figure 6 Test machine (a) with SYNBONE Generic bone (b) with bone saw blade.

2.3 Verification Tests

A variety of experimental methods were used to investigate the effect of cryogenic on bone saw blades. These methods included cutting efficiency test, tool life test, and wear observation.

Cutting efficiency test was carried out by measuring the cutting time; tool life test was accomplished by measuring the height of tooth tip of a bone saw blade; wear observation was utilized by a CCD camera.

3. Results and Discussion

3.1 Cutting Efficiency

Table 2 Comparisons of cutting efficiency with and without cryogenic treatment.

No.	K&W bone saw blades (without cryo-treated)	K&W bone saw blades (with cryo-treated)
1	11.63 (s)	10.63 (s)
2	11.88 (s)	10.66 (s)
3	11.65 (s)	10.57 (s)
4	11.66 (s)	10.41 (s)
5	11.67 (s)	10.51 (s)
Average	11.698 (s)	10.556 (s)

Cut the artificial bone material of the diameter 25mm 5 times, measuring the average time in order to evaluate cutting efficiency. Table 2 reveals that a cryo-treated saw blade can reduce 9.76% of the cutting time compared with the untreated one.

3.2 Tool Life

Cut the material of artificial bone 10 times, using the wear range of tooth tip per the number of times or numbers as a criterion of judging the tool life.

$$Avg. = \frac{\Delta L}{t} = \frac{L_2 - L_1}{t} (mm/\sec.)$$

or

$$Avg. = \frac{\Delta L}{N} = \frac{L_2 - L_1}{N} (mm/No.)$$

$Avg.$ is the average wear value per unit time and No., ΔL is the wear variation of tooth tip before and after cutting, t is per unit time, N is the number of cutting times.

Table 3 reveals that the average cutting time was 11.65 seconds without cryo-treated bone saw blade, and the average cutting time is 10.63 seconds with cryo-treated one. And ultra bone of cold treatment saw average the intersection of cutting and time not spent for 10.63 second. This result reveals by the bone saw after the cryogenic treatment, can reduce 8.75% of the cutting time. However, it is not enough to evaluate the tool life, the average wear range of tooth tip per unit time or number must be acquired.

Table 3 Comparisons of cutting time with and without cryogenic treatment.

No.	K&W bone saw blades (without cryo-treated)	K&W bone saw blades (with cryo-treated)
1	11.98 (s)	10.37 (s)
2	11.96 (s)	10.78 (s)
3	11.23 (s)	10.84 (s)
4	11.75 (s)	10.75 (s)
5	11.22 (s)	10.47 (s)
6	11.00 (s)	10.57 (s)
7	11.93 (s)	10.50 (s)
8	11.84 (s)	10.47 (s)
9	11.75 (s)	10.84 (s)
10	11.88 (s)	10.69 (s)
Average	11.65 (s)	10.63 (s)

The height of tooth tip of a brand new bone saw blade before cutting is 2.298mm. It is 2.195mm after cutting, and the height of tooth tip of a cryo-treated bone saw blade after cutting is 2.266mm.

(1) Average wear rate (not cryo-treated)

$$Avg. = \frac{2.298 - 2.195}{11.65} = 0.008841(mm/\sec.)$$

(2) Average wear rate (cryo-treated)

$$Avg. = \frac{2.298 - 2.266}{10.63} = 0.003010(mm/\sec.)$$

(3) Average wear amount (not cryo-treated)

$$Avg. = \frac{2.298 - 2.195}{10} = 0.0103(mm/No.)$$

(4) Average wear amount (cryo-treated)

$$Avg. = \frac{2.298 - 2.266}{10} = 0.0032(mm/No.)$$

Compared the testing results with and without cryogenic treatment, the average wear rate with cryo-treated one can reduce 65.95% with not-treated one, and the average amount can be reduced by 68.93% with cryo-treated one. There is obvious improvement after cryogenic treatment.

3.3 Wear Observation

The cross section of artificial bone after cutting utilized by a CCD camera is shown in Figure 7. Result reveals that no matter with and without cryogenic treatment the cross section of bone saw blade is not unusually burned under the testing situation.

The wear of tooth tip of a bone saw blade after cutting can be observed by a CCD camera. Figures 8 (a) and (b) show the wear situation of bone saw blades without and with cryogenic treatment. After comparing these two photos, there is obvious abrasion dent at tooth tip without cryo-treated one, and the abrasion dent after cryogenic treatment is much less obvious.

The tooth tip of a brand new bone saw blade before cutting is sharp and without any abrasion and rubbing mark after CBN emery wheel inserting the tooth is still apparent (as shown in Figure 9). It is obvious there is no residues before cutting. However, there are obvious residues existed in the blade after cutting (as shown in Figures 8 (a) and (b)).

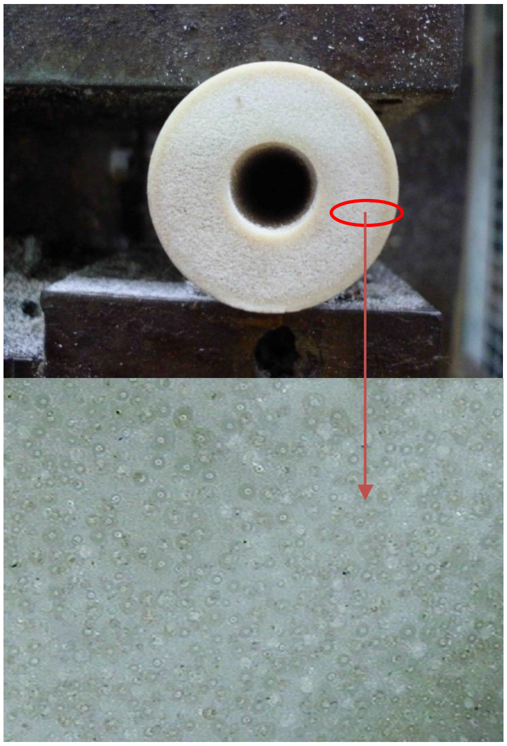

Figure 7 Cross section of an artificial bone after cutting by a CCD camera.

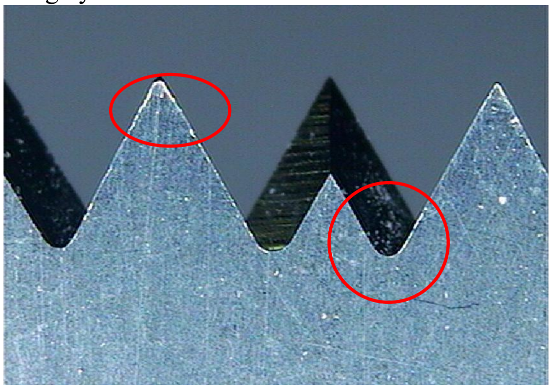

Figure 8(a) Bone saw blade without cryogenic treatment after cutting test.

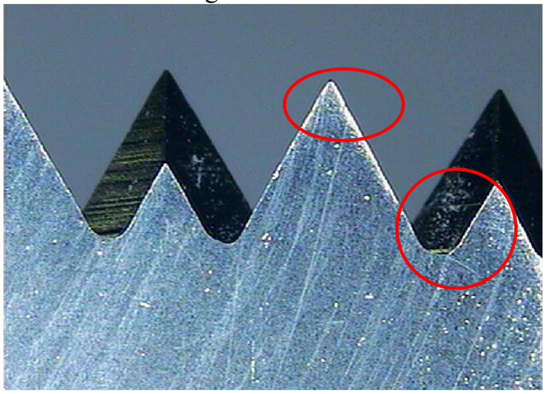

Figure 8(b) Bone saw blade with cryogenic treatment after cutting test.

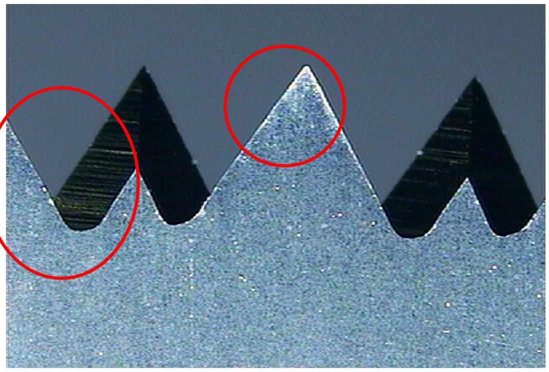

Figure 9 Bone saw blade before cutting test.

4. Conclusions

(1) The cutting time of cryo-treated bone saw blade is about one second less than that of untreated one. Regarding cutting efficiency, it can reduce 9.76% of the cutting time. Because the frictional heat can cause the risk of cell necrosis, cutting time is short as possible which is quite important for surgery.

(2) From the testing results, the average wear rate with cryo-treated one can reduce 65.95% with not-treated one, and the average amount can be reduced by 68.93% with cryo-treated one. There is obvious improvement after cryogenic treatment.

(3) By observing the tooth tip wear of a bone saw blade after cutting, there is obvious abrasion dent at tooth tip without cryo-treated one, and the abrasion dent after cryogenic treatment is much less obvious.

The above-mentioned benefits verify that cryogenic treatment can enhance the performance of a bone saw blade. However, we have not explored the reasons for creating the benefits. Further research needs to be conducted to explore the optimal cryogenic process and to elucidate the relationships between microstructure, cryogenic treatment and property of stainless steel.

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