Developments of the New Instruments for TMJ Arthroscopic Surgery

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A large and clearly visible operating area is essential for successful arthroscopic surgery of the temporo-mandibular joint. The keys to a successful operation are the safe and accurate positioning of a large scope and multiple cannulations, overcoming blind areas.

We developed some instruments to resolve these problems; i.e., scopes with a large diameter for high resolution, a triangulation instrument for multiple cannulations, a needle set-up jig for disk traction suture, a step cannulation system and a two-channel cannula for operating in the narrow lower joint space and a fixing jig for cannulas in the upper and lower joint space to observe the same portion of the discal tissue from both joint space during disk suturing.

From our experience in applying systematic procedures using these instruments in 37 arthroscopic surgeries, it is possible for this procedure to be done under a visual field and the surgical time considerably shortened.

Key words: Arthroscopic surgery, Design of instruments, Disk traction suture

INTRODUCTION

Arthroscopy of temporomandibular (TM) joint has recently been used increasingly instead of noninvasive therapy or open surgery. It has considerable merits not only in diagnostic examination, but also as an operative approach after observation to pathological changes and to positional disk displacement by direct observation on TV monitoring1-3. However, an arthroscopic surgery is not a simple procedure. Multiple cannulation techniques to obtain a larger visible operating area, proper fluid flow and performing surgical procedures are becoming common in arthroscopic surgery6. They require complicated instruments and skilled surgical manipulations such as disk traction suturing for closed lock, lysis and lavage for adhesion and cauterization of retro-discal tissue for holding the disk4,5. It is hard to perform these procedures in the small space of the TM joint.

We developed some instruments and improved procedures for arthroscopic surgery in order to simplify the complicated surgical techniques and to obtain surgical accuracy by standardized instrumentation. This article will report the new instruments and their application to systematic arthroscopic surgery of TMJ.

DESIGNS OF INSTRUMENTS

Design of a Large Diameter Scope

Large scopes with a 3.1 mm diameter and cannulas with a 3.5 mm diameter were designed in order to obtain as clear and wide operating area as possible. They have an
effective length of 148.5 mm, and entire length is 207.0 mm. The angle of view were 0 and 30
degrees and the field of view were 70 and 65 degrees as shown in Fig. 1. In addition, they have
sufficient stiffness during surgery and the large cannula also accepts various operating
instruments.

Development of the Triangulation Instrument

Figure 2 shows the design of the triangulation instrument which can hold two cannulas
during surgery. With this instrument, the ends of the cannulas containing two scopes and/
or surgical instruments align at the same point and are held steady during surgery. The
triangulation instrument consists of four aluminum plates with grooves slightly larger than
the radius of the cannulas. The four aluminum plates are assembled by three screws. The
cannulas inserted into these holes revolve around a central screw which acts as a hinge along
the same plane. By using this triangulation instrument, the ends of cannulas can easily meet
at a common point and the cannulas are held steady during surgery. The position of the hinge
can be adjusted by moving the central screw (Fig. 3).

We made two this triangulation instrument in two sizes; one for our large cannula and
another for a commercial product* (scope with a 2.3 mm diameter and cannula 2.8 mm in
diameter).

Development of Needle Set-up Jig for Disk Traction Suture

This instrument, made of acrylic resin, simplifies disk traction suturing in the upper joint
space. The instrument connects to a cannula with a scope. The acrylic instrument for
traction suture has two holes, one for a cannula, and the other, 1.3 mm in diameter, for a
puncturing needle. The hole for the injection needle is at a 30 degree angle to the cannula hole
(Fig. 4).

This instrument is connected to a cannula containing a scope. The needle is inserted into

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* 2.3mm miniscope cannula system, Stryker, Sunnyvale, CA, USA
Fig. 2 Design drawing for the triangulation instrument. Six small holes are for cannulas and the central screw is movable to adjust the position of the hinge in order to select individual puncturing point without restriction.

Fig. 3 The triangulation instrument (left) and the assembled triangulation instrument with two cannulas (right).
the hole, and then the discal tissue is punctured percutaneously. The tip of the needle and the thread passing through this needle appear in the upper joint space and can be identified at the center of the arthroscopic visual field.

Two sizes of this instrument were also made; one for our large cannula, 3.5 mm in diameter, and one for a standard size cannula with a 2.8 mm diameter** (Fig. 5).

*Development of Step Cannulation System for Lower Joint Space*

A step cannulation system was developed for accurate positioning of the cannula in the lower joint space. Using this system, a 2.8 mm cannula can be placed directly and automatically into the objective area of the narrow lower joint space, in which an 18 gauge needle can be placed.

The step cannulation system consists of six cannulas and obturators, each one increasing in diameter by 0.4 mm until 2.9 mm in diameter. Figures 6 and 7 show the step cannulation system and Fig. 8 shows a cross section drawing. As shown in Figs. 6, 7 and 8, the obturator increase in diameter from 0.5 to 2.5 mm in six steps and each has a length of 140 mm. The cannulas were from 0.9 mm to 2.9 mm in diameter. The length of each cannula became 10 mm shorter, from 130 mm down to 80 mm, as the diameter increases.

After the 18 gauge guiding needle is inserted into the lower joint space, the first obturator, 0.5 mm in diameter, is inserted into the guide needle. Then, the needle is removed, but the obturator remains. The first thinnest cannula is placed over the first obturator. Then cannulations are performed progressively, step by step, until the sixth cannula is inserted along the previous one.

The cannulas, except the sixth cannula, are removed; the final obturator is inserted into the sixth cannula; then, the sixth cannula is also removed. However, the sixth obturator remains. The final cannula with a 2.8 mm diameter containing scope can be accurately positioned into the lower joint space over the sixth obturator. The step cannulation system

** Stryker, Sunvale, CA, USA
Fig. 5 The assembled needle set-up jig with a cannula and needle for disk traction suturing (see figs. 13-B and 14).

Fig. 6 Schematic drawing of assembled step cannulation system for accurate positioning of a 2.8mm cannula into the lower joint space. The first guide obturator passing through the 18 gauge guiding needle is 0.5mm and the thinnest cannula with 0.9mm in diameter is punctured onto the first obturator. The next cannulas gradually increase by 0.4mm in diameter and are advanced along previous ones until the final cannula containing the scope is in place (see figs. 8 and 13-C).
Fig. 7 Components of the step cannulation system for positioning the scope in lower joint space. A set of six cannulas (A) and obturators (B) with diameter increased of 0.4mm. The obturators are from 0.5 to 2.5 mm in diameter and have the same length of 140 mm. The cannulas are from 0.9 mm to 2.9 mm. The length of each cannula decreased by 10 mm from 130mm to 80mm: the final cannulas (C), with 3.5mm (right) and 2.8mm (left), containing scope.

Fig. 8 Schematic drawing of step cannulation system in cross section.

is only used for inserting the cannula into the narrow lower joint space.

Development of the Two-Channel Cannula for Lower Joint Space

A two-channel cannula was developed to obtain proper fluid irrigation and/or insert operative instruments in the lower joint space via a single puncture. Because the lower joint space is very narrow, multiple cannulations in lower joint may be considerably restricted.

The two-channel cannula allows one channel with a 2.8 mm diameter for the scope and the other with a 2.0 mm diameter for irrigation and/or inserting surgical instruments (Figs. 9 and 10). The two-channel cannula was also designed to perform surgery in the lower joint space. The two channel cannula is elliptical in shape measuring 4.8 mm by 2.8 mm. However, it can be positioned surely in the lower joint space by using the step cannulation system described above.
Development of the Fixing Jig for Cannulas positioned in the Upper and Lower Joint Spaces during Disk Traction Suturing

A cannula fixing jig was developed to position two cannulas into the upper and lower joint spaces during disk traction suture. The cannulas can be aligned and held in a constant position via the disk during surgery (Figs. 11 and 12). The suturing needle through the disk from the cannula in the lower joint space appears at the common point within the visual field of the scope in the upper joint space.

In addition, a stainless steel thread, 0.34 mm in diameter (2-0 U.S. P size), was used for suturing to reconfirm and estimate the disk position by X-ray after surgery.
RESULTS AND DISCUSSION

Arthroscopy of TMJ can detect joint pathology, i.e. inflammation of the synovium membrane, chondromalacia or early bony changes, fibrosis and fibrous adhesion\(^7,8\), that could not be identified by other clinical imaging methods such as the double-contrast arthrography\(^9\) and MRI\(^10\). Arthroscopic surgeries such as lysis and lavage for adhesion, electric cauterization of posterior attachment with scarring for prevention of disk displacement, and traction suture for a dislocated disk\(^11-13\) have been performed.

However, the spatial relationships of TMJ have more complicated anatomy than other body joints\(^14,15\). The lower joint space, segregated by the disk, is smaller than the upper compartment, and is bordered by the movable mandibular head. Limited arthroscopic surgery has been applied to the upper joint space. In the lower joint space, only diagnostic observation has been performed using an ultrathin scope at present.

However, even if surgery is performed in the upper joint space, the puncture points and the size of the scope are limited. The restriction of surgical instrumentations might cause a blind operation.

We have developed some new instruments for systematic arthroscopic surgery under
visual fields covering the whole of the surgical area and simplified the techniques for arthroscopic surgery.

**Development of the Large Scope in Diameter**

It is commonly thought that using large instruments in the narrow TM joint space is cumbersome and results in damage to the joint structure. It is a fact that the techniques advancing a large scope into a trough of the joint space are more difficult. Frequently, the so-called needle scope (scope: 1.7 mm in diameter, cannula: 2.2 mm in diameter) has been used.

However, good surgical handling is based on good visualization. Basically, as the diameter of the scope increases, it becomes easier to obtain high resolution, and a clear, wide view. In addition, it provides us with mechanical strength. The key to successful surgery should depend on inserting the large scope without any damage to peripheral tissue, positioning multiple cannulas safely and certainly, and diminishing the blind area.

By careful handling of a large cannula with a scope, we minimized tissue damage and were able to operate in a wide and clear visible field. There were no problems on advancing the large cannula into the trough of the area at the intermediate zone of the disk in the upper joint space.

**Development for the Triangulation Instrument**

The triangulation instrument is designed to hold the cannulas steady in the upper joint space during multiple cannulation with scopes and surgical instruments. When it was impossible to visualize the whole of the operating area by a single scope, a second scope with a different view angle was added to obtain a wider view and to diminish the blind area. It is necessary for the ends of the cannulas to meet at a same point at that time.

However, it is difficult to position the ends of multiple cannulas at one point by a blind technique because of the limitation of puncture points and the restriction of movable area of the cannulas in the narrow joint space.

Furthermore, it is very hard for one surgeon to perform the operation while holding two or more cannulas steady and maintaining the ends of cannulas at the common point. That causes a waste of time. By using the instrument we devised, multiple cannulas connected with scopes can be properly placed making it easy to perform instrumentation under good visualization. The triangulation instrument greatly improves the design reported previously by Tarro. The mechanism of his design was very simple and was not sufficient for our operation, although his idea was correct. A specific character of the instrument is that it has six holes for inserting cannulas and a movable and adjustable hinge point. The proper puncture point could be selected individually without restrictions. By selecting the suitable hole and adjusting the angle, it enables us to position and direct multiple cannulas (Fig. 13-A).

**Development of the Needle Set-Up Jig for the Disk Traction Suture**

The aim of this instrument is to help determine the spatial relationship between the disk suturing needle and scope in the upper joint space. The needle set-up jig prevented the suturing needle from advancing out of the visible field. There would be considerable time wasted finding the needle in the previous manner. By using this jig, the needle suturing through the disk percutaneously appears into the center of the visual field of the scope in the
upper joint space. The surgery can be performed very surely, arthroscopically. The accurate suture of the posterior band of a dislocated disk and the pulling the disk posteriorly and laterally could be performed arthroscopically by triangulation suturing.

It enabled us to simplify difficult techniques and indicate the orientation of spatial relationship between a scope and the needle's puncturing point and direction of the needle, even if the surgeon was inexperienced. It also saved time during operation (Figs. 13-B and 14).
Development of a Step Cannulation System for the Lower Joint Space

Arthroscopic surgery has been performed in the upper joint space only. In the lower joint space, only observation has been done. However, not only examination but also surgery could be performed arthroscopically in the lower joint space about disk traction suture.

Surgery of the small joint requires experience and skill. The dimension of the lower joint space is altered dynamically by movement of the mandibular head is making arthroscopic surgery in the lower joint space difficult. Only an ultrathin scope has been used for diagnostic examination of the lower joint space.

The step cannulation system was improved to position the cannula into the lower joint space surely and safely. A similar system was reported by Westersson et al.\cite{17} for placing a puncturing needle scope into the upper TM joint space for examination. Another such technique for subcromial bursa cannulation with a long and large diameter ($\phi = 4.0$ mm) cannula was reported by Midorikawa et al.\cite{18}.

We improved both previous instruments to position a scope with 2.8 mm cannula into the lower joint space. The final cannula was larger than Westersson's, and shorter than Midorikawa's and the steps were increased more gradually (Fig. 13-C).

By using this step cannulation system, it is certainly possible to position a 2.8 mm cannula into the lower joint space. It is essential for positioning the scope into small joint space. The accuracy of disk traction suturing can be increased by identifying the discal tissue from both sides.

Development of the Two-Channel cannula for the Lower Joint Space

The arthroscopic surgeries previously reported, including our method described above, were performed only in the upper joint space. Especially in disk traction suturing, a blind
operation might be occur during puncturing the discal tissue. The direction of the traction of the disk might be lateral rather than posterior.

As it is hard to position multiple cannulas in the narrow lower TM joint space. A two-channel cannula was devised for proper fluid irrigation and surgery by a single puncture. A two-channel cannula was developed by Ohnishi19). His instrument was designed to be able to perform many kinds of operations by a single puncture, so the system was very complicated. Our system is simpler because our only purpose is to suture discal tissue under visualization from both joint spaces for disk traction. Actually, this two-channel cannula is large sized, 4.8 mm in maximum diameter. However, the insertion of this cannula can be done certainly by using the step cannulation system mentioned above.

We can identify the operating area and approach from both upper and lower joint spaces during traction suturing. This method diminishes the blind area and only the discal tissue is sutured. Surgery can be done within the joint space, not approached laterally and percutaneously. This disk traction suturing technique could improve on its accuracy, as the traction of the disk was directed posteriorly different from the triangulation suturing technique (Figs. 13-D and 15).

Fig. 15 Schematic drawing of disk traction suture from lower joint space (LS). After identifying the posterior band of the disk (D) by both scopes (CSU and TCL), an 18 gauge needle (IN) passing through the out-flow cannula of the two-channel cannula (TCL) punctures the upper joint space (US) through the discal tissue. The suture thread (ST) is inserted into the needle, then appears in center of the visual field of the upper scope. Alligator forceps (AF) catch and pull the thread to the external acoustic meatus.
However, instrumentation of the two-channel cannula into the trough portion of the lower joint space often could not be advanced due to its size. We are designing a reduced size of two-channel cannula by combining a smaller scope, such as the ultrathin scope.

**Development of the Fixation Jig for Upper and Lower Cannulas**

We also developed a fixing jig for holding both cannulas in the upper and lower joint space during surgery. The aim of this instrument is similar to the triangulation instrument. It also realigns the cannulas via the disk (Fig. 13-D). The suturing needle passing through the disk from a two-channel cannula in the lower joint space appears in the visual field in the upper joint space. The suture thread is inserted into the needle, and grasped by the alligator forceps coming from the external acoustic meatus within the upper joint space (Fig. 15) and can be seen on a TV monitor.

**CONCLUSION**

We have developed systematic instrument to avoid blind operation in TMJ arthroscopic surgery. This system can be performed successfully even by less experienced surgeons.

From our experiences of arthroscopic surgery on 37 joints, this systematic and standardized instrumentation increases the accuracy of surgery and shortens the operation time. It helps the surgeon introduce TMJ arthroscopic surgery and aids the training of surgery residents.

**REFERENCES**

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レーザーラマン分光学を応用した接着界面の研究
—— 4-META/MMA-TBB レジンと牛及びヒト象牙質界面の分析——

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前報で 4-MET/MMA-TBB レジンとハイドロキシアパタイト、牛歯エナメル質との接着界面の研究を行ったが、今回は統報として 4-MET と牛及び、ヒト象牙質間の化学結合の可能性を、ラマンスペクトル測定により検討した。市販モノマー液中から体積率 2/3 の MMA を揮発して得た濃縮モノマー液を 10-3 処理した牛及び、ヒトの象牙質に塗布したことら、両者共に塩の形成が認められた。この塩は、前回我々が報告したハイドロキシアパタイト及び、牛歯エナメル質表面で、4-MET が形成した塩と同様の過程で形成されたものと考えられる。一方、象牙質中の有機成分と 4-MET の間で化学変化が起こったことを示唆するバンドは認められなかった。

モルモットに対するデンチングプライマーによるアレルギー反応の検討

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象牙質の接着に不可欠な試作デンチングプライマーである GM、HEMA、EM、を用いてモルモットに対する免疫学的アレルギー反応を検討した。その結果、即時型アレルギー反応はいずれのプライマーおよびこれらの基本的化学構造物であるメタクリル酸においても観察されなかった。また、デンチングプライマーとメタクリル酸を用いモルモットの背部皮膚に長期間の反復塗布を行った。メタクリル酸では、塗布開始後 18 日で強い発赤、浮腫が認められた。GM、HEMA、EM では、軽度の発赤を認めめた。炎症が完全に消失した 25 日後の塗布試験においては 7 日間で 18 日後と同様の炎症が認められた。このことからメタクリル酸、GM、HEMA、EM の遅延型アレルギー発現の可能性は示唆された。皮内授与による局所刺激では、塗布試験より過敏な条件であることから、2 時間後に水泡、7 日後で発疹を形成した。今回の実験結果により、試作デンチングプライマーの遲延型アレルギー反応（接触性皮膚炎）発現の可能性が示唆された。

顎関節鏡視下手術のための手術器具の開発

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顎関節鏡視下手術は、従来の様々な画像診断法で観察できなかった観察内病態を直接鏡視下にて診断が可能であること、診断後に手術が行える理由により普及しつつある。
しかし狭小で複雑な類関節腔内への関節鏡や手術器具の挿入操作は容易ではなく、複雑な器具の操作と高度の熟練が要求される。そのため、手術の成否は盲目的操作をさげ、明るく広い視野の獲得と、手術器具の到達が確実で安全に行えことが必要である。

このため我々はこれらの問題を解決し、また手術操作を簡略化するために、口径の大きなスコープ、多数穿刺のためのスコープの固定器具、より狭小な下関節腔への確実な到達のためのステップ・カニュレーション穿刺法と関節円板縫合用の2チャンネル・カニューレといった一連の手術器具、およびその操作法をシステム化した。

我々の37関節の鏡視下手術の経験から、技術的問題点は改善され、手術時間も大幅に短縮した。特に困難な下関節腔からの円板牽引縫合法については、その効果と操作性に大きな改善をみることができた。