BRUNO LIVANI

Este exemplar corresponde a versão final da Tese de Doutorado apresentada ao Curso de Pós-Graduação em Cirurgia da FCM/UNICAMP, para obtenção do título de Doutor em Cirurgia, área de Cirurgia, do aluno Bruno Livani, RA:993512. Campinas, 23 de fevereiro de 2007.

Prof. Dr. William Dias Belangero – Orientador

FRATURAS DO TERÇO DISTAL DO ÚMERO ASSOCIADA À PARALISIA RADIAL:

tratamento pela técnica MIPPO

CAMPINAS

2007

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Tese de Doutorado apresentada à Pós-Graduação da Faculdade de Ciências Médicas da Universidade Estadual de Campinas para obtenção do título de Doutor em Cirurgia, área de concentração em Pesquisa Experimental.

ORIENTADOR: *PROF. DR. WILLIAM DIAS BELANGERO*

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Banca examinadora: Profº Drº William Dias Belangero
Profº Drº Humberto Santo Neto
Profº Drº Heitor José Rizzardo Ulson
Profº Drº Maurício Kfouri Júnior
Profº Drº José Soares Hungria Neto

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Banca examinadora da tese de Doutorado

Orientador: Prof. Dr. William Dias Belangero

Membros:

1. Prof. Dr. William Dias Belangero
2. Prof. Dr. Heitor José Rizardo Ulson
3. Prof. Dr. Humberto Santo Neto
4. Prof. Dr. José Soares Hungria Neto
5. Prof. Dr. Maurício Kfuri Júnior

Curso de pós-graduação em Cirurgia, da Faculdade de Ciências Médicas da Universidade Estadual de Campinas.

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DEDICATÓRIA

Fernanda, Tetê e Mandoca.

A Deus, fonte de toda luz. A Jesus mestre e irmão maior, e a todos os seus mensageiros de luz.

Aos meus pais, Michele Salvatore Livani e Therezinha Zambuzi Livani e ao meu irmão Frederico Livani, pelo apoio e confiança irrestritos.

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Ao Departamento de Anatomia do Instituto de Biologia – UNICAMP.

- Chefe Prof. Dr. Alexandre Leite Rodrigues de Oliveira.

- Técnicos em anatomia: Srs. Paulo Afonso Bernardes e Paulo Francisco dos Santos.

PÁG.

DCP	Dynamic Compression Plate
MIPPO	Minimally Invasive Percutaneous Plate Osteosynthesis.

RESUMO

O tratamento das fraturas do terço distal da diáfise do úmero associadas a lesão do nervo radial ainda é assunto de controvérsia. Especialmente nesta região o nervo pode estar comprimido ou encarcerado por fragmentos ósseos. A osteossíntese com redução indireta da fratura e fixação interna, nesses casos, pode resultar em lesão nervosa permanente.

O autor descreve uma técnica cirúrgica com a utilização da placa em ponte, introduzida percutaneamente nessas situações específicas. Seis pacientes foram operados evoluindo com a consolidação da fratura e a recuperação neurológica num tempo médio de 03 meses. Nessa casuística a única complicação foi um caso de infecção com fistula na cicatriz distal que resolveu completamente com a retirada do material de implante.

ABSTRACT

Fractures of the distal third of the humerus may be complicated by complete lesions of the radial nerve which may be entrapped or compressed by bone fragments. Indirect reduction and internal fixation may result in a permanent nerve lesion.

The author describe the treatment of these lesions by insertion of a bridge plate using the minimally-invasive percutaneous technique. Six patients were operated on and showed complete functional recovery. Healing of the fractures occurred at a mean of 2.7 months (2 to 3) and complete neurological recovery by a mean of 2.3 months (1 to 5). In one patient infection occurred wich resolved after removal of the implante.

1- INTRODUÇÃO

A partir da década de 1960, com os acidentes de tráfego tornando-se mais graves e as equipes de resgate mais eficientes, pacientes politraumatizados e polifraturados passaram a sobreviver com fraturas mais complexas (Christensen, 1967). Esses pacientes necessitam de imobilização prolongada no leito hospitalar, tornando essas fraturas, se tratadas conservadoramente, mais suscetíveis a complicações (Pehlivan, 2002; Jawa et al, 2006). No caso específico da fratura diafisária do úmero, a impossibilidade do paciente assumir a posição ortostática e de utilizar funcionalmente o membro fraturado pode repercutir negativamente sobre a manutenção do alinhamento ósseo e no tempo necessário para a consolidação (Packer et al, 1972; Bell et al, 1985). Taxas de até 10% de pseudartrose e de até 40% de consolidação viciosa são relatadas no tratamento conservador nesses pacientes (Bleeker et al, 1991).

Com a intenção de reduzir essas complicações, alguns autores passaram a estender a indicação de osteossíntese para as fraturas diafisárias transversas, oblíquas curtas, muito proximais ou distais, com lesão vásculo nervosa associada, em pacientes obesos ou com seios muito grandes (Rüedi et al, 1974; Heim et al, 1993; Paris et al, 2000).

Dentre os métodos de tratamento cirúrgico tradicionais, pode-se citar a osteossíntese a foco aberto, com a utilização de placas de compressão, ou a osteossíntese a foco fechado, com a utilização de hastes intramedulares bloqueadas (Heim et al,1993; Rommens et al 1995; Mulier et al, 1997; Ruland, 2000).

Do ponto de vista prático, a redução aberta e a fixação interna com placas continua sendo no nosso meio o método mais utilizado para o tratamento das fraturas da diáfise do úmero. Se a opção for pela placa, é indicada a placa de grandes fragmentos, estreita, com 6 a 8 furos ou larga dependendo do diâmetro da diáfise do úmero e que pode ser colocada na sua face lateral ou posterior. Os parafusos devem ser colocados de forma não alinhada para se reduzir o risco de fratura da diáfise durante movimentos torcionais do braço. Apesar de ser considerado ainda na literatura como método padrão apresenta como principal desvantagem a exposição ampla do foco de fratura, dos fragmentos ósseos, o que aumenta os riscos de infecção, de retarde de consolidação e de lesão do nervo radial (Rockwood e Green, 1996; Rüedi e Murphy, 2002).

As duas vias de acesso mais utilizadas para a redução aberta e fixação interna das fraturas da diáfise do úmero são a posterior e a ântero-lateral. A via ântero-lateral oferece menor risco de lesão do nervo radial, porém maior possibilidade de lesão do nervo musculocutâneo. O paciente necessita ser posicionado em decúbito dorsal horizontal e a placa pode ser fixada na face ântero-lateral. Por outro lado, a via de acesso dorsal apresenta como inconveniente o posicionamento do paciente em decúbito lateral ou ventral. No entanto, apesar de tecnicamente mais trabalhosa, oferece excelente exposição do nervo radial (Crenshaw, 1992; Hoppenfeld e deBoer, 1994; Gerwin, et al, 1996; Uhl et al, 1996; Mekail et al, 1999; Bono et al, 2000; Mazurek e Shin, 2001).

Respaldado pelos bons resultados obtidos com as hastes intramedulares bloqueadas nos membros inferiores, elas passaram a ser utilizadas para o tratamento das fraturas da diáfise do úmero. Entretanto, os resultados iniciais não foram tão animadores quanto se esperava. Em 2003, Rüedi e Rommens, após análise de quatro estudos clínicos comparativos entre os resultados de osteossíntese de fraturas diafisárias do úmero tratadas com placas e diversos tipos de hastes, concluíram que não há diferenças signficativas entre esses métodos em relação à taxa de consolidação das fraturas ou da incidência de infecção. As hastes, entretanto, tiveram mais complicações relacionadas à dor e função do ombro. [1]

Bhandari et al (2006), após analisar 215 artigos que utilizaram placas ou hastes intramedulares entre 1969 a 2000 para tratar fraturas da diáfise do úmero, concluíram que somente três preenchiam os critérios de qualidade, totalizando 155 pacientes. Concluiram que com o uso das placas, o risco de re-operação e a incidência da síndrome do impacto no ombro eram menores.

Changulani et al (2006) publicaram um estudo prospectivo, onde 47 pacientes com fratura da diáfise do úmero foram randomizados entre redução aberta com fixação interna com haste intramedular ou fixação com placa do tipo DCP®. Foram incluídos pacientes com fraturas expostas grau I e II (Gustilo e Anderson,1976), politraumatizados, fraturas instáveis e falhas recentes do tratamento não cirúrgico. Vinte e três pacientes foram tratados com hastes e 24 com placas. As hastes foram introduzidas por via

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(1) http://www.aopublishing.org/PFxM/422.htm

anterógrada após fresamento da cavidade medular e as placas por via ântero-lateral ou posterior. O tempo médio de união foi significativamente menor para a haste; a infecção foi mais freqüente com as placas, enquanto que o encurtamento e a restrição dos movimentos do ombro ocorreram mais com as hastes. No entanto, todos os pacientes com síndrome do impacto melhoraram após a retirada da haste intramedular. Os autores concluíram que a haste intramedular pode ser considerada a melhor opção de tratamento cirúrgico, já que apresenta menor tempo para a união da fratura e menor incidência de complicações graves.

Com relação às complicações apresentadas pelas placas e hastes intramedulares a literatura descreve taxas extremamente variadas. Retardo de união ocorre nos pacientes em 3% a 20 % quando tratados com placas e 0 a 29% com as hastes. Quanto à infecção, as taxas estão em torno de 5% para os pacientes tratados com placas e de 0 a 3% para os tratados com as hastes. Lesão iatrogênica do nervo radial acomete cerca de 8% a 14% dos pacientes tratados com placas e de 0 a 5% com hastes (Klenerman, 1966; Rüedi et al, 1974; Farragos et al, 1999).

A paralisia do nervo radial associada a fraturas da diáfise do úmero, é a lesão nervosa mais comum complicando fraturas dos ossos longos, seja durante o tratamento cirúrgico ou conservador (Crenshaw, 1992; Pehlivan, 2002; Shao et al, 2005). O nervo radial é continuação do fascículo posterior do plexo braquial logo depois da origem do nervo axilar. Suas fibras procedem das raízes C5, C6, C7,C8 e T1. Chegando no braço, penetra no espaço axilar inferior e chega à face posterior do úmero percorrendo o sulco radial. Perfura de posterior para anterior o septo intermuscular lateral, passando do compartimento posterior para o anterior do braço. Percorre o sulco bicipital lateral até próximo da linha interarticular onde se divide em dois ramos terminais com possibilidade de algumas variações anatômicas (Testut e Jacob, 1932; Rouviére, 1959; Testut e Latarjet,1959).

Na face posterior, está em íntimo contato com a diáfise do úmero, no sulco radial, sendo impossível a realização de osteossíntese com placas em ponte nessa região (Guse e Ostrum, 1995; Livani e Belangero, 2004 a,b). No terço inferior do braço, o nervo radial situa-se no sulco bicipital lateral, formado: pelo septo intermuscular lateral, atrás; pelos músculos braquial e bíceps, medialmente; pelos músculos braquiorradial, extensores radial longo e curto do carpo, lateralmente. Dessa forma, no compartimento anterior, encontra-se mais afastado da diáfise do úmero devido a presença de um coxim muscular composto pelos músculos braquial, braquiorradial e extensores radial longo e curto do carpo, sendo possível a realização da osteossíntese em ponte com assentamento seguro da placa na face anterior da diáfise ou na face anterior da coluna lateral da diáfise do úmero (Testut e Jacob, 1932; Rouviére, 1959; Testut e Latarjet,1959; Livani,2001; Livani e Belangero, 2004 a,b).

O septo intermuscular lateral representa o ponto de maior vulnerabilidade de lesão permanente do nervo radial, secundária a fraturas diafisárias do úmero. Nessa região, ao atravessar o septo, o nervo radial embora não esteja em contato tão mais íntimo com a diáfise, encontra-se fixo pelo septo, sendo susceptível a traumas direto ou indireto, com pinçamento ou encarceramento do nervo por fragmentos ósseos ou pelo calo ósseo. As fraturas do terço distal, com traço espiralado ou oblíquo, são sujeitas a ter lesões nervosas mais graves, causadas por laceração ou interposição do nervo radial. Nessas fraturas, o fragmento distal é desviado cranialmente e em varo produzindo contusão e/ou encarceramento do nervo no foco da fratura (Whitson, 1954; Holstein e Lewis,1963; Kleinert e Metha, 1996; Chesser e Leslie, 2000).

A fratura diafisária do úmero, quando associada à lesão do nervo radial, suscita discussão quanto à indicação do tratamento, se conservador ou cirúrgico (Holstein e Lewis, 1963, Keinert e Metha, 1996). Há autores que preconizam a exploração cirúrgica imediata do nervo radial com a fixação interna da fratura, procedimento não isento de risco (Holstein e Lewis, 1963; Packer et al, 1972) . Outros acreditam que a conduta nesses casos deva ser conservadora, já que 88% dessas paralisias recuperam-se espontaneamente (Pollock, 1981; Sonneveld et al, 1987; Barbieri et al, 1996; Shao et al, 2005). A exceção ocorre nas fraturas do terço distal do úmero, com traço espiralado ou oblíquo curto, como descrito por Whitson, 1954 e comprovado clinicamente por Holstein e Lewis, 1963. Nesses casos, como o nervo radial apresenta-se fixo pelo septo intermuscular, pode ser aprisionado pelos fragmentos ósseos no foco de fratura, reduzindo assim, a possibilidade de recuperação espontânea (Whitson,1954; Holstein e Lewis, 1963; Chesser e Leslie, 2000).

Os defensores da exploração precoce do nervo radial alegam que a cirurgia precoce é tecnicamente mais fácil e segura. A visualização direta do nervo permite um diagnóstico mais preciso da gravidade da lesão definindo-se melhor o prognóstico, possibilitando até a indicação precoce de transferências tendinosas precoces ou concomitantes à cirurgia do nervo. A redução e fixação da fratura previne dano nervoso adicional pelos fragmentos ósseos e pela formação do calo. Entretanto, seus oponentes referem que a taxa de recuperação espontânea é alta e a conduta expectante evita complicações de uma cirurgia desnecessária. Além disso, sugerem que a recuperação nervosa com reparo cirúrgico precoce é semelhante ao reparo tardio e que o espessamento da bainha do neurilema que ocorre no processo de mielinização ajuda a definir a extensão do dano nervoso e facilita o reparo cirúrgico (deMourgues et al, 1966; Deburge e Delisle, 1971; Pollock et al, 1981; Vichard, 1982; Alnot e Reun, 1989; Samardzic et al, 1990; Amillo et al,1993; Vichard, 2000; Alnot et al, 2000; Marsh et al 2004; Cognet et al, 2002; Lowe et al, 2002 a,b; Ring et al 2004; Shao et al, 2005)

Desde a década de 80 a cirurgia minimamente invasiva vem sendo utilizada no tratamento de fraturas da diáfise dos ossos longos dos membros inferiores (Heitemeyer et al, 1987; Krettek et al, 1997; Miclau e Martin, 1997).Esse método tem como princípio obter o alinhamento dos fragmentos ósseos, sem abordar diretamente o foco da fratura, fixando-os com estabilidade relativa, minimizando-se assim a agressão cirúrgica e a morbidade pós-operatória decorrente. No caso das fraturas cominutivas, a preservação dos pedículos vasculares ligados aos fragmentos ósseos é de fundamental importância na formação do calo ósseo (Farouk et al, 1997).

Estudos recentes relatam com sucesso e segurança, o emprego dessa técnica para o tratamento das fraturas da diáfise do úmero sem lesão associada do nervo radial (Livani, 2001; Dell'Oca, 2002; Hernandez, 2003; Livani e Belangero, 2004 a,b; Apivathakakul et al, 2005).

Entretanto, as fraturas do terço distal do úmero associadas à lesão do nervo radial, como descrito por Holstein e Lewis continuam sendo uma situação não muito bem definida quanto à forma de tratamento. Nesses casos, métodos de redução indireta e fixação a foco fechado podem aumentar os riscos da lesão nervosa permanente.

2- OBJETIVOS

Apresentar a descrição de uma nova abordagem cirúrgica para o tratamento das fraturas do terço distal da diáfise do úmero associadas à lesão completa (sensitiva e motora) do nervo radial, empregando-se a técnica MIPPO.

3- MATERIAL E MÉTODOS

Esse estudo foi desenvolvido em três etapas:

1) Estudo com dissecção de cadáveres, da anatomia cirúrgica do nervo radial, especialmente na região entre o terço médio e distal da diáfise do úmero, e sua implicação na osteossíntese com placas em ponte.

2) Desenvolvimento em cadáver, da técnica cirúrgica a ser empregada nas fraturas do terço distal da diáfise do úmero associadas a lesão do nervo radial.

3) Aplicação clínica da técnica e apresentação da casuística e dos resultados.

Anatomia cirúrgica do nervo radial e suas implicações na Osteossíntese minimamente invasiva das fraturas diafisárias do úmero com placas em ponte:

Há diversos trabalhos na literatura que enfatizam os reparos anatômicos para a localização do nervo radial devido à possibilidade de lesão associada a fraturas diafisárias do úmero, seja no momento do trauma ou durante o tratamento conservador ou cirúrgico(Whitson, 1954; Holstein e Lewis, 1963; Packer et al, 1972; Pollock et al, 1981; Guse e Ostrum, 1995 ; Kleinert e Metha, 1996; Uhl et al, 1996; Mekhail, et al, 1999; Bono et al, 2000; Mazurek & Shin, 2001). Contudo, essas descrições, relacionam a anatomia do nervo em situações particulares de risco em relação ao tratamento cirúrgico convencional, através de vias de acesso classicamente utilizadas: via de acesso posterior, lateral ou ântero-lateral, todas necessitando dissecção e visualização amplas do nervo e da fratura(Hoppenfeld e deBoer, 1994; Gerwin , 1996; Hassan e Johnston, 1999) .

A osteossíntese minimamente invasiva dessas fraturas (MIPPO) é realizada pela passagem de uma placa DCP, LC-DCP ou LCP, estreita, de 4,5 mm, pela face anterior do úmero, através de duas pequenas incisões e redução indireta da fratura e sem visualização do nervo radial (Livani, 2001; Livani e Belangero, 2004 a e b).

Realizou-se um estudo de dissecção anatômica com objetivo de se estudar a anatomia do nervo radial nos pontos de sua maior susceptibilidade de lesão durante o trauma ou tratamento convencional (região médio-diafisária e distal) e sua implicação durante a realização de técnicas de osteossíntese minimamente invasiva por redução indireta e fixação percutânea da fratura.

Foram realizadas dissecções das regiões ântero-lateral, lateral e póstero-lateral de 21 braços de membros superiores formolizados desarticulados na sisarcose escapulotorácica e na esternoclavicular de cadáveres adultos constando de 12 membros direitos e 9 esquerdos. Um membro direito foi eliminado do estudo devido à ocorrência de calo ósseo umeral com aparente encurtamento e discreto desvio em varo.

Os membros foram dissecados em "posição anatômica" (rotação neutra do braço + extensão do cotovelo + supinação do antebraço) iniciando-se com incisão longitudinal na face lateral e a divulsão de um mesmo plano se estendendo em direção anterior e posterior.

Os reparos anatômicos utilizados foram à porção posterior do acrômio, a tuberosidade deltóidea, o centro do epicôndilo lateral e o tendão bicipital na fossa antecubital. Os reparos ósseos foram identificados sobre visualização direta e marcados com fios de Kirschner, fixados perpendicularmente ao osso.

Os parâmetros utilizados foram: 1- comprimento umeral (medido da porção posterior do acrômio ao centro do epicôndilo lateral); 2- distância do acrômio ao local onde o nervo radial perfura o septo; 3- distância da tuberosidade deltóidea ao local onde o nervo radial perfura o septo; 4- distância do local onde o nervo radial perfura o septo ao epicôndilo lateral; 5- distância do nervo radial em relação ao tendão bicipital na prega flexora do cotovelo (fig.01).

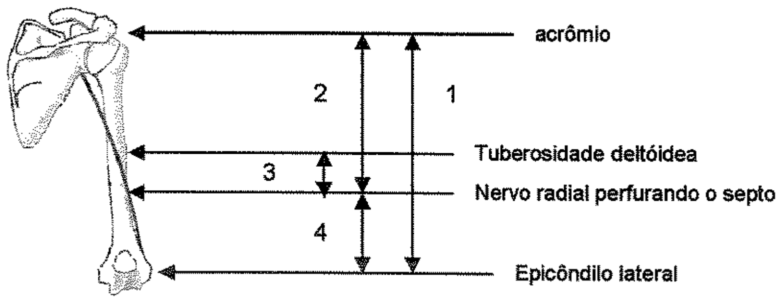

Figura 1- Reparos anatômicos mensurados

Após identificação do septo intermuscular lateral e o ponto de perfuração do mesmo pelo nervo radial, eram feitas 3 aferições em escala milimétrica, de cada dado analisado e por um mesmo examinador, das correlações anatômicas supracitadas para evitar erros de mensuração.

As outras variáveis morfométricas analisadas com suas respectivas técnicas de mensuração foram: 6- o comprimento do nervo radial que estava em contato direto com o periósteo no sulco espiral antes e após perfurar o septo intermuscular lateral (uso de fita métrica maleável); 7- a espessura "in situ" da musculatura braquial sob o ponto médio do trajeto do nervo radial entre a perfuração do septo até a fossa antecubital (uso de medidor de profundidade milimetrado); 8- a espessura do nervo radial onde esse perfura o septo (uso de paquímetro) e por fim, 9- o ângulo com o qual o nervo radial perfura o septo intermuscular lateral ao adentrar no compartimento anterior do braço, (uso de transferidor geométrico sendo o septo intermuscular lateral considerado o eixo das abscissas).

Os dados foram compilados, calculados as médias reais e percentuais das proporções anatômicas e os resultados apresentados em tabelas.

O comprimento umeral médio foi de 301,4mm (270 – 332mm) (tabela 01). Em todos os casos analisados, o nervo radial percorreu grande parte da face posterior do úmero proximal sobre cabeça medial do tríceps.

Ao aproximar-se do septo intermuscular lateral, o nervo (envolto por fina camada de gordura e acompanhado pela artéria braquial profunda) entra em contato direto com o periósteo no sulco espiral por uma extensão média de 39mm (15 – 70mm), ainda no compartimento posterior antes de alcançar o septo (tabela 01). A seguir, perfura o septo com um diâmetro médio de 5.5mm (4 - 7mm) e com angulação média de 17° (10 - 21°) Tabela 01. Este foi o local de maior fixação do nervo radial ao úmero em todas as peças dissecadas.

Tabela 1- Mensurações morfométricas do nervo radial e músculo braquial

	Ângulo de perfuração do septo intermuscular lateral pelo nervo radial(graus)	Largura do nervo radial no septo intermuscular lateral (mm)	Espessura do músculo braquial interposto entre o nervo radial e a diáfise umeral(mm)
Variação	10-21	4 -7	4 -7
Média	17	5,5	5,2

A perfuração do septo está situada um pouco além da metade do comprimento umeral, mais precisamente a uma média de 191,4mm do acrômio (168 – 217mm) e a 110mm (80 – 126mm) do epicôndilo lateral, o que corresponde a 63.5% e 36.5% da distância proporcional do comprimento umeral, respectivamente. Em relação à tuberosidade deltóidea, a perfuração septal está distalmente localizada em média por 32,8mm (15 – 55mm) (tabela 02).

Imediatamente após o nervo radial penetrar no compartimento anterior do braço, entre as origens septal do braquiorradial lateralmente e diafisária do braquial medialmente, seu contato direto com o periósteo do sulco espiral variou de 0 a 25mm com média de 7,7mm. Neste plano intermuscular, todos os espécimes avaliados apresentaram o nervo radial mais intimamente relacionado com o músculo braquiorradial enquanto o braquial ia se interpondo entre o nervo e a diáfise umeral à medida que se afastava do septo.

No compartimento anterior do braço o nervo radial, a partir do septo intermuscular lateral, dirige-se distal e medialmente estando situado lateralmente ao tendão do bíceps braquial a uma distância média de 6.9mm (5 – 9mm) na prega flexora da fossa antecubital (tabela 02). No ponto médio deste trajeto, o músculo braquial se interpõe entre o nervo radial e a diáfise umeral com uma espessura média de 5.2mm (4 - 7mm) (tabela 01). Após a prega flexora do cotovelo, o nervo orienta-se lateralmente para baixo do braquiorradial e dos extensores radiais longo e curto do carpo onde se dividirá em interróseo posterior e sensitivo radial.

Tabela 2- Mensuração da sintopia do nervo radial no úmero

Distâncias mensuradas	Variação (mm)	Média (mm)
Comprimento umeral	270-332	301,4
Distância do acrômio ao nervo radial	168-217	191,4
Distância da tuberosidade deltóidea ao nervo radial	15-55	32,8
Distância do nervo radial ao epicôndilo lateral	80-126	110
Distância do nervo radial ao tendão bicipital na prega flexora do cotovelo	5-9	6,9
Comprimento do nervo radial em contato direto com o sulco espiral:		
Antes de perfurar o septo	15-70	39
Após perfurar o septo	0-25	7,7

Técnica cirúrgica empregada:

Os pacientes foram posicionados em supino, em mesa cirúrgica convencional conforme descrito por Livani & Belangero, 2004.

Através de uma incisão obliqua de aproximadamente 5,0 a 8,0 cm, na transição do terço médio para distal do braço, o nervo radial era localizado entre os músculos braquial e braquioestilorradial e reparado. Após a identificação do nervo na sua porção mais superficial, este era liberado de distal para proximal até o do foco da fratura na emergência do septo intermuscular lateral. O septo intermuscular era aberto o quanto fosse necessário até que houvesse certeza de que estivesse completamente livre para realização segura da fixação da fratura. Essa fixação era feita por técnica minimamente invasiva (MIPPO) utilizando-se placa reta estreita de grandes fragmentos, descrita a seguir:

O acesso proximal foi entre o tendão do músculo bíceps braquial medialmente e o tendão do músculo deltóide e veia cefálica lateralmente. O acesso distal foi o mesmo descrito por Kocher (Crenshaw, 1992). Uma placa DCP estreita de 4,5 mm foi escolhida e moldada para se adaptar a face anterior da coluna lateral do úmero. A placa era introduzida de distal para proximal e o parafuso mais distal foi inserido, deixando-o não muito apertado. O braço então, era abduzido em torno de 60 a 90 graus para se corrigir o desvio em varo, que é freqüente nessas fraturas. Em seguida, após correção do comprimento por leve tração manual, o fragmento distal era rodado de forma que o eixo entre os côndilos medial e lateral ficassem num plano ortogonal com o tendão longo do bíceps braquial. Somente então o fragmento proximal era fixado com um parafuso e o parafuso distal era apertado totalmente. Os fragmentos distal e proximal foram geralmente fixos com dois parafusos em furos alternados ou três parafusos consecutivos. A ferida cirúrgica era fechada de modo convencional sem necessidade de drenos ou imobilização externa adicional. Após a cirurgia, os pacientes foram encaminhados à fisioterapia e orientados a utilizar o membro operado para realização de atividades de vida diária. Os pacientes foram avaliados clinicamente a cada 15 dias e radiograficamente a cada 30 dias.

4- CASUÍSTICA

Esse estudo foi aprovado pelo Comitê de Ética da Faculdade de Ciências Médicas da UNICAMP (apêndice 01). Todos os pacientes com fratura do terço distal da diáfise do úmero associadas com paralisia do nervo radial que foram atendidos de março de 2004 a agosto de 2005 foram incluídos nesse estudo após assinarem termo de consentimento pós informado.

Durante esse período, foram tratados 06 pacientes (4 masculinos e 2 femininos), com idade entre 14 e 42 anos. Todas as fraturas eram fechadas e unilateral.

Em quatro pacientes a lesão do nervo radial ocorreu no momento do trauma e em dois pacientes a lesão ocorreu no curso do tratamento conservador. Um paciente foi operado no mesmo dia do trauma e os outros cinco foram operados num intervalo entre 10 e 30 dias do acidente.

O seguimento pós-operatório variou entre 08 e 22 meses.

Todas as informações da fase pré-operatória dos pacientes estão apresentadas na tabela 3.

Tabela 3- Apresentação da casuística

caso	**sexo**	**Idade (anos)**	**Trauma**	**Tempo Trauma/Paralisia (dias)**	**Intervalo Trauma/Cirurgia (dias)**
1	F	17	Espancamento	Imediato	30
2	M	28	Automobilístico	Imediato	Mesmo dia
3	M	14	Queda de bicicleta	Imediato	21
4	M	31	Automobilístico	08	15
5	M	23	Espancamento	Imediato	12
6	F	42	Queda da própria altura	05	13

5- RESULTADOS

Todas as fraturas consolidaram antes das 12 semanas de seguimento e a recuperação da lesão do nervo ocorreu entre 4 semanas a 5 meses (tabela 4).

O ângulo de carregamento e arco de movimentos foram restabelecidos em todos os pacientes. Um caso (numero 04) evoluiu com infecção superficial (hematoma infectado) na incisão distal após ter sofrido queda da própria altura no pós-operatório imediato (tabela 05). Inicialmente o paciente foi tratado com gelo e antibiótico oral sem melhora definitiva. Posteriormente, apesar da exploração cirúrgica do hematoma e administração de antibióticos o paciente continuou tendo recidivas da infecção com desenvolvimento de fístula ativa na incisão distal. Após 10 meses foi retirado o material de síntese pelos mesmos acessos cirúrgicos sem intercorrências e com resolução da infecção.

Tabela 4- Resultados clínicos pós-operatórios

Caso	Seguimento (meses)	Tempo de consolidação da fratura (meses)	Recuperação da lesão nervosa (meses)
1	22	3	3
2	18	3	5
3	18	2	1
4	16	3	2
5	14	2	1
6	8	3	2

Tabela 5- Resultados clínicos pós-operatório

Caso	Ângulo de carregamento (graus)	Flexão do cotovelo (graus)	Extensão do cotovelo (graus)	Complicações
1	7	130	0	Nenhuma
2	5	130	0	Nenhuma
3	5	130	0	Nenhuma
4	5	120	0	Infecção
5	5	130	0	Nenhuma
6	5	130	0	nenhuma

Fractures of the distal third of the humerus with palsy of the radial nerve

MANAGEMENT USING MINIMALLY-INVASIVE PERCUTANEOUS PLATE OSTEOSYNTHESIS

B. Livani,
W. D. Belangero,
R. Castro de Medeiros

From the State University of Campinas, São Paulo, Brazil

Fractures of the distal third of the humerus may be complicated by complete lesions of t radial nerve which may be entrapped or compressed by bone fragments. Indirect reducti and internal fixation may result in a permanent nerve lesion.

We describe the treatment of these lesions by insertion of a bridge plate using the minimally-invasive percutaneous technique. Six patients were operated on and showed complete functional recovery. Healing of the fractures occurred at a mean of 2.7 month (2 to 3) and complete neurological recovery by a mean of 2.3 months (1 to 5). In one patie infection occurred which resolved after removal of the implant.

Minimally-invasive surgery for the treatment of diaphyseal fractures of long bones in the lower limbs was introduced in the 1980s.[1-3] It has been used successfully for the management of fractures of the shaft of the humerus without palsy of the radial nerve.[4-6]

Fractures of the distal third of the humerus may be complicated by lesions of the radial nerve[7] and treatment by indirect reduction and fixation may increase the risk of a permanent nerve lesion. Spiral or oblique fractures of the distal third may be complicated by laceration, contusion or interposition of the radial nerve at the site of the fracture.[7]

We describe an approach to the management of such fractures with complete palsy of the radial nerve using minimally-invasive percutaneous plate osteosynthesis.

▪ B. Livani, MD, Orthopaedic Surgeon
▪ W. D. Belangero, PhD, Professor
▪ R. Castro de Medeiros, MD, Orthopaedic Surgeon, Resident
Orthopedics and Traumatology Department
Cidade Universitária Zeferino Vaz, CEP 13083-970, Campinas, São Paulo, Brazil.

Correspondence should be sent to Dr B. Livani at Rua Vicente Porto 208, Residencial Barão do Café 03, Bairro Barão Geraldo, CEP 13085-895, Campinas, São Paulo, Brazil; e-mail: brunolivani@hotmail.com

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Patients and Methods

Between March 2004 and June 2005, six patients with fractures of the distal third of the shaft of the humerus with palsy of the radial nerve were treated by minimally-invasive percutaneous plate osteosynthesis. Four were male and two female with a mean age of 25.8 years (14 to 42). All the fractures were closed and unilateral. A lesion of the radial nerve had occurred at the time of injury in four patients and in the other two during conservative treatment. One patient had surgery on the day of the injury and the other five at a mean of 18 days later (12 to 30). The mean follow-up was 16 months (8 to 22). Table I gives the pre-operative details of the patients.

Operative technique. The radial nerve v exposed between the brachialis and brach radialis muscles through an oblique incis approximately 5.0 cm to 8.0 cm long at junction of the middle and distal thirds of forearm (Fig. 1). After identifying the nerv was freed from its distal part proximal to emergence from the lateral intermuscular s tum, which was released (Fig. 2). Fixation v performed using the technique of minimal invasive percutaneous plate osteosynthes Proximal access was gained between the bic tendon medially and the tendon of deltoid a the cephalic vein laterally. The distal approa was as described by Kocher.[8] A narrow dynar compression plate (Synthes, Sao Paulo, Bra was moulded to fit the anterior face of the l eral column and inserted through the dis incision. The hole for the most distal screw w then drilled. The arm was then abducted between 60° and 90° to correct the varus de ation, the length re-established by traction a the distal fragment rotated into alignment w the proximal part of the shaft before attachi the plate by a single proximal screw. The pro imal and distal fragments were then fixed wi further screws (Fig. 3). The wound was clos without drains or external immobilisatic After operation the patients were referred f physiotherapy and were instructed to use t arm for the activities of daily living.

Results

All the fractures had healed at a mean of 2 months (2 to 3) and the nerve lesion recover at a mean of 2.3 months (1 to 5). The carryi

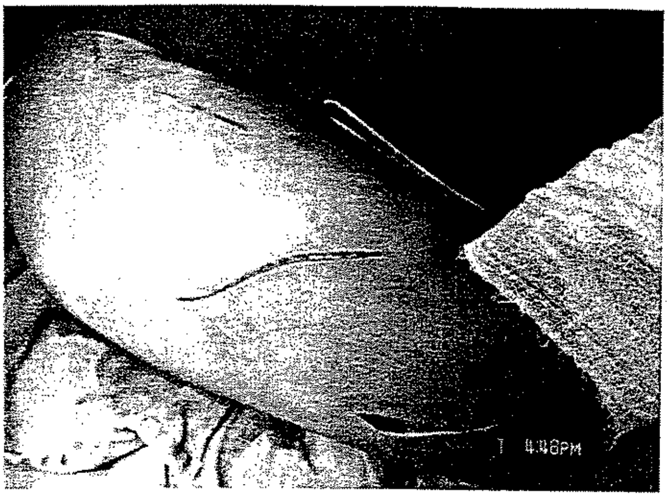

Fig. 1

Photograph of the three incisions.

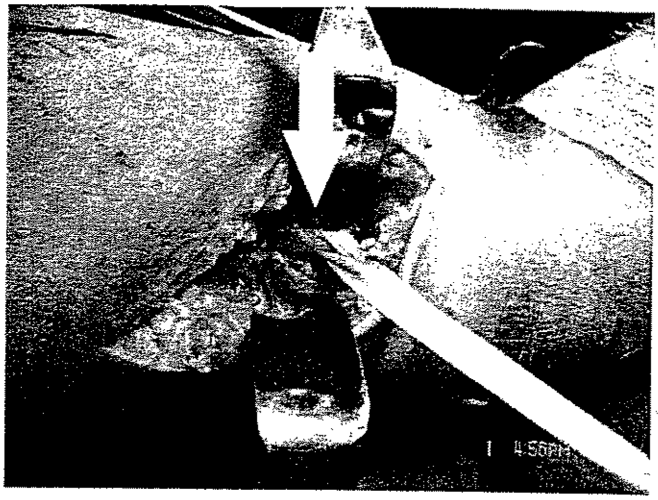

Fig. 2

Photograph of the radial nerve (arrow) and its exit from the intermuscular septum.

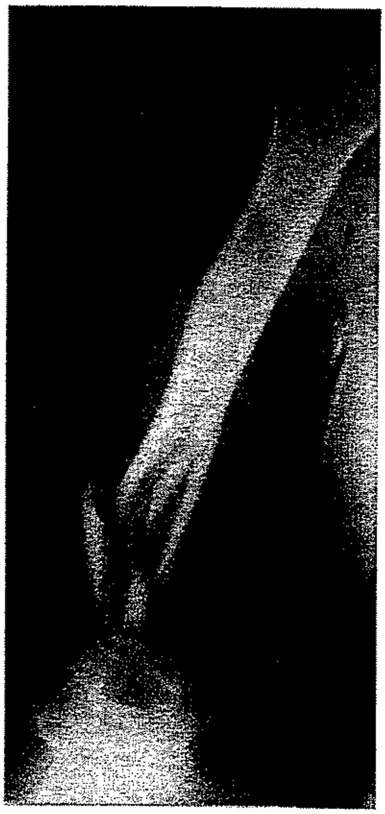

Fig. 3a

Fig. 3b

a) Pre-operative and b) immediate post-operative radiographs.

angle of the elbow and a normal range of movement were re-established in all cases (Table II). One patient developed a haematoma in the distal incision after a fall. This became infected and in spite of exploration and treatment with antibiotics it did not resolve until the implants had been removed through the original incisions ten months after the first operation.

Discussion

The incidence of fractures of the diaphysis of the humerus in North America is 20 per 100 000 inhabitants per year. Half involve the middle third and 20% to 30% are in the distal third.[9] Transverse fractures are more common in the middle third and spiral and oblique fractures in the distal third.[9]

Table I. Clinical details of the six patients

Case	Gender	Age (yrs)	Trauma	Time interval, trauma to nerve palsy	Time interval, trauma to surgery (days)
1	F	17	Assault	Immediate	30
2	M	28	Traffic accident	Immediate	Same day
3	M	14	Falling from a bicycle	Immediate	21
4	M	31	Traffic accident	8 days	15
5	M	23	Assault	Immediate	12
6	F	42	Fall	5 days	13

Table II. Details of outcome in the six patients

Case	Follow-up (mths)	Healing time (mths)	Recovery of radial nerve (mths)	Elbow movement (°) Final carrying angle (° valgus)	Flexion	Extension	Complications
1	22	3	3	7	130	0	None
2	18	3	5	5	130	0	None
3	18	2	1	5	130	0	None
4	16	3	2	5	120	0	Infection
5	14	2	1	5	130	0	None
6	8	3	2	5	130	0	None

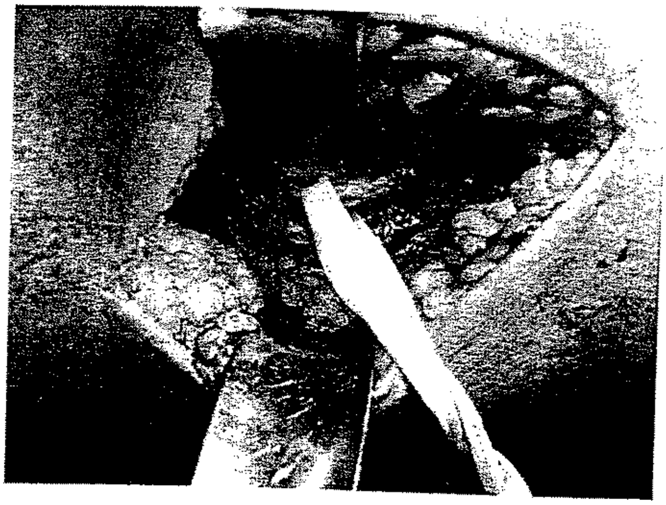

Fig. 4

Photograph of the radial nerve tethered by a distal bone fragment.

Lesions of the radial nerve occur in between 1.8% and 18% of cases with a mean of approximately 11%.[3,7,9] Some recommend conservative treatment of the fracture in these cases since in more than 80% the nerve will recover function spontaneously.[10] However, others advise immediate surgical exploration of the nerve with internal fixation of the fracture.[2,9,10] In the middle third of the humerus the radial nerve is still not fixed by the intermuscular septum and there is a greater protective layer of soft tissue between the nerve and the shaft of the humerus. Traumatic lesions of the radial nerve at this level are generally due to neurapraxia and have a high potential for spontaneous recovery.[11] In the distal third of the humerus, the nerve is fixed by the lateral intermuscular septum and is in close contact with the diaphysis. Acute lesions or those which develop during conservative management of a fracture at this level are due to contusion or entrapment of the radial nerve. Spiral or oblique fractures have a greater propensity towards causing this type of nerve lesion, making spontaneous recovery impossible, improbable or unpredictable.[7,9,11,12] In two of our six patients the nerve was interposed between bone fragments and in the remaining four it was compressed by a spike of bone due to proximal deviation of the distal fragment (Fig. 4).

The cases reported in the literature are not uniform as regards the type of lesion. In partial lesions or motor lesions with preserved sensory function, the rate of spontaneous recovery is greater than in those with complete sensory and motor loss.

Intramedullary implants are not the treatment of choice in most distal fractures.[13-15] Open reduction and internal fixation with plates is more appropriate despite the greater surgical morbidity.[16]

The procedure described in our study uses the advantages of the minimally-invasive percutaneous osteosynthesis technique with the need for exploration and freeing of the radial nerve in these cases. It reduces morbidity and the length of the operation and lessens the risk of infection, delayed union and pseudarthrosis.[1,2,16,17] It facilitates early exploration of the nerve and allows stabilisation of the fracture without requiring more than minor exposure of the bone fragments, thus minimising their devitalisation and enhancing consolidation. If it is necessary to remove the plate this may be done through the original proximal and distal incisions without risk of further compromise of the radial nerve.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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6- DISCUSSÃO

A discussão desse estudo poderia questionar inicialmente a forma de como obter resultados de boa qualidade metodológica na área cirúrgica, onde os estudos prospectivos, com distribuição aleatória dos casos e grupo controle, são geralmente impraticáveis do ponto de vista operacional e ético. Por outro lado, os estudos retrospectivos apesar de mais factíveis são até certo ponto questionados como fonte segura para nortearem diretrizes e mudar condutas estabelecidas ou em discussão. Em geral nos estudos retrospectivos a casuística não é conduzida segundo objetivos pré-determinados, sendo assim passível de crítica pela subjetividade, pela seleção as vezes inadequada dos casos e até pela forma como os resultados são analisados, mesmo que não seja de modo intencional. Conclusões baseadas em apenas seis casos pode ser motivo de crítica. A definição prévia do tamanho da amostra é uma variável importante que depende não só do planejamento prévio e dos critérios que levam em conta o tipo do procedimento e a variabilidade dos resultados como também da incidência da doença em questão (Belangero, 2001).

A utilização de um grupo controle poderia conferir também maior qualidade e confiabilidade ao resultado da pesquisa, já que raramente estes estudos podem ser realizados selecionando-se os pacientes de forma aleatória e quase nunca em um ensaio do tipo duplo cego. No entanto apesar de todas essas considerações cabíveis, vale ressaltar que a incidência da fratura da diáfise do úmero é de apenas 20 fraturas por 100.000 habitantes por ano, correspondendo entre 3 a 5 % de todas as fraturas do esqueleto. Dessas, as fraturas do terço médio representa 50% dos casos e as do terço distal, motivo maior do estudo, apenas 20 a 30% (Bostman et al,1985; Tytherleigh-Strong et al, 1998; Ekholm et al, 2006). Além disso, se considerarem-se as lesões do nervo radial que ocorrem em somente 1,8 a 18 % das fraturas, com média relatada na literatura de 11% (Holstein e Lewis, 1963; Bostman et al, 1985; Miclau e Martin, 1997) a obtenção da casuística passa a ser extremamente difícil, a não ser em estudos multicêntricos utilizando o mesmo protocolo de tratamento.

Desse modo, pode-se dizer que a baixa incidência dessa associação gera dificuldades operacionais importantes e é pertinente considerar-se que isso torna quase impossível atingir em um período de estudo viável um número expressivo de casos. Por outro lado, qual seria esse valor numérico necessário para que as conclusões apresentadas tivessem confiabilidade irrefutável e respaldo metodológico inquestionável? A resposta a essa questão provavelmente é difícil de ser encontrada. A maioria dos estudos apresentam casuísticas heterogêneas e com pequeno número de casos.

O tratamento das fraturas da diáfise do úmero associadas à lesão do nervo radial é ainda motivo de discussão. Alguns autores preconizam o tratamento não cirúrgico da fratura e da lesão do nervo radial já que em mais de 80% dos casos a recuperação da lesão desse nervo pode ocorrer espontaneamente (Pollock et al, 1981; Barbieri et al, 1996; Shao et al, 2005). Há, entretanto, quem proponha a exploração cirúrgica imediata do nervo com fixação interna da fratura, referindo taxa maior de recuperação com confiabilidade e segurança (Packer et al, 1972; Bostman et al, 1985).

Em 2005, Shao et al realizaram revisão sistemática da literartura sobre o tema, referindo uma taxa de recuperação espontânea das lesões do nervo radial secundária as fraturas da diáfise do úmero em torno de 70%, não justificando, portanto, segundo os autores, a exploração cirúrgica e imediata do nervo em todos os casos.

A análise crítica dessas linhas de conduta diferentes revela que na verdade as casuísticas não levam em consideração algumas peculiaridades anatômicas do nervo radial que podem interferir na gênese da lesão e na sua recuperação.

No terço médio do úmero, o nervo radial ainda não está fixo pelo septo intermuscular lateral e existe uma camada protetora maior de partes moles entre ele e a diáfise do úmero. As lesões traumáticas do nervo radial nesse nível, são em geral, produzidas por neuropraxia e apresentam grande potencial de recuperação espontânea (Whitson, 1954; Holstein e Lewis, 1963; Shao et al, 2005).

No terço distal do úmero, o nervo encontra-se fixado pelo septo intermuscular lateral e em íntimo contato com a diáfise do úmero. Nessa região, a força deformante responsável pela produção da fratura move o fragmento proximal no sentido distal, deslocando o septo intermuscular lateral exatamente no ponto em que o nervo esta passando do compartimento posterior para o anterior. O fragmento distal se desvia em sentido proximal e em varo podendo assim produzir o aprisionamento ou laceração do nervo pelos fragmentos ósseos, especialmente nas fraturas com traço em espiral ou em cunha. As lesões do nervo radial produzidas no momento do trauma (agudas) ou durante o tratamento conservador da fratura, nesse nível, são em geral causadas por contusão ou pelo aprisionamento do nervo conforme relatado por Holstein e Lewis (1963). As fraturas espiraladas ou com traço oblíquo são as que oferecem maior risco para o nervo radial quando ocorrem no terço distal do úmero tornando improvável ou imprevisível a sua recuperação espontânea, (Whitson, 1954; Holstein e Lewis, 1963; Packer et al, 1972, Bostman et al,1985).

Segundo Testut & Latarjet (1932, 1959), o nervo radial é acompanhado pela artéria umeral profunda. No seu terço distal o nervo está em íntimo contato com o ramo colateral posterior da artéria antes de cruzar o septo intermuscular lateral e com o ramo colateral anterior após cruzar esse septo. Dos dois casos em que foi evidenciado o aprisionamento do nervo no foco de fratura, em um (fig.2,3 e 4) ficou evidente a associação do trauma mecânico com um possível insulto vascular e isquemia do nervo, ambos causados pela compressão do fragmento ósseo. Após a redução da fratura, houve melhora significativa da irrigação do nervo, constatado pelo retorno do enchimento vascular ao redor do nervo. Nos quatro casos restantes o nervo estava sendo estirado pelo fragmento ósseo devido ao desvio proximal e em varo do fragmento distal.

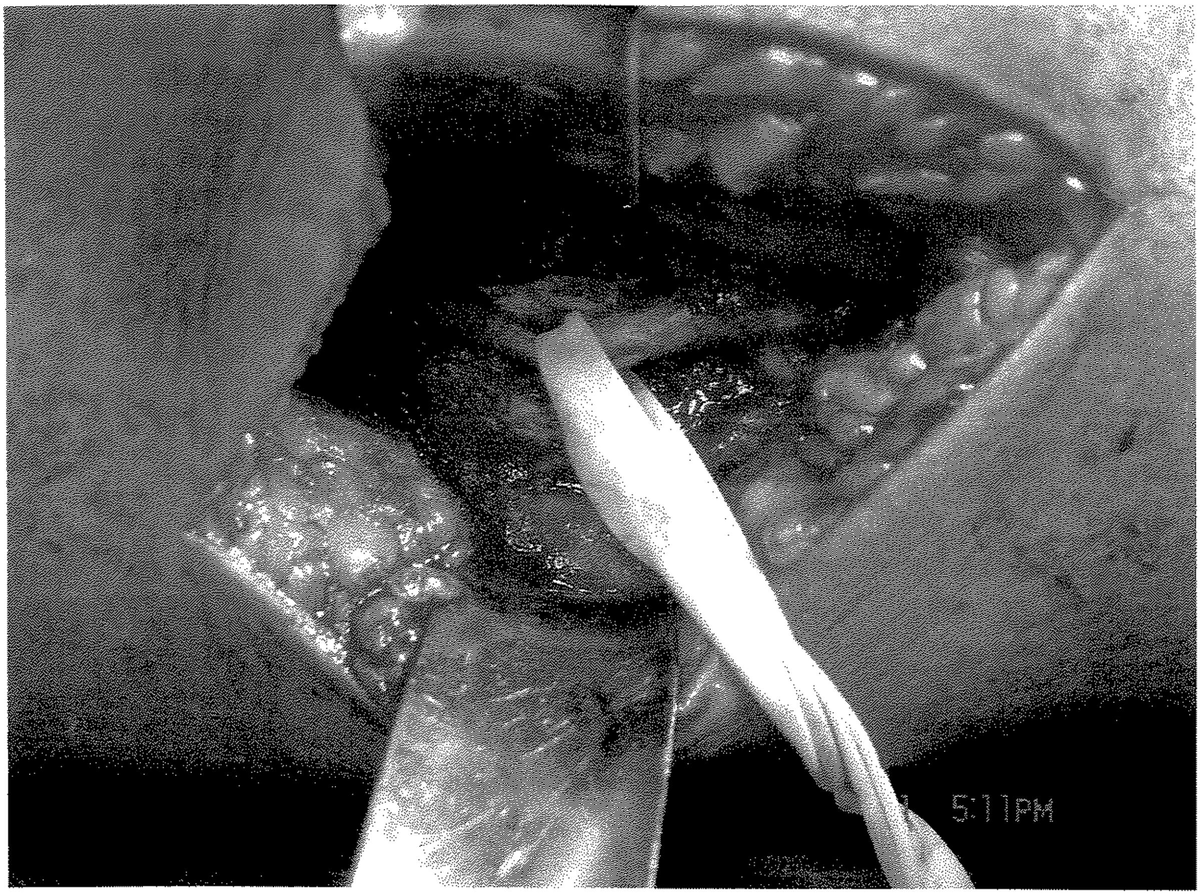

Figura 2- Nervo radial comprimido por fragmento ósseo.

Figura 3- Nervo radial após a redução da fratura. Notar restabelecimento do fluxo sanguíneo perineural.

Figura 4- Peça anatômica revelando a presença constante da vascularização ao redor do nervo radial na região do septo interbraquial lateral.

Na fase aguda, exames como a eletroneuromiografia não tem valor algum, no entanto, são importantes durante o seguimento clínico do paciente para a determinação do nível e da gravidade da lesão. Após três ou quatro semanas da lesão, este exame passa a ter valor para medir o grau de lesão e o aparecimento de sinais de recuperação do nervo caracterizados pela presença de potenciais de reinervação (DeFranco e Lawton, 2006). Uma alternativa atraente e promissora, ainda não investigada em nosso meio, seria a utilização de aparelho de ultra-som portátil na sala de cirurgia (intra-operatório), utilizando a técnica descrita por Bodner et al (Bodner et al, 1999; Bodner et al, 2001). Se o nervo estiver apenas comprimido ou angulado sem interposição e ou encarceramento pelos fragmentos ósseos, a redução indireta poderia ser realizada e acompanhada pelo exame com o ultra-som. A fixação da fratura pelo método da placa em ponte poderia ser realizada com apenas duas incisões, uma proximal e outra distal, sem necessidade da exploração cirúrgica do nervo, cuja recuperação seria acompanhada durante o período de consolidação com uso de órteses para a manutenção do punho e dedos. Caso o nervo estivesse interposto ou ocorresse interposição durante as manobras de redução da fratura, nesse caso seria imperiosa a exploração cirúrgica do nervo com a fixação da fratura pela placa colocada em ponte com três acessos conforme descrito.

Outra causa importante de erro na interpretação dessas informações é que as séries de casos relatadas na literatura não são uniformes em relação ao tipo de lesão, se primárias ou secundárias, completas ou incompletas. Nas lesões parciais, ou seja, com lesão motora e com sensibilidade preservada, a taxa de recuperação espontânea é maior do que nos casos com lesão completa (sensitiva e motora).

Os seis casos relatados são de fraturas do terço distal do úmero associadas à lesão completa do nervo radial ocorrida no momento do trauma ou durante o tratamento conservador. Nessas circunstâncias não há dúvida da necessidade de exploração do nervo e realização da fixação interna da fratura (Whitson,1954; Holstein e Lewis, 1963; Packer etal, 1972, Bostman et al, 1985).

Nas fraturas distais, as hastes intramedulares não são a melhor opção de tratamento (Rommens et al 1995; Blum et al, 1999; Rommens et al, 1999; Rommens e Blum, 2000) pela dificuldade técnica existente na colocação desses implantes tanto por via anterógrada como retrógrada. A melhor alternativa é a utilização das placas optando-se pela redução direta e anatômica da fratura com fixação interna e estabilidade absoluta apesar da maior morbidade cirúrgica (Heim et al, 1993).

Recentemente, outra opção de tratamento cirúrgico apresentada foi a da placa em ponte colocada após a redução indireta da fratura com a finalidade de se obter estabilidade relativa e consolidação por segunda intenção propiciada pela preservação dos pedículos vasculares e movimento controlado no foco da fratura (Farouk et al, 1997; Livani, 2001; Dell'Oca, 2002; Hernandez, 2003; Livani e Belangero, 2004 a e b; Apivathakakul et al, 2005).

Outro aspecto interessante e que deve ser ressaltado é que nenhum dos outros autores faz referência específica ao tratamento das fraturas do terço distal do úmero associada ou não à lesão do nervo radial. (Dell'Oca, 2002; Hernandez, 2003; Apivathakakul et al, 2005).

Essa nova abordagem terapêutica surge como uma alternativa sobre as técnicas existentes, já que permite que as fraturas com lesão do nervo radial sejam tratadas com técnica minimamente invasiva, com consolidação pela formação de calo periosteal reduzindo a morbidade, o tempo de cirurgia e conseqüentemente os riscos associados como a infecção, o retardo de união e a pseudoartrose (Heitemeyer et al, 1987; Heim et al, 1993; Farouk et al, 1997; Krettek, 1997).

A infecção presente em um dos casos pode até certo ponto ser justificada pelo fato de que o paciente sofreu queda da própria altura, no pós-operatório imediato, com trauma adicional sobre a região operada, e formação de hematoma. De qualquer modo, apesar da infecção a consolidação óssea ocorreu de modo semelhante aos demais pacientes. Provavelmente a preservação dos pedículos vasculares nos fragmentos fraturados protegeu os mesmos da disseminação do foco de infecção. A retirada da placa pela mesma via de acesso sem dificuldades e sem outras intercorrências é um fator favorável ao método, reduzindo possíveis preocupações com esse procedimento que teoricamente pode ser dificultado pelo crescimento de tecido mole através dos furos da placa.

Estudos realizados na área cirúrgica envolvem variáveis difíceis de controlar como a habilidade e a experiência do cirurgião. Para diminuir a influência desses fatores as alternativas mais utilizadas são o aumento da casuística ou o treinamento prévio em animais ou cadáveres.Nesse estudo apesar de terem sido tratados apenas seis pacientes todos os procedimentos cirúrgicos desenvolvidos foram ensaiados e embasados em estudos anatômicos (figs. 5 e 6) realizados pelo autor e apresentados em publicações prévias que constituíram substrato para o estudo em questão (Livani e Belangero, 2004 a e b; apêndice).

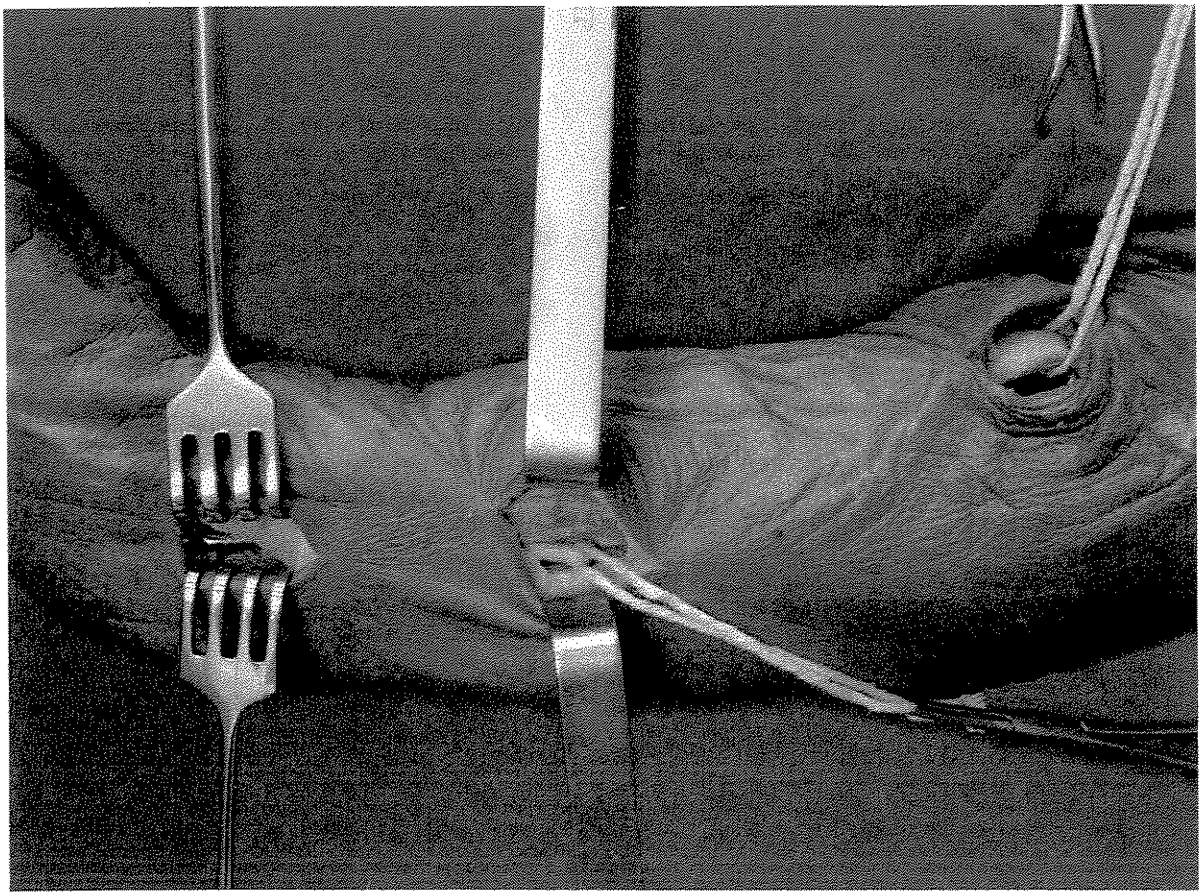

Figura 5- Peça anatômica com a técnica cirúrgica realizada e placa implantada. Notar nervo radial reparado na incisão intermediária e tendão da porção longa do bíceps reparado na incisão proximal.

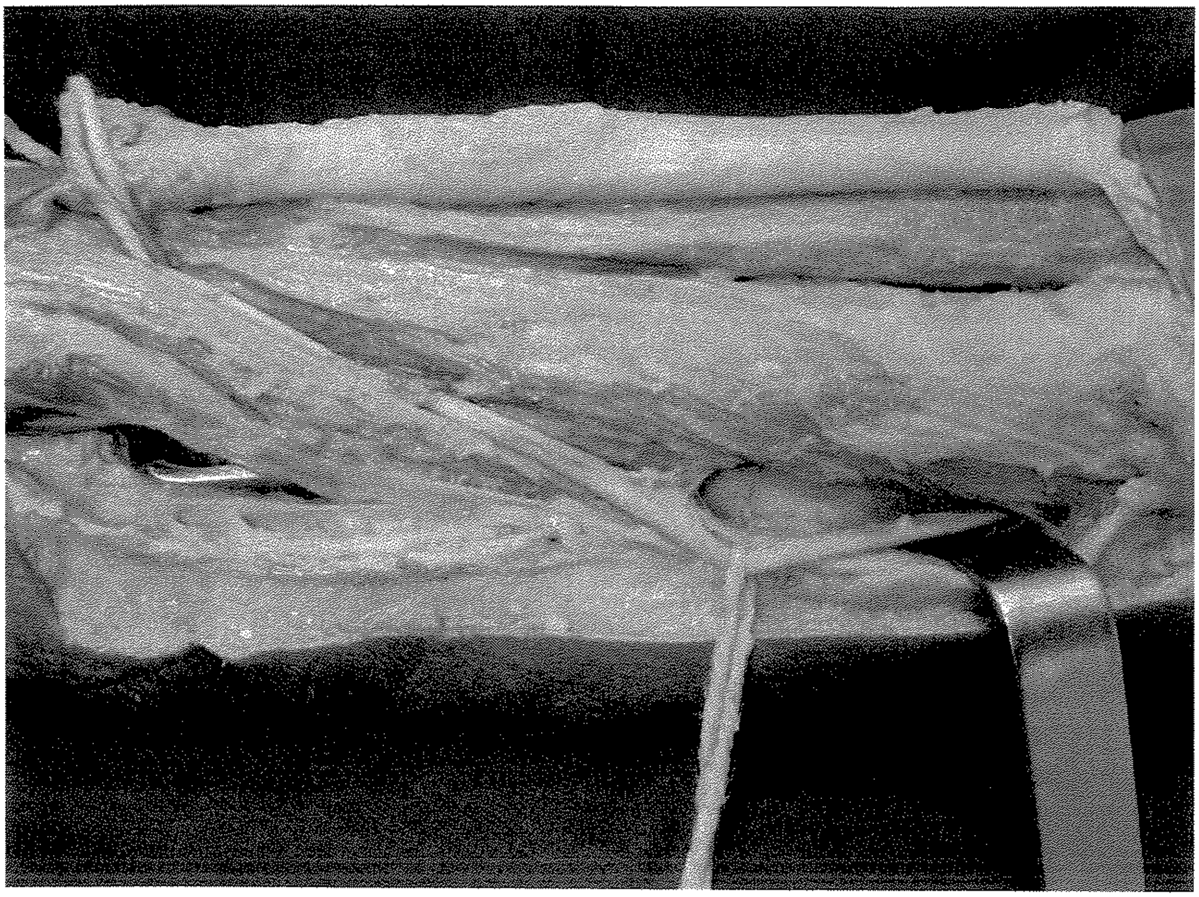

Figura 6- Peça anatômica correspondente à figura 4, dissecção profunda. Notar que não há contato algum entre o material de implante e o nervo radial.

Deve-se ter em mente que por trás de todo estudo há, além da curiosidade científica, o objetivo da sua divulgação é o da aplicação dos seus resultados para o bem-estar do paciente, fecho precípuo do ciclo do pesquisador na área clínico cirúrgica.

7- CONCLUSÃO

Frente aos resultados obtidos em seis pacientes, o autor recomenda que essa nova forma de tratamento descrita deva ser incluída como opção no arsenal terapêutico das fraturas do terço distal do úmero associadas com a lesão do nervo radial.

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9- APÊNDICES

APÊNDICE 1

PARECER DO COMITÊ DE ÉTICA EM PESQUISA – FACULDADE DE CIÊNCIAS MÉDICAS – UNIVERSIDADE ESTADUAL DE CAMPINAS, 28 de novembro de 2006.

CEP, 28/11/06.
(PARECER PROJETO: N° 116/2001)

PARECER

I-IDENTIFICAÇÃO:

PROJETO: **"OSTEOSSÍNTESE BIOLÓGICA DAS FRATURAS DIAFISÁRIAS DO ÚMERO COM UTILIZAÇÃO DAS PLACAS EM PONTE"**

PESQUISADOR RESPONSÁVEL: Bruno Livani

II - PARECER DO CEP

O Comitê de Ética em Pesquisa da Faculdade de Ciências Médicas da UNICAMP tomou ciência e aprovou o Adendo que inclui o projeto de pesquisa intitulado "**TRATAMENTO DE FRATURAS DO TERÇO DISTAL DA DIÁFISE DO ÚMERO ÀS LESÕES DO NERVO RADIA COM A PLACA EM PONTE**", com finalidade de tese de doutorado, referente ao protocolo de pesquisa supracitado.

O conteúdo e as conclusões aqui apresentados são de responsabilidade exclusiva do CEP/FCM/UNICAMP e não representam a opinião da Universidade Estadual de Campinas nem a comprometem.

Homologado na XI Reunião Ordinária do CEP/FCM, em 28 de novembro de 2006.

Profa. Dra. Carmen Silvia Bertuzzo
PRESIDENTE DO COMITÊ DE ÉTICA EM PESQUISA
FCM / UNICAMP

Comitê de Ética em Pesquisa - UNICAMP
Rua: Tessália Vieira de Camargo, 126
Caixa Postal 6111
13084-971 Campinas – SP

FONE (019) 3521-8936
FAX (019) 3521-7187
cep@fcm.unicamp.br

APÊNDICE 2

ARTIGO PUBLICADO

Livani B, Belangero WD. Osteossíntese de fratura diafisária do úmero com placa em ponte: Apresentação e descrição da técnica. Acta Ortop Bras 2004; 12(2): 113-117.

Osteossíntese de fratura diafisária do úmero com placa em ponte: Apresentação e descrição da técnica

Osteosynthesis of the humeral shaft fractures, with bridge plate

BRUNO LIVANI[1], WILLIAM DIAS BELANGERO[2]

RESUMO

Os autores descrevem o método cirúrgico inédito para o tratamento das fraturas da diáfise do úmero, com placa colocada por técnica minimamente invasiva. Após estudos anatômicos, foram identificadas três acessos cirúrgicos pelos quais se pode introduzir uma placa na face anterior do úmero, sem risco de lesão vásculo nervosa. O acesso proximal se faz entre os múculos deltóide, lateralmente, e bíceps braquial, medialmente. Nas fraturas do terço médio o acesso distal é feito entre os músculos bíceps braquial e braquial com a placa introduzida de proximal para distal. Nas fraturas distais do úmero o acesso proximal é o mesmo, mas o acesso distal é o descrito por Kocher, com a placa introduzida de distal para proximal e fixada na face anterior da coluna lateral do úmero. O método aqui apresentado vem sendo utilizado desde junho de 2001, principalmente nos pacientes politraumatizados e polifraturados, por ser rápida, segura e por permitir que o paciente possa ser operado em decúbito dorsal horizontal. Além disso, não há necessidade de intensificador de imagem, ou mesmo aparelho de radiografia. Até o momento não foram observadas complicações vásculo nervosas nos 22 pacientes tratados.

Descritores: Fraturas do úmero; Fixação interna de fraturas; Placas óssseas; Diáfises

SUMMARY

The authors describe for the first time ever a minimally invasive plate osteosythesis for the treatment of the humeral shatf fractures. After anatomic human cadaver's studies, it was identified three surgical approaches for plate percutaneous insertion on the anterior surface of the humerus without vascular and nervous injury. The proximal approach is between the biceps and deltoid muscles. The distal approach for medial third fractures is between the biceps brachialis and brachialis muscles. The plate is inserted from the proximal to distal direction. For distal fractures, the proximal approach is the same described by Krocher, with the plate inserted from distal to proximal and fixed on the anterior surface of the lateral column of the humerus. This method has been used since June/2001 mainly for the treatment of multiple trauma patients, allowing other surgical procedures, and it has been showed very efficient. The patient is operated in DHD without image intensifier or x ray apparatus. Until the moment, 22 patients have been treated without vascular or nervous complications.

Key words: *Humeral fractures; Fracture fixation, Internal; Bone plates; Diaphysis.*

INTRODUÇÃO

O tratamento conservador continua sendo o tratamento de escolha para as fraturas isoladas da diáfise do úmero[16]. No entanto, o tratamento cirúrgico é apontado como a melhor opção[15] nos pacientes obesos, nos pacientes com lesões vásculo-nervosas associadas e principalmente nos politraumatizados e polifraturados, cuja freqüência tem aumentado cada vez mais devido aos traumas de alta energia[3], resultando em fraturas complexas, inclusive do membro superior. Nessas circunstâncias, os pacientes têm dificuldade de assumir a posição ortostática e de utilizar funcionalmente o membro superior fraturado, devido à presença de lesões associadas e devido ao grave comprometimento sistêmico, contra indicando assim o tratamento conservador[2,13]. Assim, o tratamento cirúrgico, realizado com redução aberta e fixação interna rígida (placa e parafuso), ou a foco fechado com estabilidade relativa (haste intramedular bloqueada), são os métodos mais aceitos na literatura[7,14].

Procedimentos minimamente invasivos, como têm sido preconizados para o tratamento das fraturas dos membros inferiores [1,8,11,12], poderiam ser uma opção atraente para o tratamento dessa fraturas, principalmente em pacientes graves. Das opções possíveis, a haste intramedular bloqueada a foco fechado é a alternativa mais indicada. No entanto, estudos multicêntricos randomizados que comparam o desempenho das hastes bloqueadas a foco fechado com as placas a foco aberto, têm mostrado que não há vantagens com relação às hastes, já que houve significativamente maior número de casos com

INTRODUCTION

The traditional treatment is still used to the humeral shaft isolated fractures[16]. However the surgical treatment is shown as the best choice [15] in obese people, patients with vascular or nervous injuries and mainly the ones with the multiple traumas, whose frequency has increased due to severe traumas[3], result in complex fractures, mainly the upper limbs. Under the circumstances the patients have difficulty in assuming the orthostatic position and of using successfully the upper limbs fractured because of the injuries and also systemic healthy, not indicated the conventional treatment[2,13]. The surgical treatment, made with open reduction and tough internal fixation (plate and screws) or with the close focus with relative stability (blocked intramedular stalk), are the most used method[7,14].

Procedures minimally invasive are suggested to the lower limbs treatment[1,8,11,12] could be a very interesting choice fractures treatment, mainly in severe clinical patients. However, multicentered random studies that compare the performance of the blocked stalks to close focus with the plates to open focus, has shown some advantages towards the stalks, as its has been large number of cases with no retard of joining, pain dysfunction of the shoulder and re-operations in the patients treated with stalks. In addition, there was no important inter-operatory bleeding in in the surgery time procedure[5].

Technically, against the stalks there is still the fact that these

Trabalho realizado no Departamento de Ortopedia e Traumatologia - Faculdade de Ciências Médicas - Universidade Estadual de Campinas

1 - Mestre em Cirurgia pela FCM – UNICAMP
2 - Professor Doutor do Departamento Ortopedia e Traumatologia da FCM – UNICAMP

Endereço para correspondência: Rua Vicente Porto no. 208, Barão Geraldo, 13085-895 – Campinas/SP, e-mail: brunolivani@hotmail.com - Telefone: 019 37887750 e 37887715

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Work performed at Orthopedics and Traumatology Department of FCM – UNICAMP) - State University of Campinas

1 - Master in Surgery FCM – UNICAMP
2 - PhD Professor of the Orthopedics and Traumatology Department of FCM – UNICAMP

Address: Rua Vicente Porto, 208, Barão Geraldo - 13085-895 – Campinas -São Paulo
E-mail: brunolivani@hotmail.com - phone: 019 37887750 and 37887715

retardo de união, de dor, de disfunção do ombro e de reoperações no grupo dos pacientes tratados com as hastes. Além disso, não houve diferença significativa quanto ao sangramento intra-operatório e o tempo de duração do procedimento cirúrgico[5]. Tecnicamente, contra as hastes existe ainda o fato de que essas necessitam do uso do intensificador de imagem e do posicionamento do paciente em decúbito lateral, ventral ou semi-sentado, o que pode dificultar o tratamento de outras fraturas ou de lesões associadas nos pacientes polifraturados ou politraumatizados [14].

Tendo em vista essas considerações, os autores apresentam o método da placa em ponte para o tratamento cirúrgico das fraturas diafisárias do úmero, com técnica minimamente invasiva.

MATERIAL E MÉTODOS

Considerações sobre a técnica cirúrgica:

Quando se pensa em introduzir uma placa com técnica minimamente invasiva para o tratamento das fraturas da diáfise do úmero, a primeira questão que se coloca é como evitar a lesão do nervo radial. Revendo-se a anatomia do braço e realizando-se estudos em cadáveres, foram estabelecidas as vias de acesso para esse procedimento, sem riscos de lesão do nervo radial, ou de outras estruturas neurovasculares, além de se definir marcos anatômicos para orientar a redução dos fragmentos ósseos. Estudando-se as vias de acesso anterior ou ântero-lateral descritas por Thompson em 1918 e Henry em 1966 [4], pôde-se definir um corredor livre de estruturas vásculo-nervosas na face anterior do úmero. Nessa face situa-se o músculo braquial, que é inervado na sua porção lateral pelo nervo radial e na sua porção medial pelo nervo músculocutâneo. Esta particularidade anatômica permite que o mesmo possa ser divulsionado longitudinalmente em toda a sua extensão, sem comprometimento da sua função. As únicas estruturas potencialmente em risco nessa abordagem são o nervo cutâneo lateral do antebraço, ramo sensitivo do nervo musculocutâneo situado entre os músculos bíceps braquial e o braquial e o nervo radial entre os músculos braquial e o braquioestilorradial no terço distal do braço [6,10].

Apresentação da técnica operatória:

O procedimento é realizado com o paciente em decúbito dorsal horizontal, em mesa operatória convencional, com o cotovelo semi-fletido (Figura 1). Foram definidas três vias de acesso: uma proximal e duas distais, dependendo da localização da fratura, se médio-diafisária ou distal.

O acesso proximal é feito entre os músculos bíceps braquial, medialmente, e o músculo deltóide, lateralmente, junto com a veia cefálica, com 3,0 a 5,0 cm de comprimento. Para as fraturas do terço médio, o acesso distal com o mesmo comprimento é feito entre os músculos bíceps braquial e o braquial, abaixo do foco. Neste espaço visualiza-se facilmente o nervo cutâneo lateral do antebraço, situado medialmente e superiormente ao músculo braquial (Figura 2). O músculo braquial é dividido longitudinalmente para expor a face anterior do úmero (Figura 3). Nas fraturas do terço distal utiliza-se a via descrita por Kocher [4] para abordar a coluna lateral do úmero, com dissecção sub-periosteal da crista supra-epicondilar lateral do úmero e afastamento conjunto dos músculos braquioestilorradial e extensor longo radial do carpo e do nervo radial anteriormente (Figuras 4a, 4b e 4c). O afastamento deve ser feito sempre sem o uso de alavancas ou afastadores do tipo Hohmann para se evitar a lesão do nervo radial. Para as fraturas do terço médio, utilizam-se placas retas DCP

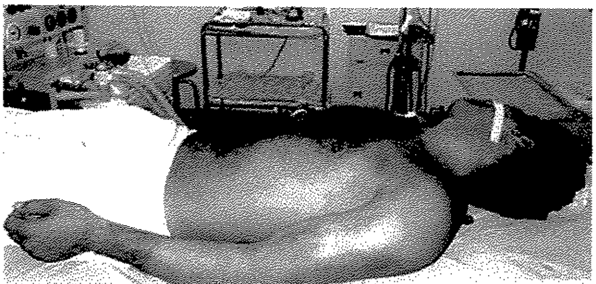

Figura 1 - Posicionamento intraoperatório do paciente em mesa cirúrgica convencional com o membro completamente apoiado sobre a mesa

Figure 1 - Intra operatory position of the patient on the conventional surgical tale having the limbs completed rested on the table.

stalks need the intensifier image use and the position of the patient in lateral, ventral and semi-sitting, decubitus what can cause difficulty the others fractures treatment to be associated with multiple fractured and multiple traumatized patients[14].

Taking these into considerations, the authors show the minimally invasive method for humeral shaft fractures surgical treatment.

MATERIALS AND METHODS

About the surgical technique

When a minimally invasive plate osteossynthesis is thought to be used in humeral shaft fractures, the first thing to avoid is the nervous radialis injury. Studying and seeing the human cadavers again, the approach for this procedure with no nervous radialis injury, or any other nervous vascular structures, defining the anatomical reduction of the bone fragments the anterior or posterior lateral surface described by Thompson in 1918 and Henry in 1966 [4], a free approach structure on the anterior surface of the humerus, which is full of nervous, on this surface is the brachialis muscle, which is innervated at the lateral surface by the radialis nervous and in the region of the medial by the cutaneous muscles. This anatomical detail allows the same to happen in the widespread longitudinal region, without harming its function. The only potentially risky structures of this study is the cutaneous lateral nervous of the forearm, sensitive branch of the cutaneous muscle located between the biceps brachialis muscles, brachialis and the radialis nervous between the brachialis muscles and the brachialisstyloradialis of the third distal of the arm[6,10].

The operatory technique presentations

The procedures are done with the patient in horizontal dorsal decubitus on a conventional operatory table, with the elbows semi-flexed (Figure 1). Three approaches were defined, one proximal and two distal, depending on the fracture local, if medium or distal shaft.

The proximal approach is done between the biceps brachialis muscles, medially, and the deltoids muscle, laterally together with the cephalic vein, with 3,0 to 5,0 cm length. For the median third fractures, the distal approach with the same length is done between the biceps brachialis muscles and the brachialis, below of the focus. In this space the lateral cutaneous nervous of the forearm is easily seen, situated medially and superiorly to the brachialis muscle (Figure 2). The brachialis muscle is divided longitudinally to show the anterior surface of the humerus Figure 3. In the third distal fractures the approach used by Krocher [4] is to abort the lateral column of the humerus, with subperiosteos dissection of the crest of superepycondilus lateral humerus and distance of the set of muscles, the brachialis stylusradial and extensor radialis longus of the carpus and the radial nervous on the anterior surface (Figures 4a, 4b and 4c) The distance must be done with the use of a lever or separation apparatus of the Hohmann in order to avoid the radial nervous injury. For the third median fractures, straight plate DCP is used, normally with twelve punctures, of big fragments, which does not need mouldling, as the anterior surface of the humerus plane. The plate is inserted from distal to estreitas, em geral com doze furos, de grandes fragmentos, que não precisam ser moldadas, já que a face anterior do úmero é plana. A placa é introduzida de proximal para distal e fixa-se primeiro o último parafuso distal, deixando-o relativamente frouxo para permitir a adaptação da mesma sobre o osso. Em seguida, abduz-se o braço em torno de 60° para se corrigir o desvio em varo e com leve tração roda-se o fragmento distal, de forma que o eixo bicondilar fique em um plano ortogonal em relação ao tendão longo do bíceps braquial, colocando-se a seguir o primeiro parafuso proximal (Figura 5). Segue-se, então, com a colocação dos demais parafusos, num total de dois (preferencialmente em furos alternados) ou três em cada fragmento. Para as fraturas distais utiliza-se o mesmo implante, que deve ser moldada na sua porção distal para se adaptar na coluna lateral do úmero, evitando-se o bloqueio da fossa coronóide ou da olecraneana (Figura 6). Nessas fraturas a placa é introduzida de distal para proximal, a fim de se evitar falso trajeto e lesão do nervo radial na sua porção distal que, nesse acesso, encontra-se localizado anteriormente à placa (Figura 7).

O fechamento da ferida é realizado de maneira habitual e não há necessidade do uso de dreno de aspiração, nem de imobilização externa. Não há necessidade do uso do intensificador de imagens ou de controles radiográficos durante o procedimento cirúrgico. Imediatamente após a cirurgia, o paciente é orientado a movimentar livremente as articulações do ombro e do cotovelo e a utilizar o membro operado para atividades de vida diária, tais como se alimentar e realizar higiene pessoal. Os pontos de sutura são retirados rotineiramente entre o 10° e 15° dia pós-operatório.

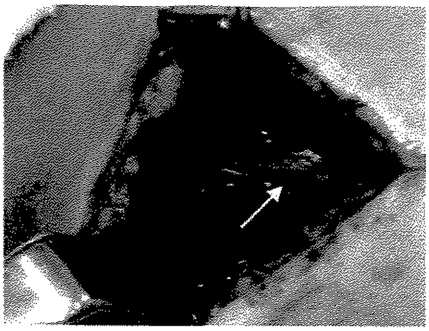

Figura 2 - **Foto intraoperatória mostrando o nervo cutâneo lateral do antebraço (seta) sobre o a face anterior do músculo braquial**

Figure 2 - **Inter-operatory photo showing a lateral cutaneous nerve of the forearm (arrow) on the anterior surface of the brachialis muscle.**

Figura 3 - **Foto intraoperatória de fratura do terço médio do úmero. Nota-se a incisão proximal (seta) entre os músculos deltóide e bíceps e a incisão distal (seta) entre os músculos bíceps e braquial. A introdução da placa está sendo feita de proximal para distal**

Figure 3 - **Interoperatory photo of the median third fracture of the humerus. It is noticeable the proximal incision (arrow) between the deltoids and biceps muscles and the distal incision (arrow) between the brachialis and biceps muscles. The inserting of the plate is being done from the proximal to distal directions.**

proximal, first the distal screw is the last to be fixed, let it slightly loosen to allow its adaptation to the bone. Next, abduct the arm around 60° to correct the deviation in varus and smooth traction spin the distal fragment, as long as the biochondilar axis stays in a orthogonal plane in relation of the biceps brachialis longus of the tendon, inserting, then the first proximal screw (Figure 5), Then the next screws, total of two (preferable with alternate punctures) or three in each fragment. For the distal fractures the same implant is used, which must be mouldied in its distal region to be fit in the lateral column of humerus, avoiding the blocking of the coronoid fossa or the olecranon (Figure 6). In this case the place is inserted from distal to proximal direction, to avoid wrong trajectory and the nervous radialis injury in the distal region, in this approach is located in the anterior surface to the plate (Figure 7).

The injury healing is used in a usual way and there is no need of the use of an aspirator drain, neither external immobilization. There is no need of the image intensifier or the radigraphs control during the surgical procedure. Sooner after the surgery, the patient if allowed to move freely the joints of the shoulder and elbow and use the operated limb for daily activities, such as, feeding and personal hygiene. The stitches of the suture are removed routinely between 10° and 15° days post operatory.

Figura 4a - *Foto intraoperatória de fratura diafisária distal do úmero. Nota-se a incisão proximal (seta) entre os músculos deltóide e bíceps e a incisão distal (seta) segundo a via de acesso descrita por Kocher.*

Figure 4a - *Interoperatory photo of the distal shafts of humerus. It is noticeable the proximal incision (arrow) between the deltoids and biceps muscles and the distal incision (arrow) according to the approach described by Kocher.*

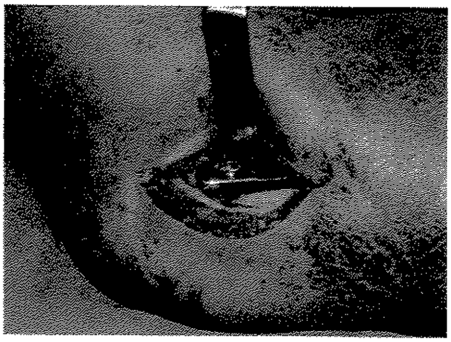

Figura 4b - *Foto intraoperatória de fratura diafisária distal do úmero. Nota-se a incisão distal, segundo a via de acesso descrita por Kocher, com a exposição da face anterior da coluna lateral do úmero e da placa já fixada*

Figure 4b - *Interoperatory photo of the distal shafts of humerus fracture. It is noticeable the distal incision, according to the approach described by Kocher, with the anterior surface exposition of the lateral column of the humerus and the plate already fixed.*

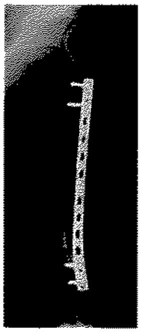

Figura 4c - *Radiografia do pós-operatório tardio (um ano) de uma fratura diafisária distal consolidada*

Figure 4c - *Radiography of the late pot operatory (one year) of a distal shafts fracture consolidated.*

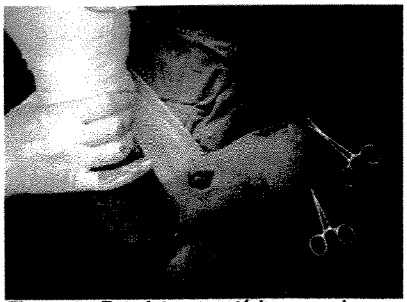

Figura 5 - *Foto intraoperatória com o braço abduzido em torno de 60º para correção do varo do fragmento distal, antes da fixação do fragmento proximal.*
Figure 5 - *Interoperatory photo with the arm abducted around 60º to correct the distal varus fragment, before the fixation of the proximal one*

Figura 6 - *Placa DCP de grandes fragmentos assentada na face anterior do coluna lateral do úmero para o tratamento de fraturas diafisárias distais*
Figure 6 - *The big DCP plate fragments sitting on the anterior surface of the lateral column of humerus to the distal shafts fractures treatment.*

Figura 8 - *Placa DCP de grandes fragmentos assentada na face anterior do úmero para o tratamento de fraturas médio diafisárias*
Figure 8 - *The big DCP plate fragments sitting on the anterior surface of the humerus to the median shafts fractures treatment.*

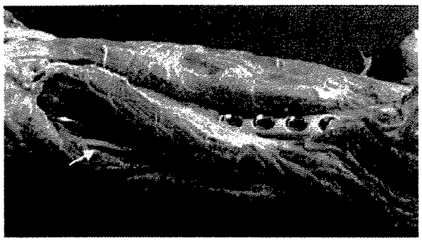

Figura 7 - *Placa situada entre os músculos bíceps e braquial e nervo radial (seta) situado num plano mais profundo entre os músculos braquial e braquio estilo radial*
Figure 7 - *Place located between the biceps and brachialis muscles and radialis nervous (arrow) situated in a deeper plane between the brachialis muscles and brachial stylus radialis.*

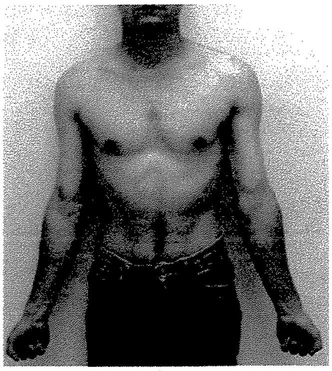

Figura 9a - *Foto do paciente no pós-operatório tardio (18 meses), mostrando ângulo de carregamento e extensão normais do cotovelo*
Figure 9a - *the late post operatory photo of the patient (18 months), showing loading angle and normal extension of the elbow.*

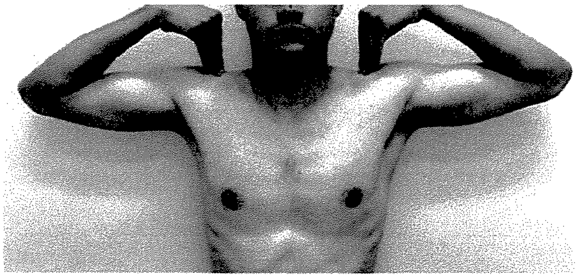

Figura 9b - *Foto do paciente no pós-operatório tardio (18 meses), com flexão completa do cotovelo e abdução e rotação externa dos ombros simétricas*
Figure 9b - *the late post operatory photo of the patient (18 months), with complete flexion of the elbow and abduction and external rotation of the symmetric shoulders.*

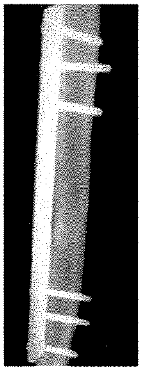

Figura 9c - *Radiografia do pós-operatório tardio (18 meses) de uma fratura médio diafisária tratada pela técnica da placa em ponte consolidada*
Figure 9c - *Radiography of the late post operatory (18 months) of a median shaft fracture treated done with the technique of the plate bridge consolidate.*

DISCUSSÃO

Apesar do tratamento conservador continuar sendo o método de escolha para as fraturas isoladas da diáfise do úmero[16], nos pacientes em que há necessidade do tratamento cirúrgico os métodos disponíveis não são isentos de riscos e complicações e a maioria dessas ocorrem pela própria técnica e pela exposição cirúrgica da fratura [7]. A partir década de 80, os procedimentos minimamente invasivos tornaram-se comuns e a placa em ponte destacou-se no tratamento das fraturas dos membros inferiores, mas sem se encontrar relatos da utilização para as fraturas da diáfise do úmero. A grande contribuição deste estudo é demonstrar que é possível tratar as fraturas da diáfise do úmero por técnica minimamente invasiva, com a placa sendo colocada por dois pequenos acessos, sem risco de lesão iatrogênica do nervo radial, complicação descrita no tratamento dessas fraturas por via aberta [7]. A utilização do acesso anterior,

DISCUSSION

Despite the traditional method continue to be the chosen method for isolate fractures of the shafts of humerus[16], in patients who need surgical treatment , the available methods are not free of risks and complication, and most of them occur because of this technique or the submission to the surgery[7]. From the 80 decade on, the procedure shortly invasive became common and the plate became outstanding in the treatment of the lower limbs fractures, but not for the shafts humerus fractures. The main purpose of this study is to show the possibility of treating shafts humerus fractures by minimally invasive technique, using two approaches to insert the plates, with no risk of iatrogenic injury of the radialis nervous, complication described in the treatment of these fractures by open approach. The use of the anterior surface approach, inserting the plate in the anterior com a colocação da placa na face anterior do úmero, é uma excelente solução para se evitar a lesão do nervo radial que circunda a região medial, posterior e lateral da diáfise desse osso. Coincidentemente, a face anterior do úmero, por ser plana, permite que a placa deslize facilmente sobre sua superfície e pelo foco de fratura, adaptando-se perfeitamente à topografia desse osso (Figura 8).

Quanto ao desempenho da técnica, os pacientes se beneficiam não só da mobilização precoce e ativa do membro, devido à pequena agressão cirúrgica, como também da estabilidade obtida, que é suficiente para suportar os esforços das atividades de vida diária, eliminar a dor e propiciar a rápida recuperação do arco de movimento articular do ombro e cotovelo (Figuras 9a, 9b e 9c)

Esta técnica abre uma nova perspectiva para o tratamento das fraturas da diáfise do úmero, principalmente nos pacientes politraumatizados ou polifraturados. No entanto, a técnica não está indicada para os pacientes com lesão do plexo braquial, que não consigam realizar a flexo extensão ativa do cotovelo. Teoricamente, fraturas associadas à lesão do nervo radial, fraturas patológicas e fraturas expostas grau III-B ou III-C também não devem ser tratadas por esse método. Nas fraturas com lesão do nervo radial e padrão clássico descrito por Holstein and Lewis[9] o nervo pode estar aprisionado entre os fragmentos ósseos, sendo necessário portanto a abordagem direta do foco de fratura. Já nas fraturas patológicas ou com pouco estoque ósseo (tumores, doenças metabólicas ou osteoporose) a qualidade do osso pode comprometer a fixação dos parafusos e, portanto, o resultado final do tratamento. Já com relação às fraturas expostas III-B e III-C, o fixador externo é ainda a opção mais segura até a resolução das lesões de partes moles, para só então se indicar o tratamento definitivo mais adequado.

CONCLUSÃO

Pode-se concluir que a técnica inédita aqui apresentada, além de poder ser executada com relativa facilidade e segurança, tem como principal vantagem a possibilidade de ser feita em decúbito dorsal horizontal, sem instrumental cirúrgico sofisticado e sem o uso do intensificador de imagem ou aparelho de radiografia. Esta técnica está indicada para o tratamento de pacientes polifraturados ou politraumatizados, nos quais há necessidade da fixação de fraturas concomitantes em outros segmentos e da realização de procedimentos cirúrgicos por outras especialidades.

surface of the humerus, is an excellent choice to avoid the radial nervous injury that rounded the medial, posterior and lateral region of the shafts of this bone. Coincidently, the humerus anterior surface, due to be plane, allows the plate slides easily on the surface and the focus of fracture, adapting perfectly to the topography of this bone (Figure 8)

About the technique performance, the patients not only took advantage of the previous and active immobilization of the limb, due to the slight severity of the surgery, but also with the obtained stability, that is enough to sustain the efforts of the daily activities, relieving the pain and fast recovery of the arch joint movement of the shoulder and elbow (Figures 9a, 9b, 9c)

This technique is a new perspective to the shafts humerus fractures treatment, especially in multiple traumatized and multiple fractured patients. However this technique is not suggested for patients with plexus brachialis injury, who were not able to do the active flexion extensive of the elbow. Theorically, fractures associated to radialis nervous injury, pathological fractures and exposed fractures of IIIB or IIIC degrees neither can be treated using this method. In radial nervous injury fractures and classical pattern described by Holstein and Lewis[9], the nervous can be tied between the bones fragments, being necessary the direct approach of focus of the fracture. In the pathological fractures or with little bone storage (tumors, metabolic illness or osteoporoses) the quality of the bone can reject the fixation of the screws, and then, the end of the treatment. About the exposed fractures III-B and III-C, the external fixer is still the safer choice until the resolution of the injuries of the smooth regions; therefore prescribe the definite treatment as more appropriate.

CONCLUSION

The technique shown, besides being done with certain facility and security, has as main advantage of the possibility to be made in dorsal horizontal decubitus, with no need of sophisticated surgical instruments and neither they use of an intensifier image or radiographic apparatus. This technique is advised to multiple traumatized and multiple fractured patients, where there is need of the fixation of the concomitant fractures in other fragments and surgical procedures for other specialties.

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APÊNDICE 3

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Bridging plate osteosynthesis of humeral shaft fractures

Bruno Livani*, William Dias Belangero

Department of Orthopedics and Traumatology, Faculty of Medical Sciences, State University of Campinas (UNICAMP), P.O. Box 6111, 13070-170 Campinas, SP, Brazil

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KEYWORDS
Fracture fixation;
Internal;
Humeral fractures;
Arm injuries;
Multiple trauma

Summary This study was approved by the Ethics Committee of the Faculty of Medical Sciences and developed during November 2000 and July 2001 in the Orthopedic and Traumatology Department of UNICAMP. There were 15 patients, 11 males, age between 14 and 66 years. All fractures were unilateral. Of the 15 patients eight were polytraumatised, two of them had open fractures. The others had an isolated fracture of the humerus, of which one was open. None of the patients had previous lesions of the radial nerve, but in two patients there was a lesion of the brachial plexus. All of the patients underwent a bridging plate osteosynthesis of the humeral shaft fractures using only two small incisions proximal and distal to the fracture site. We used broad or narrow D.C.P.® plates for large fragments mostly with 12 holes, fixed with two or three screws at each end. All cases united with an average time of 8–12 weeks, with the exception of one case with a grade III open fracture and a brachial plexus lesion on the same side. We had no major complications. All patients recovered good function of the limb without significant residual deformity.

Introduction

The inability of patients with humeral shaft fractures to maintain an orthostatic position and use the fractured limb has an unfavorable effect on bone alignment and fracture healing time.[2,20]

This condition is becoming more common because traffic accidents have become more serious and the rescue teams are now more efficient, which means that a greater number of polytraumatised patients with more serious fractures, including those of the upper limbs, have survived.[3]

The best treatment for these patients is surgery, and the most acceptable methods are plate osteosynthesis using DCP® or LCDCP®[1] or closed osteosynthesis with intramedullary nails.[5,17,18,21–23] Surgical treatment is also recommended in the case of humeral diaphyseal fractures with neurovascular damage, in obese patients, or patients with very large breasts.[24]

Randomised multicentre studies done towards the end of the 1980s to compare the results of nails and plates demonstrated that the theoretical advantages of nails were not confirmed in practice. Union retardation was significantly greater and there was a higher incidence of pain and shoulder

*Corresponding author. Present address: Residencial Barão do Café no. 03, Rua Vicente Porto 208, Barao Geraldo CEP 13085-895, Campinas, SP, Brazil. Tel.: +55-19-32891235; fax: +55-19-32891235.
E-mail address: brunolivani@hotmail.com (B. Livani).

[1]AO-ASIF: association for the study of internal fixation; DCP: dinamic compression plate; LCDCP: limited contact dinamic compression plate.

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dysfunction in patients treated with nails. Reoperations were also more frequent and there was no significant difference in relation to intraoperative bleeding and the duration of surgery.[6]

In general, the use of intramedullary nails in closed fractures requires image intensifiers and a specific patient position (lateral, ventral or half-seated decubitus) that may interfere with the treatment of other fractures or associated lesions in polytraumatised patients.[23]

Minimally invasive surgery is widely used in treating diaphyseal fractures of the lower limbs,[1,11,14,16] but there is only one report of its use in the treatment of humeral shaft fractures using helical implants.[7]

In this paper, we describe another method to perform the bridging plate technique and its usefulness in minimally invasive surgery for the treatment of humeral shaft fractures.

Patients and methods

Casuistic

This study was approved by the Ethics Committee of the Faculty of Medical Sciences, UNICAMP. All patients with humeral shaft fractures who attended from November 2000 to July 2001 were included in the study after they had signed a term of informed consent.

During this period, we treated 15 patients (11 males and 4 females), 14–66 years old. There were eight cases of polytrauma with 16 humeral shaft fractures. All of the fractures were unilateral; with one patient being reoperated on the same side 45 days after the first operation because of another accident that involved a fracture proximal to the plate.

The follow-up ranged from 21 to 28 months

All of the fractures were classified according to the AO-ASIF classification[19] and the open fractures were classified according to the Gustilo and Anderson classification.[9]

Anatomical aspects

One of many questions relates to how radial nerve lesions can be avoided since identification of this nerve during surgery is difficult. Other questions concern the correction of rotational and angular deformity of the fracture and the minimum size of the proximal and distal shaft fragment required to obtain a reliable fixation with this technique.

With regard to the radial nerve, all the neurovascular structures of the arm, including the radial nerve, can be avoided by using the anterior a antero-lateral approaches described by Thomps and Henry.[4,13] This is partly because the anatomic peculiarity of the brachialis muscle, with its later portion innervated by the radial nerve and its me ial portion innervated by musculocutaneous nerv allowing the division of this muscle along its enti length without compromising its function.[8,13,27] Th only neurovascular structures that are potentially risk in this approach are the lateral antebrachi cutaneous nerve, which is a sensory branch of th musculocutaneous nerve located between th biceps brachialis and the brachialis muscles, ar the radial nerve located between the brachialis ar brachioradialis muscles. The lateral antebrachi cutaneous nerve is easily visualised during dist surgical access and is medial and anterior to th implanted material since the brachialis muscle mu undergo longitudinal splitting for bone exposure ar insertion and fixation of the plate (Fig. 1).

However, the radial nerve does not have to b identified and damage is avoided because the nerv is protected by the lateral portion of the brachial muscles when the plate is placed on the anteri face of the humeral shaft, or the radial nerve protected by subperiosteal dissection and retrac tion of the brachioradialis and extensors radial carpi muscles origin at the lateral supraepicondyla crest of the humerus when the plate is placed on th anterior face of the lateral column of the dista humeral shaft (Figs. 2 and 4).

Since the bicipital incision is practically on a orthogonal plane to the bicondilar axis (betwee the medial and lateral condyles), these anatomica landmarks may guide the correction of possibl rotational deviation, putting the bicondilar axi (found by palpation) to an orthogonal plane t

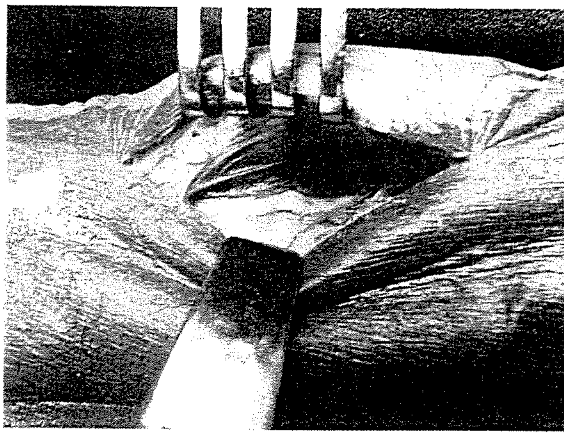
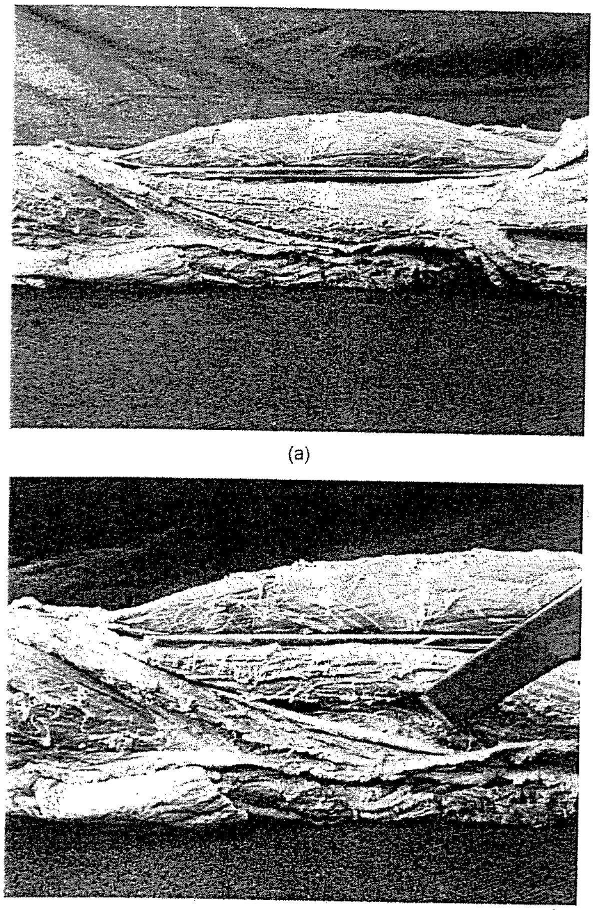


Figure 1 Lateral antebrachial cutaneous nerve on th anterior surface of the brachialis muscle.



(a)

(b)

Figure 2 (a) Plate between biceps and brachialis muscles. (b) Radial nerve between brachialis and brachioradialis muscles.

the longus biceps tendon visualised from the proximal access.

Varus deformity is the most common angular deviation. It can be corrected by putting the arm in 60 abduction before inserting all of the screws.

To obtain a reliable fixation with this method, the proximal fragment should be at least 5 cm long when measured from the greater tuberosity apex and the distal fragment should be at least 3 cm long from the elbow joint line.

Surgical technique

The patients were placed supine on a conventional operating table and the arm to be operated on was carefully supported on the table. Two assistants were needed during the surgery. One assistant maintained traction with the elbow semi-flexed and the other assistant helped directly with the procedure.

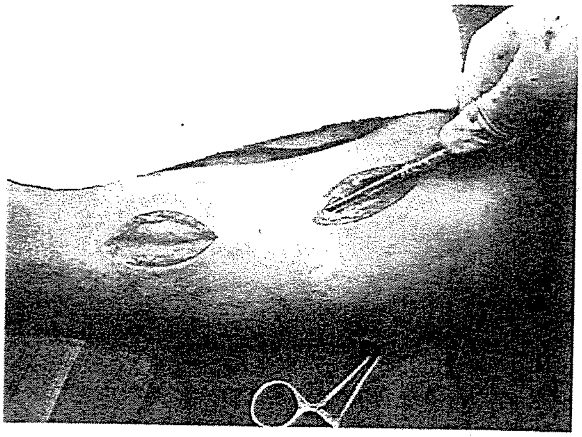


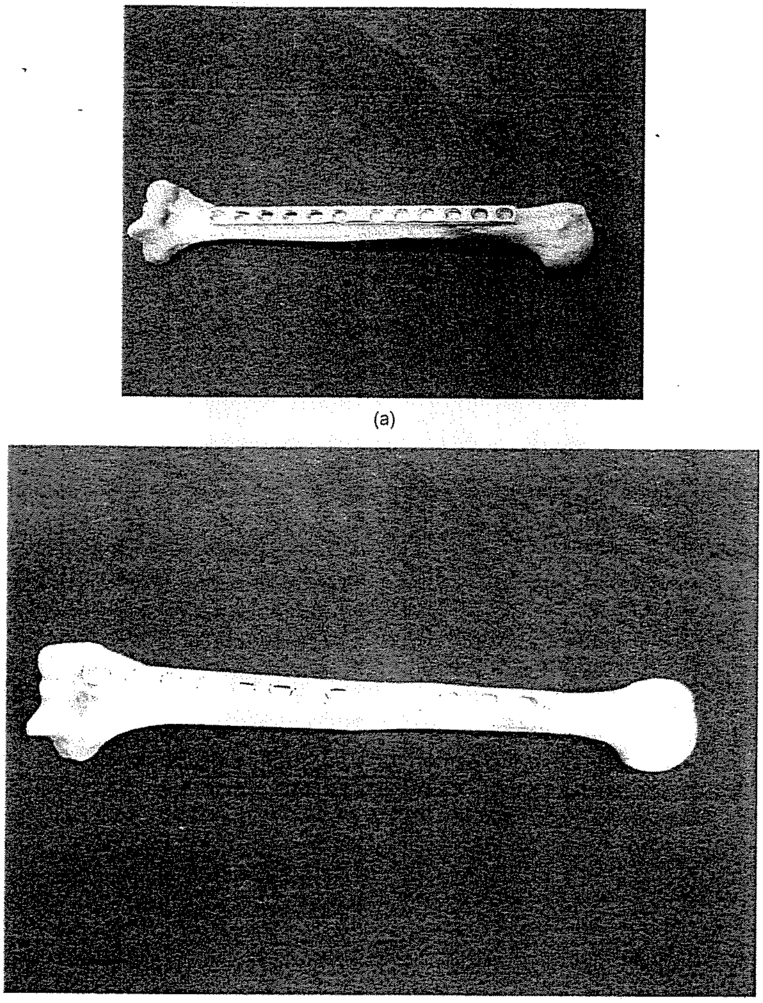
Figure 3 Case number 1: incisions and plate introduction.

In the case of mid shaft fractures, large fragment DCP® plates (broad or narrow) that did not have to be moulded were used because the anterior face of the humerus is flat. The implant was inserted through an incision approximately 3–5 cm long made on the anterior side of the arm by following the lateral edge of the biceps brachialis muscle and obeying the dissection planes based on the description of surgical approach by Thompson and Henry[4,13] (Fig. 3).

The distal access was usually obtained first, between the biceps muscle and the brachialis muscle. Once the lateral antebrachial cutaneous nerve was identified, the brachialis muscle underwent longitudinal splitting in its distal third for an extension of 3–5 cm long in order to expose the anterior face of the humerus. Retractors or levers were not used to expose the humerus because of the risk of radial nerve damage.

The proximal access was between the biceps tendon medially and the deltoid tendon and cephalic vein laterally. The plate was inserted from proximal to distal and the most distal screw which was kept slightly tightened was the first to be drilled (Fig. 3). The arm was then abducted approximately 60 to correct the varus deviation. After applying traction to re-establish the length, the distal fragment was rotated so that the axis between the medial and lateral condyles was in an orthogonal plane with the long tendon of the biceps. Only then was the proximal fragment fixed with a screw and the distal screw fully tightened. The proximal and distal fragments were generally fixed with two or three screws.

In the case of fractures with a small distal fragment, fixation on the anterior face of the humerus is impossible, so a narrow DCP® is chosen and moulded with a slight anterior inclination at its distal end so



(a)

(b)

Figure 4 (a) Plate on the anterior face of humeral shaft (midshaft fractures) and (b) plate on the lateral column o humeral shaft (distal fractures).

that it fits the anterior face of the lateral column, thereby avoiding the coronoid fossa (Fig. 4). The plate is inserted through the same proximal access as described above and through Kocher's distal access.[4,13] In these cases, the plates were always introduced in the distal to proximal direction and fixed in the same way as for mid shaft fractures. The wound was closed without drains or external immobilization. There was no need for an image intensifier or radiographic equipment during these procedures.

After the surgery, the patients were instructed to move the shoulder and elbow and to use the operated limb to perform daily activities (eating and personal hygiene) (Fig. 5). The patients came for a weekly check-up during the first 2 weeks and then monthly. All visits consisted of radiographic and clinical evaluations to assess the healing and recuperations of elbow and shoulder movements anc function. Tables 1 and 2 summarise all of the infor mation about the patients.

Results

Nine of the 15 patients had suffered fracture resulting from high-energy trauma and eight o them presented associated lesions. The left side was most affected (12/16) and most (13/16) were closed fractures. The classification revealed five type A fractures, seven type B fractures and four type C fractures (Tables 1 and 2).

Sixteen procedures were performed on 15 patients. One patient suffered an automobile accident 6 weeks after the first surgery and fractured the same humerus proximal to the plate. All but one

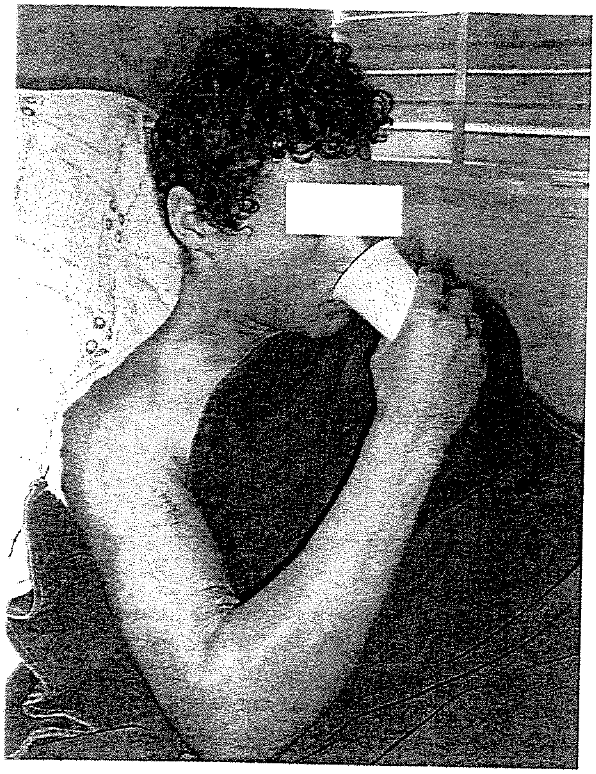


Figure 5 Patient number 5 in the first postoperative day.

of the fractures healed between 2 and 3 months after surgery. The non-healed case (number 11) was a polytraumatised patient who suffered an open grade III fracture with ipsi-lateral complete brachial plexus palsy. This was accompanied by superficial infection that was treated with systemic antibiotic therapy. Although the screws in case N 13 loosened, the fracture healed without major problems.

The normal final elbow carrying angle was re-established in all cases, except for two patients who healed with a 10 and 5 varus deviation (cases N 3–12, respectively).Six broad plates and 10 narrow plates were used with most of them having 12 holes. Three or four screws were used for each fragment in the first two cases, whereas from the third case onwards only two screws were used for each fragment in most cases.

Discussion

Although conservative treatment continues to be the procedure of choice for isolated humeral shaft fractures,[25,26] the methods available for patients who need surgical treatment are still not free of risks and complications, most of which one inherent to the technique itself and to the surgical exposure of the fracture.[10] In the 1980s, minimally invasive procedures based largely on bridging-plate osteosynthesis were introduced, but there has been only one report of the use of this procedure for humeral shaft fractures.[7] As shown here, bridging plate osteosynthesis could be used to successfully treat these fractures with no risk of iatrogenic lesions to the radial nerve (Figs. 6 and 7). The latter is still a complication in a conventional osteosynthesis,

Table 1 Patients, sex, age, soft tissue damage, AO classification and associate lesions

Number	Sex	Age	Gustilo & Aderson classification	AO classification	Associate lesions
1	M	30	Closed	12B3	Acromioclavicular dislocation
2	F	21	Closed	12C3	None
			Closed	12C3	None
3	F	33	Closed	12B1	None
4	M	45	Closed	12B1	Bladder rupture and carpal dislocation
5	M	20	Closed	12A2	None
6	M	23	Grade II	12A2	None
7	M	30	Closed	12B2	Forearm closed fracture. temporary brachial plexus palsy and posterior wall acetabulum fracture with hip dislocation
8	M	66	Closed	12A3	None
9	M	57	Closed	12C2	None
10	F	17	Closed	12B2	Closed femur shaft fracture
11	M	26	Grade III	12B2	Brachial plexus palsy, closed forearm fracture and closed ankle fracture
12	M	48	Closed	12A3	Closed forearm fracture
13	M	65	Closed	12B1	Rib fracture with haemotorax
14	M	44	Closed	12A1	None
15	F	14	Grade I	12C3	Closed pelvic ring fracture

Table 2 Patients, follow-up, complications, healing time and final elbow alignment and function

Number	Follow-up (months)	Complications	Healing time (months)	Final elbow carrying angle (°)	Elbow flexion (°)	Elbow extension (°
1	28	Extension deficit	3	10 valgus	135	−10
2	28	Flexion deficit	2	10 valgus	110	0
3	28	Varus deformity	2	10 varus	135	0
4	28		2	10 valgus	135	0
5	27		2	10 valgus	135	0
6	24		2	10 valgus	135	0
7	24		3	10 valgus	135	0
8	23		2	10 valgus	135	0
9	23		2	10 valgus	135	0
10	22		3	10 valgus	135	0
11	21	Superficial infection	Non healed	10 valgus	135 (passive)	0
12	21	Varus deformity	2	5 varus	135	0
13	21		3	10 valgus	135	0
14	21		3	10 valgus	135	0
15	21		3	10 valgus	135	0

especially when using plates with an open reduction.[10]

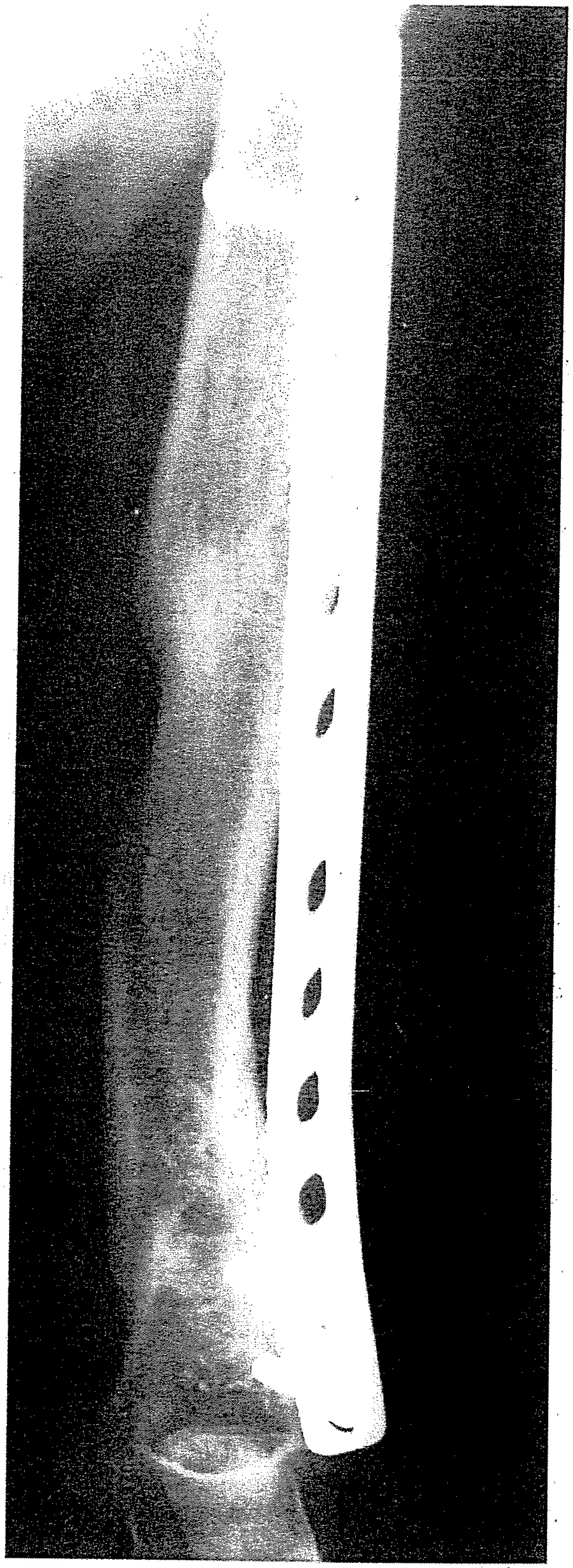
The use of the anterior access and the placement of the plate on the anterior face of the humerus avoided lesions of the radial nerve that encircles the medial, posterior and lateral regions of the humeral shaft. Since the anterior surface of the humerus is flat, the plate is able to slide easily over its surface and the fracture focus, thereby adapting perfectly to the topography of this bone. Although prior anatomical assessment was performed in this study, the size and type of plate as well as the number of screws needed for fracture fixation were defined better during the clinical evolution of the patients. In cases 1–5, broad plates with three or four screws were used in each fragment and healing occurred with no evidence of callus, indicating that the structure had excessive stability. Therefore, in cases 6 and 7, the number of screws was reduced (two in each fragment), but there was no change in the healing pattern. Narrow plates fixed with two screws in each fragment were used in cases 8–14. The consolidation period in these cases was similar to that of the previous cases but with the formation of callus, thus indicating that this set-up had characteristics that were compatible with the objectives of this type of osteosynthesis.

In the patient who suffered a second fracture (case 2), the original plate was replaced with a longer one. Plate fixation was verified peroperatively, which confirmed the fixation capacity of two screws at least in this case. However, removal of the plate through the previous incisions was not possible because the soft tissues had grown into the unused holes. To avoid iatrogenic lesion of the radial nerve, the surgical access had to be extended and the implant completely exposed. This case raised th possibility of using plates with holes only at th extremities so that they could be removed throug previously used accesses whenever needed. Th type of implant was used in cases 13–15 and th fracture consolidation period with bone callus fo mation was similar to that of the previous case thus demonstrating the viability of these change with the advantages mentioned above.

Although the bridging plate technique is be indicated for the treatment of type C diaphysea fractures, there were only four patients with th type of classification in this study, despite the fac that, nine of the 15 patients were victims of high energy trauma. An interesting observation was tha fractures classified as type A and B evolved wit consolidation in the same way when compared wit type C fractures, except for case 11 in which ther was ipsi-lateral brachial plexus palsy secondary to grade III open fracture. A critical analysis of th procedure revealed that bridging plate osteosynth esis indication was inadequate in this case becaus the patient was unable to execute mechanical st mulus at the fracture focus as a result of no muscl contractions caused by paralysis and adverse vaso motor conditions at the site. The proximal screws i case 13 loosened, probably secondary to osteoporo sis, although this was not confirmed by subsidiar examinations.

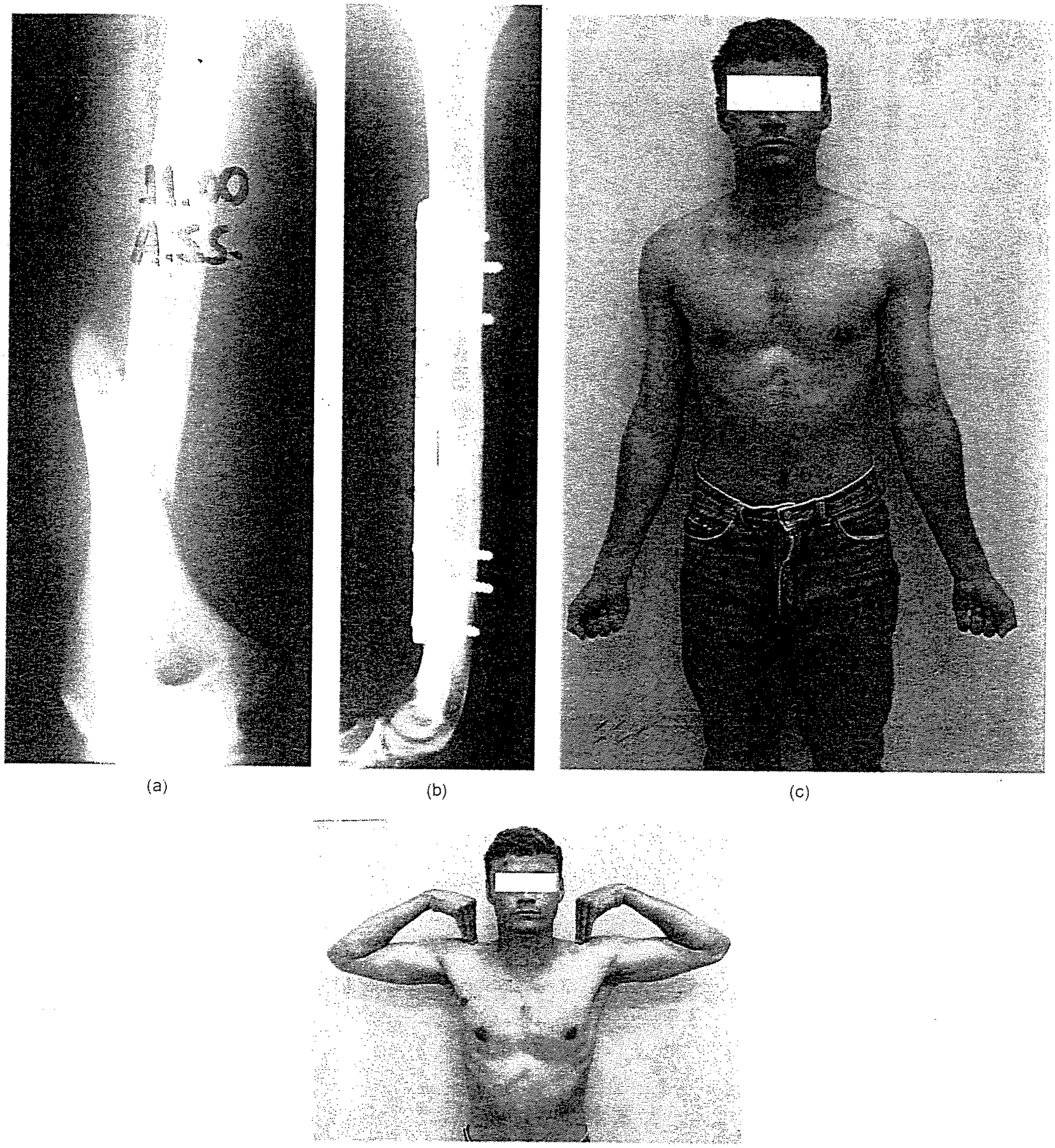
The low incidence of complications and the goo results obtained favour the continued use of th treatment when operative treatment of humera shaft fractures is indicated, especially becaus humeral shaft fracture treatment is not free o complications. Although delayed and non unio are less common in conservative treatment, the

(a)



(b)

Figure 6 (a) Case number 2: preoperative X-ray; and (b) case number 2: 1 year postoperative X-ray.



(a) (b) (c)

(d)

Figure 7 (a) Case number 5: preoperative X-ray; (b) case number 5: 1 year postoperative X-ray; (c) case number 5 final elbow carrying angle; and (d) case number 5: shoulder and elbow arch of movement.

occur in 1–12% of the cases. In surgical treatment, this incidence is higher with plates (3–20%) and nails (0–29%). Iatrogenic lesions of the radial nerve (8–14%), just like infections (5%), tend to occur more frequently in patients treated with plates.[6,15,24–26]

One of the most positive aspects of this technique was that all of the patients benefited not only from early limb mobility with minimal surgical aggression, but also from the resulting stability tha was adequate to support the stress and eliminate the pain that resulted in a rapid recovery of the articular elbow arch movement.

These results open up new perspectives for the treatment of humeral shaft fractures, especially ir polytraumatised patients. Theoretically, grade II open fractures, pathological fractures or relatec to muscle paralysis should not be treated by this method. Fractures with radial nerve lesions and the classic pattern as described by Holstein and Lewis may have the nerve caught within the bone fragments.[12] In such cases, minimally invasive fixation is not advisable, instead an exploratory examination of the fracture site and nerve is recommended. In the case of pathological fractures, the bone quality may affect screw fixation and, consequently, the final result of the treatment. In the case of open fractures with a massive soft tissue injury, external fixation may be still the safest option until lesions of the soft tissue are resolved, after which the definitive treatment can be chosen.

Finally, the main advantage of the procedure described here, besides its safety and relative ease of execution, is the fact that it does not require sophisticated surgical instruments or radiographic imaging equipment. The supine position facilitates anaesthetic procedures as well as concomitant fracture fixations in other segments, and is also useful for other surgical procedures that may be performed simultaneously.

Conclusion

This paper presents one technique for bridging plate osteosynthesis of humeral shaft fractures. The results obtained in 15 patients have shown that the technique described in this paper is feasible, safe and efficient, since there were no major complications and 14 healed within a similar healing time to other methods with both good alignment and function of shoulder and elbow joints.

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APÊNDICE 4

ARTIGO ACEITO PARA PUBLICAÇÃO

Percutaneous Plating of the Humerus with Locked Plating: Technique and Case Reports.

Editorial Manager for The Journal of Trauma, Injury and Critical Care.

JOT – 2006 – 10692R1

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Great news everybody. Our perc humerus paper has been accepted. This is the first time I have seen an "acceptance" with such minor revision. Super duper work to all. Lets follow up with the series.
Bruce H. Ziran, M.D.
Director of Orthopaedic Trauma
St. Elizabeth Health Center
Associate Professor of Orthopaedic Surgery
Northeast Ohio Universities College of Medicine
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Order of Authors: Bruce H. Ziran, MD; William Belangero, MD; Rodrigo Pesantez, MD; Bruno Livani, MD

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5 May 2006

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Dear Dr. Pruitt:

Attached please find one copy of our revised manuscript entitled *Percutaneous Plating of the Humerus with Locked Plating: Technique and Case Reports*. Also attached is a point-by-point response to reviewer no. 1's comments.

Thank you for your time and cooperation in this matter.

Sincerely,

Bruce H. Ziran
Corresponding Author
Director of Orthopaedic Trauma
St. Elizabeth Health Center
Associate Professor of Orthopaedic Surgery
Northeastern Ohio Universities College of Medicine
Phone: 330.480.2986
Fax: 330.480.3522
Email: Bruce_Ziran@hmis.org

PERCUTANEOUS PLATING OF THE HUMERUS WITH LOCKED PLATING: TECHNIQUE AND CASE REPORTS

PLATING OF HUMERUS WITH LOCKED PLATING

Bruce H. Ziran MD, St. Elizabeth Health Center, Youngstown, Ohio
Bruce_Ziran@hmis.org

William Belangero MD, Sao Paulo, Brazil
belanger@sigmanet.com.br

Bruno Livani MD
Rua Vicente Porto 208, Campinas, Sao Paulo, Brazil, CEP 13085-895

Rodrigo Pesantez MD, Bogota Colombia
rodrigopesantez@etb.net.co

Bruce H. Ziran MD
Corresponding Author
Director of Orthopaedic Trauma
St. Elizabeth Health Center
Associate Professor of Orthopaedic Surgery
Northeastern Ohio Universities College of Medicine
Phone: 330.480.2986
Fax: 330.480.3522
Email: Bruce_Ziran@hmis.org

INTRODUCTION

Humerus fractures are treated in a variety of different ways. Closed treatment is most common with isolated injuries while intramedullary nailing and plating are the most commonly used methods of surgical treatment. While there are polarized views on which method is better, each has its distinct advantages and disadvantages. Plating incurs a more invasive approach, may be less desirable cosmetically (especially in women), and may incur more elbow issues, but it is reliable and has a good success rate. Nailing is known to incur more shoulder complaints, has a slightly less success rate than plating, but it does not impose on the biology of the fracture and is minimally invasive.[1,2,3,4] A recent analysis of the literature found that both methods are acceptable methods of treatment with the differences noted above [1,2,3,4].

Traditional plating is associated with the need for anatomic alignment and reduction with respect to the biology. When bone-to-bone contact is achievable, compression and load sharing is possible and desirable. When load sharing is not possible, standard plates are subject to failure either by loosening between the implant bone interface or by fatigue failure of the metal. Furthermore, in osteoporotic bone, the purchase of standard bone screws can be difficult and prone to early loosening.

Recently, locked plating has been introduced as a new paradigm in plating technique. The screws do not toggle in the plate, and resistance to axial loading is improved, thus, the plate can function as an internal fixator. In this mode, two methods of application are possible. In the first, the plate can be used with traditional goals of more rigid fixation. The fracture is reduced and screws are placed to provide balanced fixation. With screws near and remote to the fracture site, a relatively stiff and stable construct is created. In the second mode, the plate is placed with remote stabilization (screws further from the zone of injury) and a relatively long working length. With this method, the resulting construct is flexible due to the long working length and stable due to the locking mechanism. With the first method of application, an environment of absolute stability is sought, while with the second method relative stability is sought. Use of the locked plate with remote fixation makes the application of the plate from remote window possible, which avoids opening of the fracture site and preserves the biologic envelope. Thus, the plate can be placed with a minimally invasive approach.

Recent reports in a cadaveric study and one clinical series have demonstrated that it is feasible to perform minimally invasive plating using two small incisions [5,6,7]. In the clinical series by Livani and Belangero, the plate was placed anteriorly using standard plating techniques with non-locking plates, and good results were reported. Yet, if standard plates are used, there remains a possibility that construct loosening could occur, especially with unstable fracture patterns. While this could be minimized with a load sharing or more anatomic reductions, it would be difficult with minimally invasive methods and would necessitate some exposure of the fracture zone. Using a long locking plate, indirect reduction methods could be used and the plate could be placed from remote windows, which would provide a flexible yet stable construct. As long as alignment was acceptable, the fracture would be allowed to heal in an environment of relative stability with minimal biologic insult. This would be due to the use of long plate spans with stable locked constructs. In the present report, we describe the technique of minimally invasive (semi-percutaneous) placement of an anterior humeral plate using locked plating technique and concepts.

TECHNIQUES

The patient is supine with use of a radiolucent armboard. An assistant provides gentle in-line traction to achieve length, and a roll of towels acts as a fulcrum to overcome gravitational sag. A long plate narrow 4.5 mm locking plate with combi-holes (Synthes, Paoli PA), usually 10-14 holes is chosen and centered anteriorly over the fracture zone. A marker is used to mark the ends of the plate (Figure 1). From these ends, a small 3-4 cm incision is made and carried to the fascial layer. Proximally, the cephalic vein may course in the field. The deltopectoral fascia is opened and with blunt dissection the deep anatomy is exposed. The pectoralis insertion as well as the deltoid insertion on the humerus is palpable with the fingertip. Proximally, the pectoralis is taken down and the biceps tendon is identified. It is generally retracted medially and a finger is used to feel for any fascial obstruction to plate placement. Distally, another 3-4 cm incision is made and taken to the fascial layer. Using the concept of a "mobile-operating-window", the skin incision is moved laterally to identify the interval between the brachioradialis and brachialis. In this interval, the radial nerve is identified by direct vision to ensure its safety (Figures 2 A-C). Then the skin incision is moved medially, and blunt dissection of the brachialis is performed. Usually the tip of the plate is easily found. Once the bone under each end of the plate is identified, the plate is oriented anteriorly, and the arm is aligned clinically. We use the recommendations of Livani and Belangero, where the arm is positioned with approximately 60 degrees of shoulder abduction, the elbow is flexed, and a small bump is placed under the apex of the fracture (Figure 3). Fluoroscopy is used to determine any adjustments that are needed. Once satisfactory alignment is achieved, the plate is centered over the bone in each window.

We find it useful to carefully place on each side of the bone two small Hohmann retractors to assist with the centering of the plate. The locking handles can be used in the end holes to facilitate alignment and positioning of the plate (Figures 4 A-B).

A unicortical screw is place in the second hole from one end and gently tightened to pull the bone to the plate (Figures 5 A-B). Then the bump under the fracture apex is used to maintain reduction in the sagittal plane, and fluoroscopy is used to verify appropriate alignment before placing the second unicortical 4.5 mm screw on the opposite end of the plate (again in the second hole from the end). Rotational alignment was determined using the landmarks of the biceps tendon and flexed elbow forearm. If the fracture is stable, it is possible to provide some manual compression via proprioceptive feedback. As these screws are further tightened, the bone and plate construct have some provisional stability. The sagittal reduction can usually be verified with rotation of the shoulder at this point.

If at this point, alignment of the fracture and orientation of the plate is acceptable, then bicortical locking screws are placed in holes one and three at each end of the plate. Now, the unicortical 4.5 mm locking screw can be converted to a bicortical 4.5 mm standard screw or exchanged for a bicortical locking screw. The unicortical 4.5 mm is used so that adjustments can be made without jeopardizing the far cortex of the bone. The 4.5 mm screw can be loosened and the plate and bone can then be adjusted. If needed, another unicortical 4.5 mm screw could be placed into holes one or three but would need to be exchanged to a bicortical locking screw at the end of the case. The final desired configuration is at least two locking screws in holes one and three at each end, with either a standard 4.5 mm screw or a locked 5 mm locking screw in between (in hole two) (Figure 5 C). The incisions are cleansed and closed in standard fashion. Bracing is provided for comfort and active and passive motion with weight-bearing as tolerated is allowed. Figures 6 A-C show initial postoperative and healed radiographs.

CASE REPORTS

Table I summarizes the patient data; eight patients were treated with this technique and went on to heal uneventfully. In the following text, a brief summary of each patient's course is presented. Patients were allowed unrestricted activity with weight-bearing as tolerated using a standard humeral fracture brace for comfort. All patients went on to radiographic and clinical healing. There were no cases of antebrachial radial nerve injury. The radial nerve was identified in each case in the distal window and protected during plate and screw insertion. As seen in the table, the incision size progressively decreased between 2.5 and 3.5 cm, as experience grew. Also, a 12-hole plate became the standard plate size. At first, the initial standard screws in the second to last holes were replaced with locking screws. With experience, the initial unicortical standard screw was not exchanged and only two bicortical locked screws were used.

In two cases, the fracture involved either the surgical neck or the proximal ¼ of the humerus; so long 3.5 Proximal Humeral Locking Plates were used in the same fashion. In some of the earlier cases a 10-hole plate was used, but we realized that it would be more advantageous to use a 12-hole plate. A 12-hole not only allows for windows of insertion further from the zone of injury, but it also increases the working length and the flexibility of the construct. In a few segmental cases, the plate ends were relatively close to the fracture. If there were fracture patterns amenable to closed reduction and lag screw fixation, this was performed to enhance the construct strength. Flexible fixation was used when anatomic reduction with lag screws was not possible.

Two patients (numbers 3 and 4) had slight loss of motion of the shoulder but each had an ipsilateral clavicle fracture. We feel that these associated conditions may have influenced the resultant motion. One patient (number 5) with a head injury was transferred out of the area with only short-term clinical (1 mo.) follow-up, but radiographs obtained remotely demonstrated good healing. The last patient had preoperative radial nerve palsy. Since she also had a closed manipulation and reduction during plate placement, she had a small incision made laterally to ensure that the nerve was not accidentally entrapped in the fracture site because of intervention. In fact, the nerve crossed the septum at the level of the fracture but was free from tenting and entrapment. At the time of this writing, the nerve had recovered function.

DISCUSSION

The theory behind the present technique rests on the concept of relative stability. If such a methodology were to be used with standard plates and screws, the construct would undoubtedly fail because of the high stresses experienced at the plate bone interface. The frictional interface would be easily overcome from the long moment arms. If a standard plate were used, it would be highly recommended to have greater separation between screws and to have screws closer to the fracture zone. This would require more exposure and would be very difficult to perform percutaneously. When locking screws are used remotely from the fracture zone, there is load transfer to the plate more directly and motion at the fracture site is reflected by the flexibility of the construct. Thus, there is a controlled and stable micromotion present in the fracture zone consistent with relative stability. Also with remote screw placement, the motion is distributed over a longer span, and the effects of Perren's interfragmentary strain theory are invoked. In fact, if the locking screws are placed too close to the fracture zone with the presence of a fracture gap, Perren's strain theory would imply that this would potentially amplify the effects of gap instability and potentially reduce healing.

However, there is one theoretical caution that exists with locked plating theory. If bone contact is not achieved during reduction and gaps exist, a construct that is too stiff may not allow the stimulus of micromotion that is involved with secondary healing (endochondral). In this scenario, gaps beyond a critical threshold with too much stiffness would be at risk for non-union. Thus, indirect reduction techniques that do not allow compression of the fracture require flexibility of the construct as a stimulus for healing. Much like an intramedullary nail or external fixation provides stability with flexibility, and with remote fixation, our described technique applies a similar theory. The plate is extramedullary, and the fixation is stable due to the locked screws. Yet, because of the long plate span, there is enough flexibility to provide an environment of relative stability. We feel that if screws were to be placed too close to the fracture site, the resultant stiffness of the plate construct in the presence of any gaps (absence of fracture compression) would be too great and may risk non-union. With placement of the locked screws farther from the fracture, the plate is used in a relatively stable mode that is more tolerant of small fracture gaps.

The technique described in the current report uses a plate in a combined method. After percutaneous placement, initial reduction and provisional stabilization is performed with standard screws that allow minor adjustments. The placement of standard screws helps pull the bone to the plate (effect a reduction) and uses the plate in a "standard" mode. A unicortical screw is used if placement of the plate has to be changed. The far cortex is not violated and does not compromise placement of screws placed later. The second screw from each end was used, because it allows the locked screws to be placed into holes one and three and thus increases the spread of the locked screws. The unicortical screw can be replaced with either a bicortical standard screw or a locking screw. In this aspect, the plate is applied with a similar philosophy to external fixation. In fact, locked plates have been termed internal fixators because of the similarities of their mechanical function to external fixators.

We acknowledge that the present technique is unproven and requires further study and that followup is short. Yet, we feel that it is important to first establish the safety and feasibility of any new technique and then assess its efficacy. For the purposes of the present report, we feel that the technique is feasible and appears safe. It is too early to comment on efficacy without a larger series with longer followup and ultimately a comparative series. However, we also note that locked plating itself has little evidence based clinical validation and also requires further evaluation. Standard plates and open plating technique remain the standard by which newer methods and implants must be judged. Furthermore, the costs of new technology must be weighed against potential benefits, and we have not identified any studies that make any valid comparisons. As such, new products and techniques as described in the present report must be interpreted in this context. The intention of the present report is not to purport this technique as a replacement to standard techniques but to describe a potential application of such plates in a manner that utilizes the theories behind its design.

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LEGEND

Figure 1: The plate is centered anteriorly over the fracture site, which is determined with fluoroscopic guidance. Incisions are centered over the second hole from each end.

Figures 2 A-C: A) Distal operating window showing the antebrachial cutaneous nerve. B) Moving to the interval between the brachialis and the brachioradialis, the radial nerve is identified. After the nerves are identified, the interval through the lateral third of the brachialis is used to expose the humerus. C) Retractors on each side of the bone protect the nerves. Retraction is only performed during screw placement in order to avoid any inadvertent traction injury during manipulation.

Figure 3: A bump is placed under the arm as a fulcrum, and a towel is used for traction. The arm is place at approximately 60 degrees of abduction, and the elbow is flexed to determine rotation.

Figures 4 A-B: A) The plate is slid under the muscle, and alignment is facilitated with the locking handles. B) A standard screw is place into the second hole on each end once the plate is centered over the bone and satisfactory fracture alignment is verified.

Figures 5 A-C: A-B) The second to last hole is used to place a unicortical standard screw to help pull the plate and bone together. This allows provisional alignment and fixation and in case repositioning is needed, the far cortex is not sacrificed. Thereafter, the final fixation is performed. C) Where bicortical locking screws are placed in holes 1 and 3 for stability. The initial standard unicortical screw can be exchanged for either a bicortical screw or a locking screw; we have not found this to be necessary.

Figures 6 A-C: Serial radiographs of healing. A) Initial lateral demonstrating construct. B-C) Radiographs at 3 months.

Figure 1
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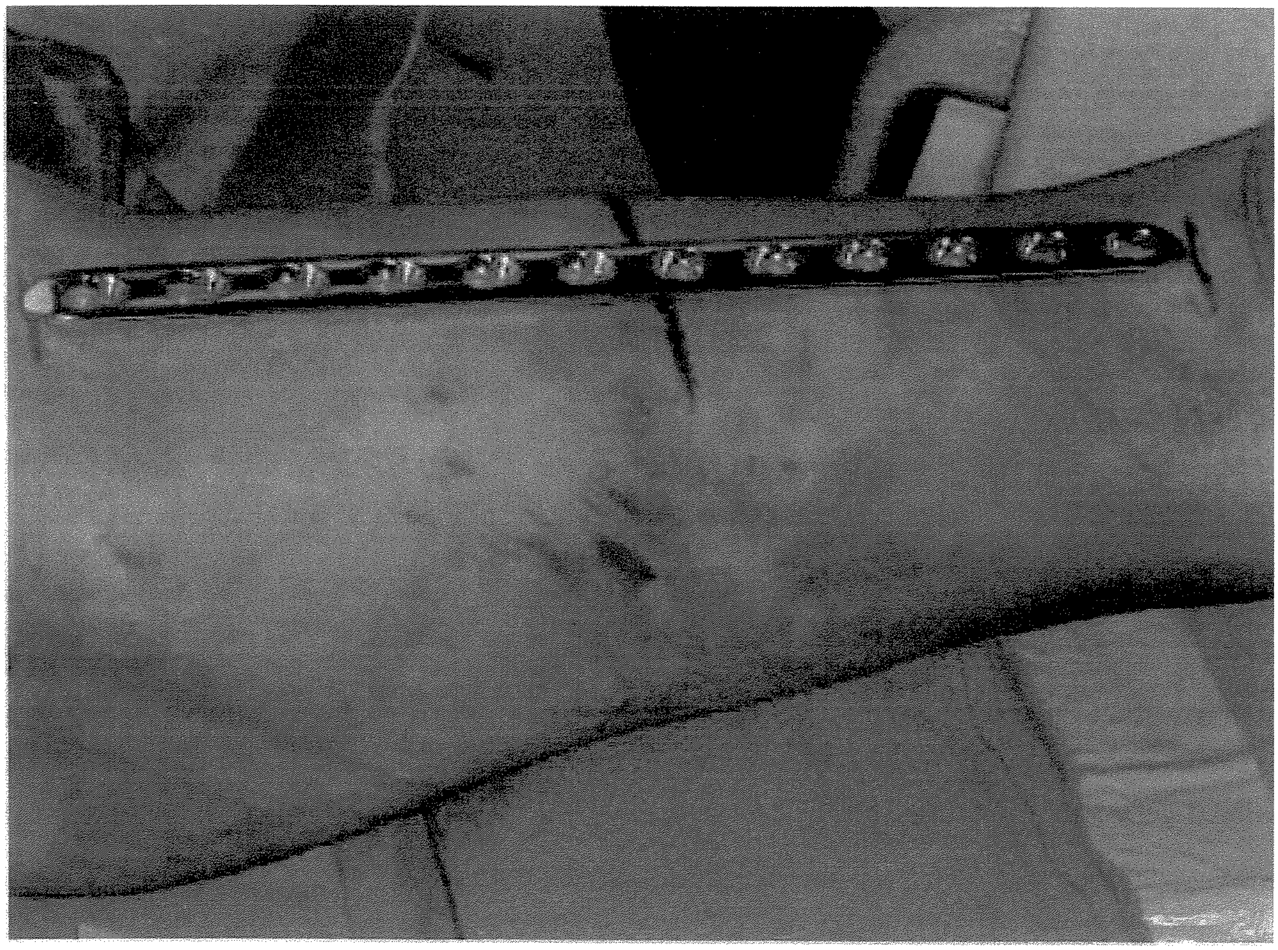

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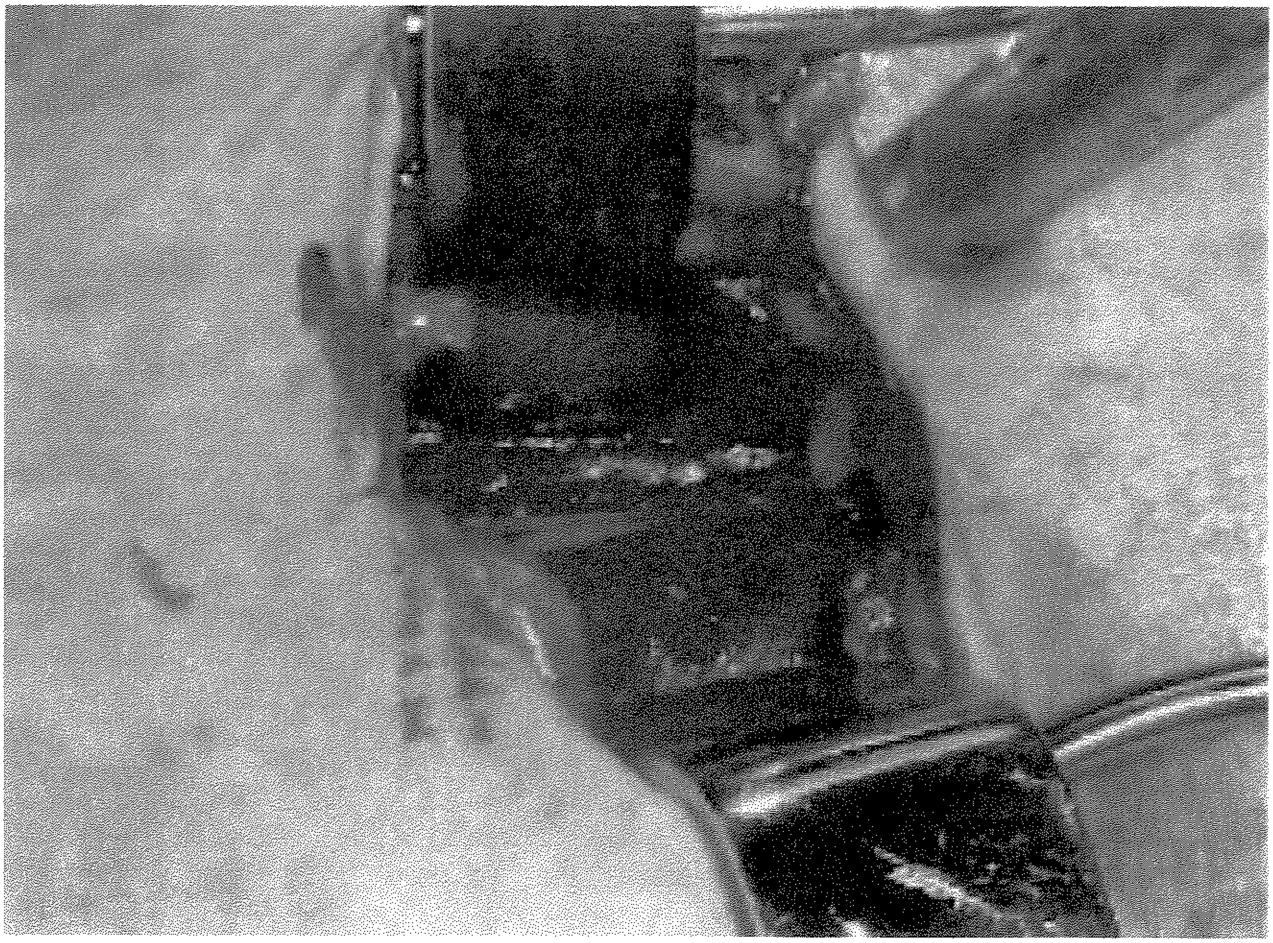

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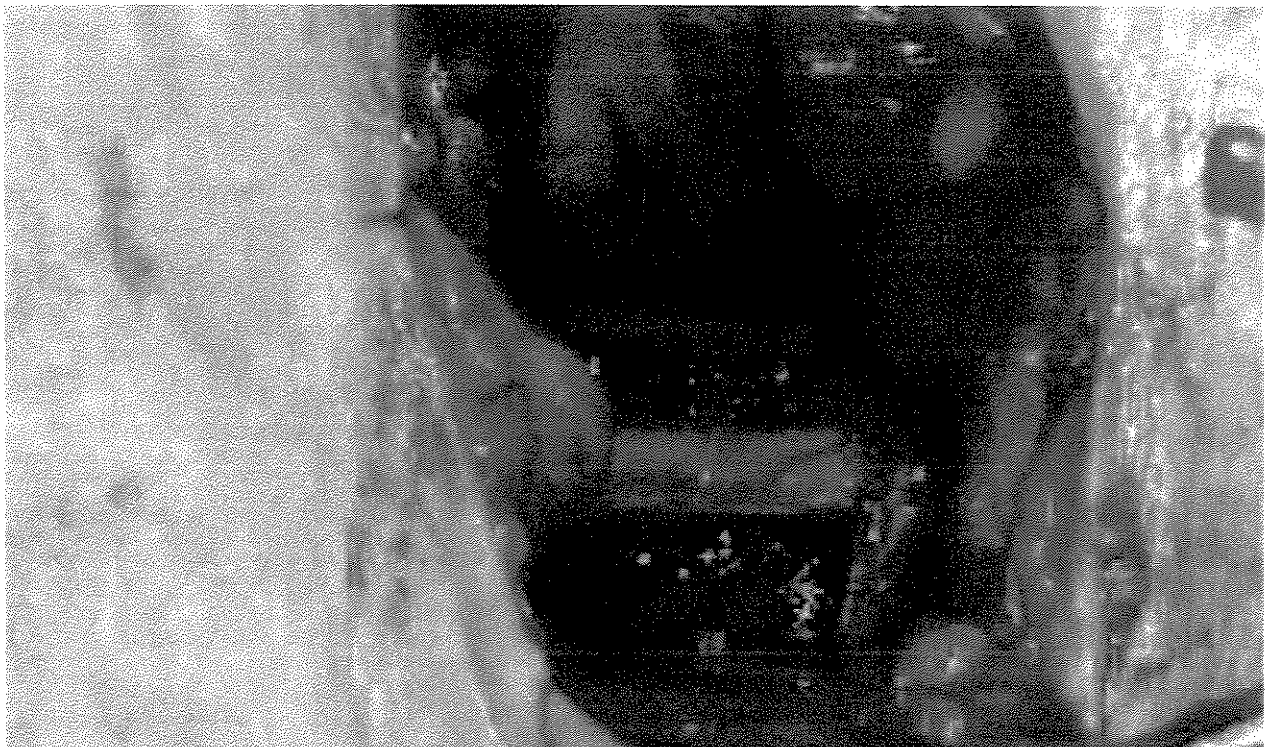

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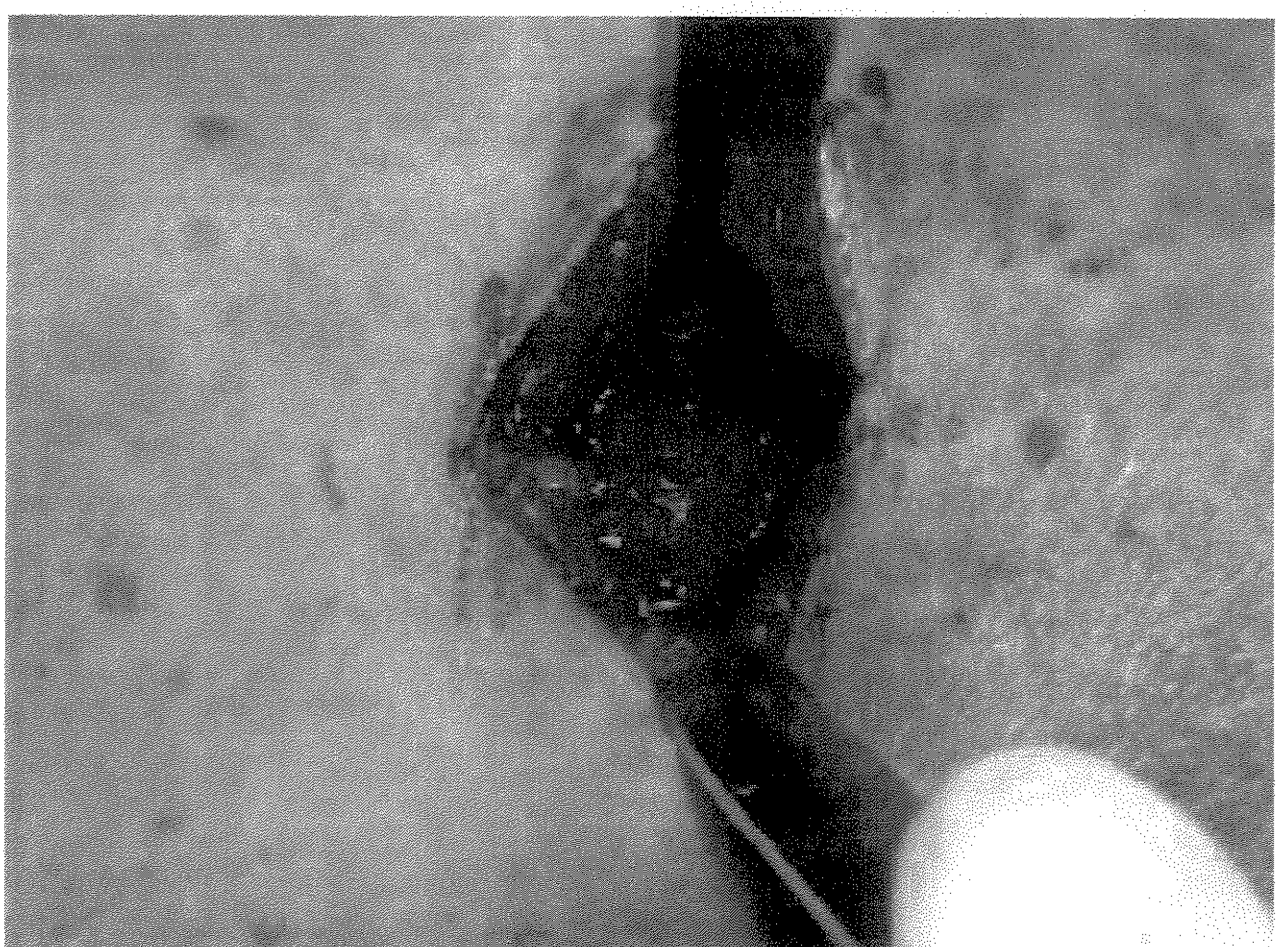

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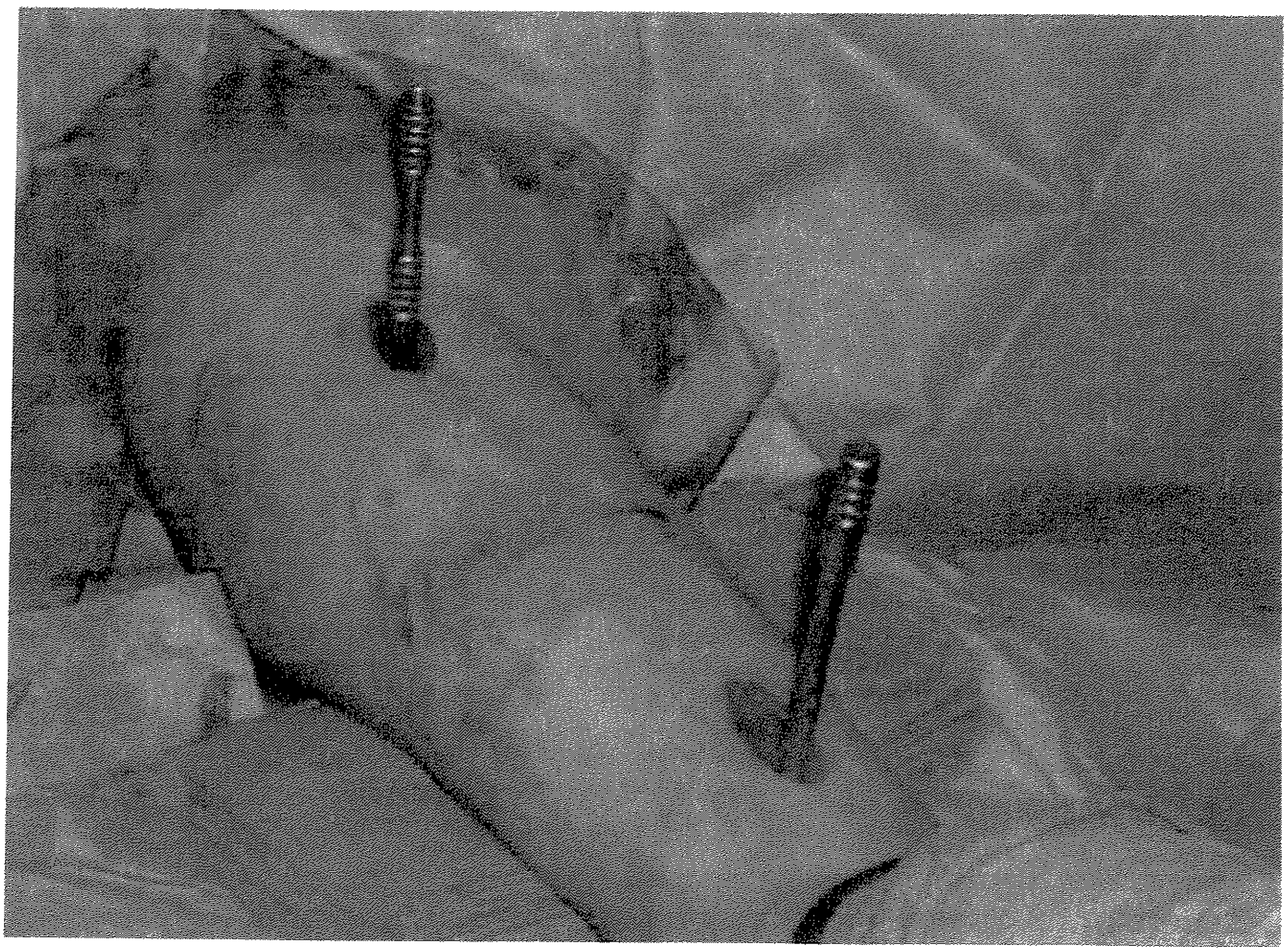

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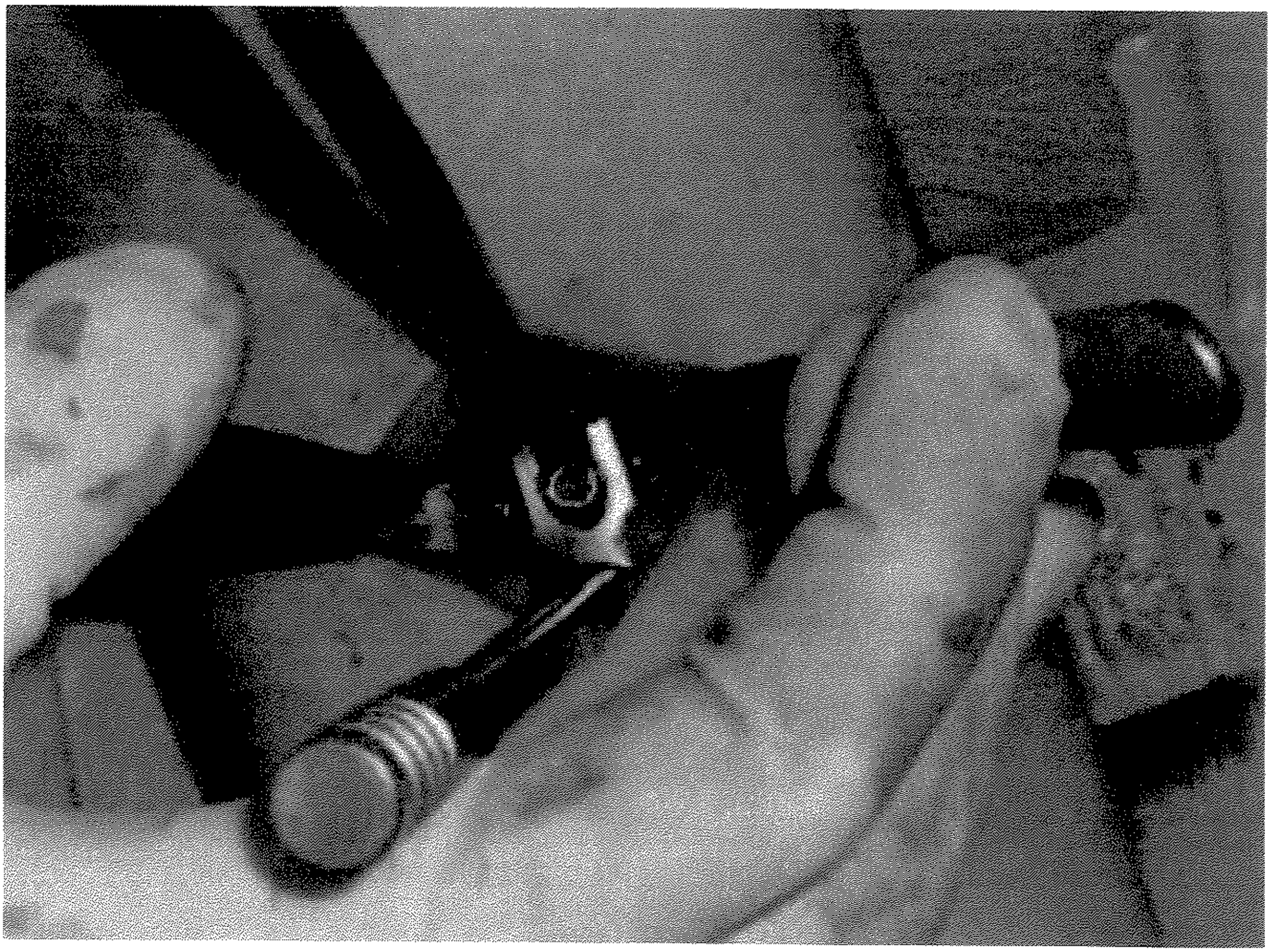

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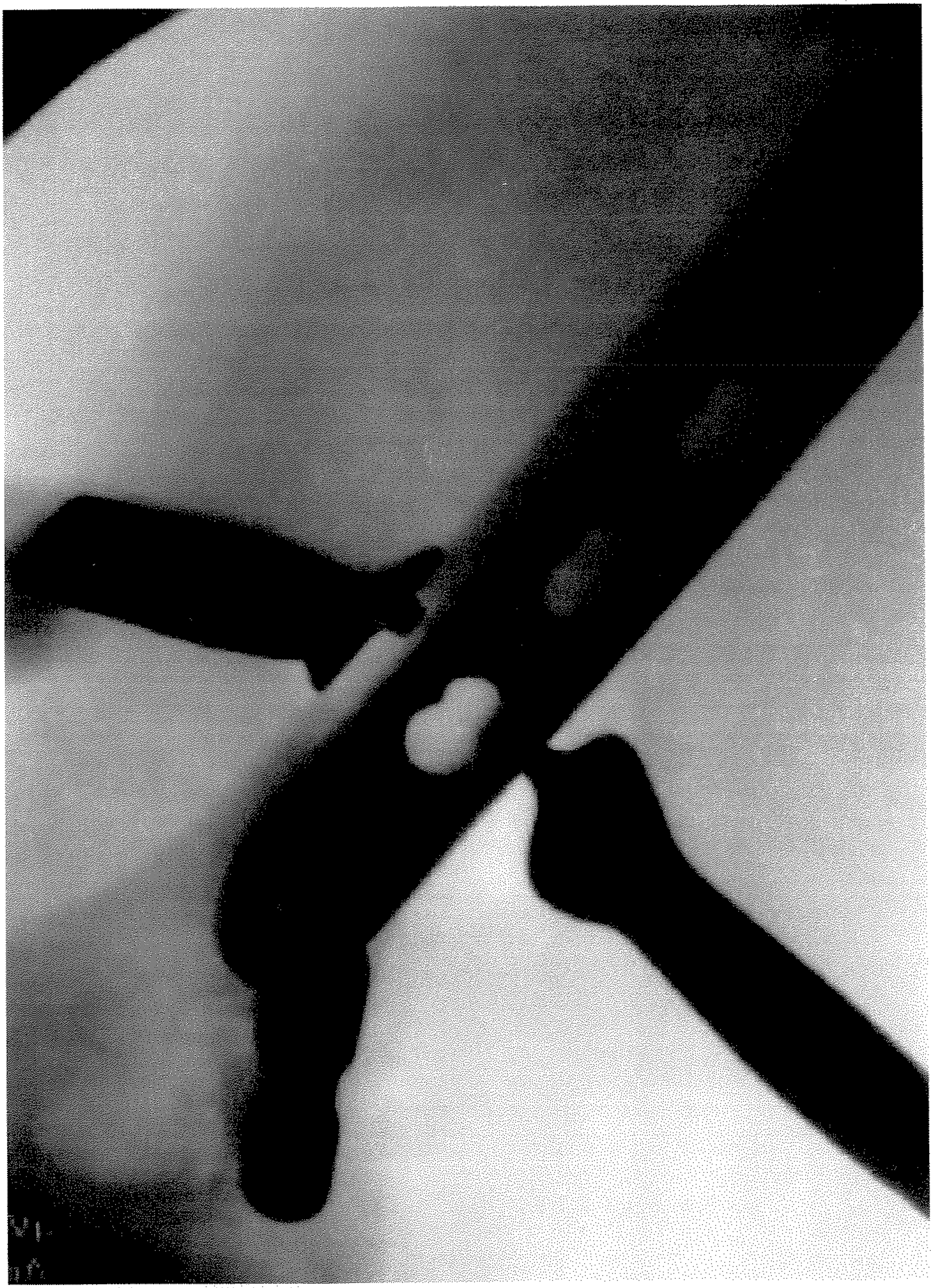

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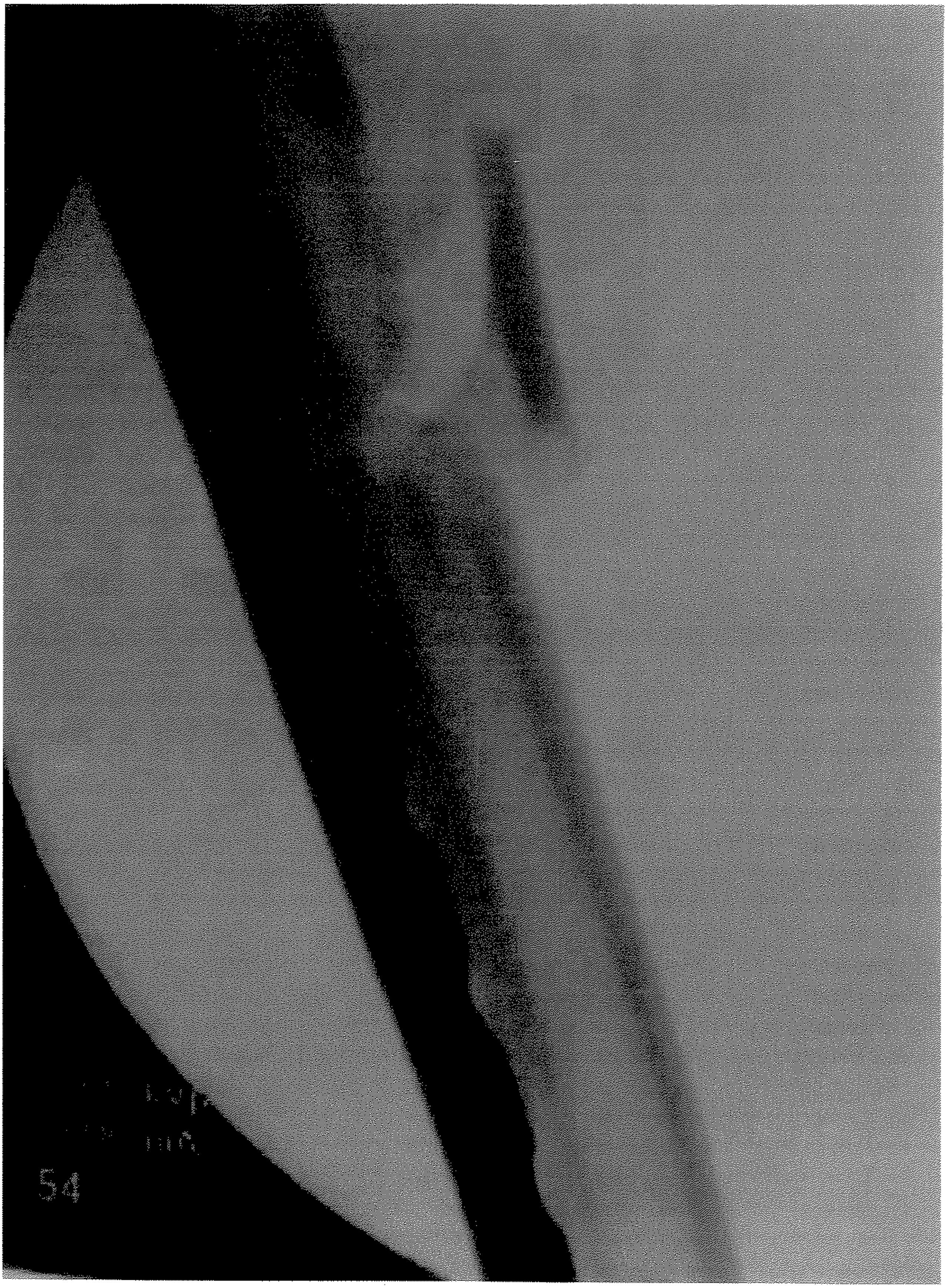

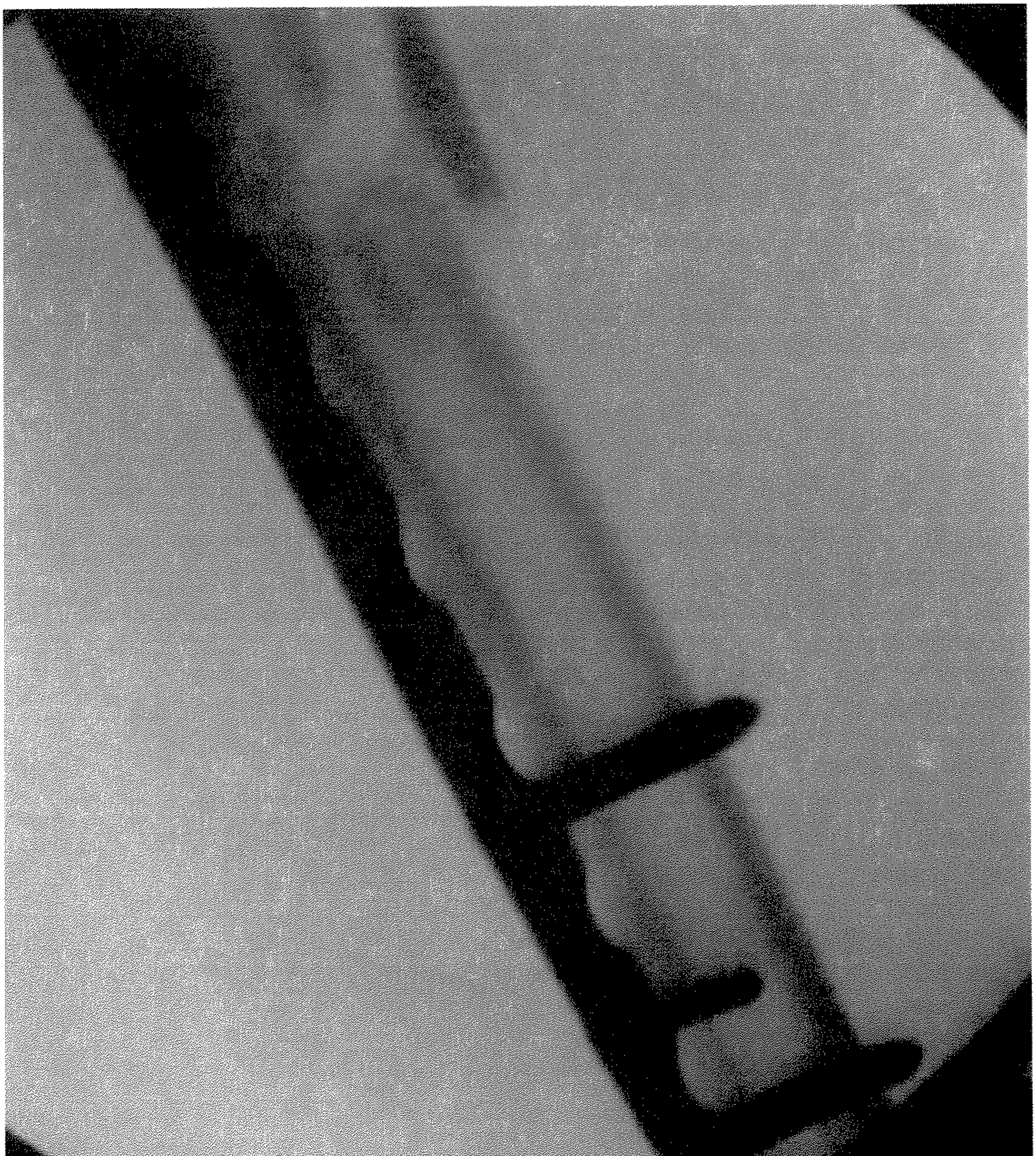

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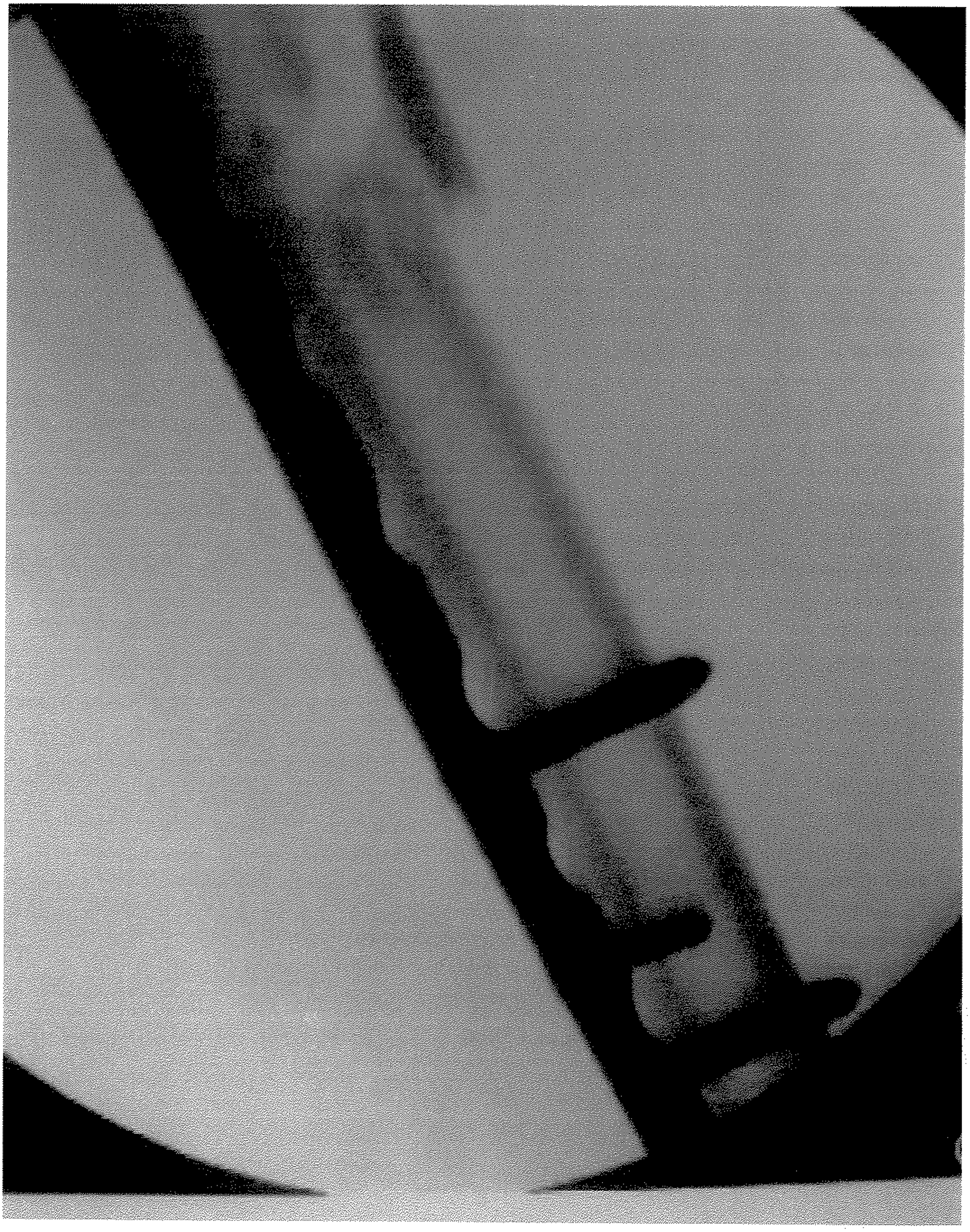

Table I: Patient Data

Pt.	F/U mos	Age	Sex	L/R	AO/ OTA	Plate	Holes	Ass. Inj.	Shoulder Pain	Elbow Pain	Compl.	Shoulder ROM	Elbow ROM	Healed	Incision (cm)
1 (JC)	14	23	M	L	C2.1	12 hole	1,2,3,9,10, 11,12	None	No	No	None	Abd-160 Flex-150 IR-L2 ER-30	0-130	Yes	Prox 4.0 Dist 4.0
2 (RW)	12	43	M	L	A3.2	10 hole	1,2,3, 8,9,10	None	No	No	None	Abd-160 Flex-160 IR - L2 ER- 30	0-135	Yes	Prox 3.5 Dist 4.0
3 (JL)	12	35	M	R	B1.2	10 hole	1,2,3,8,9, 10	R clavicle	No	No	None	Abd-150 Flex-150 IR-L3 ER-25	5-130	Yes	Prox 2.5 Dist 3.5
4 (DG)	lost	48	M	R	B2.2	12 hole	1,2,3, 10,11, 12	Clavicle, CHI	N/A	N/A	N/A	Abd-150 Flex-150 IR- L4 ER-20	0-125	yes	Prox 2.5 Dist 2.5
5 (JF)	9	21	M	R	B2.2	12 hole	1,2,3, 10,11, 12	CHI, L BBFA, L tibia/fibul a	No	No	None	Abd-140 Flex-140 ER-30 IR-L3	0-135	Yes	Prox 2.5 Dist 2.5
6 (JW)	6	64	F	L	A3.2	12 hole	1,2,3, 10,11, 12	L tibial plateau, L MC neck	No	No	Preop radial nerve palsy	Abd- 160 Flex- 160 IR – L3 ER – 25	5-125	Yes	Prox 2.5 Dist 3.0
8 (AH)	4	22	F	L	A3	12 hole	1,2,3,9,10, 11	R acet.	No	No	Radial nerve. Improved	Abd – 180 Flex – 150 IR – L3 ER - 30	0 - 135	Yes	Prox. 3.5 Dist 3.5

Legend: CHI-closed head injury, BBFA-both bone forearm fracture, MC-metacarpal, IR-internal rotation, ER-external rotation, Abd-abduction, Flex-flexion, Prox-proximal, Dist-Distal, Ass. Inj.-Associated Injury, and Acet.-acetabulum.

APÊNDICE 5

CAPÍTULO DE LIVRO ACEITO PARA PUBLICAÇÃO

Diaphyseal fractures of the humerus: current opinion on surgical treatment.

Romania (Europe)

Dear Dr. Livani,
My name is Paul Dan Sirbu, MD PhD at the dept of Orthopaedics and Traumatology in Iasi, Romania (Europe).
Being passionate of MIPO I have introduced this technique in Romania in 1999 as seen in my CV
Now I am the director in a research grant regarding MIPO and I have found your article "Bridging plate osteosynthesis of humeral shaft fractures" very interesting. In this research grant I am rediging a book with the title "Minimally invasive plate osteosynthesis in long bone fractures".
The chapters will be as follows:
1. Prof. Schneider (Davos Swizerland) - Introduction
2. P.D. Sirbu et al. - Minimally invasive plate osteosynthesis in distal femoral fractures.
3. N. Schwarz (Klagenfurt Austria) - Minimally invasive plate osteosynthesis with LISS in distal femoral fractures.
4. P.D. Sirbu et al. - Minimally invasive plate osteosynthesis in subtrochanteric fractures
5. Dr. H. Bail (Charite, Berlin) - Minimally invasive plate osteosynthesis with LISS in fracture of the proximal tibia.
6. P.D. Sirbu - Medial approach and minimally invasive plate osteosynthesis in complex fractures of the proximal tibia.
7. ..Author.. - Postoperative rehabilitation of the knee
8. Dr. R. Mihaila et al. - Minimally invasive plate osteosynthesis in fractures of the distal tibia.
9. Lisz Margrit (Austria) - Postoperative rehabiltation of the knee

I wonder if you will be interested to participate in this project with a chapter regarding the Bridging plate osteosynthesis of humeral shaft fractures. The book will be published with no commercial interest and will be distributed as educational material in the orthopaedic clinics in Romania.
Best regards
Dr. Paul Dan Sirbu

PAUL

msn Hotmail®

brunolivani@hotmail.com Impresso: segunda-feira, 5 de fevereiro de 2007 15:10:33

De:	Paul-Dan Sirbu <pdsirbu@yahoo.com>
Enviado:	terça-feira, 30 de janeiro de 2007 18:09:38
Para:	bruno livani <brunolivani@hotmail.com>
Assunto:	dr Sirbu small request

Dear Dr Livani,
I have read the whole article and I was stunned by the accuracy of the pictures and really impressed about the scientific content and the practical application. The pictures are also excellent.
Tonight it snowed for the first time this year in Iasi so that tomorrow I will may have enough clinical cases in order to apply your technique here in Iasi too.
Regarding the book, I would like you to tell me the exact position in your department for you and the co-author in the article, while the sub-cover of the book will contain a list with the authors an their positions in their departments/hospitals
Thanks in advance and best regards
Paul

PAUL

Diaphyseal fractures of the humerus: current opinion on surgical treatment.

William Dias Belangero

Bruno Livani

Department of Orthopedics and Traumatology of the School of Medical Science Unicamp (State University of Campinas), São Paulo, Brazil

Introduction

Taking into consideration all of the possible fractures of the skeleton, diaphyseal fractures of the humerus correspond to between 1% and 3%. Approximately 20 fractures of the shaft of the humerus occur for every 100,000 inhabitants/year. Most of the times it is caused by indirect trauma (torsion), with 50% located in the middle third and from 20% to 30% in the distal third. The fractures in the middle third are usually transverse, while in the distal third they are oblique or spiral. Among the associated lesions, those on the radial nerve are the most common, whereas vascular lesions are rare.

There is absolute indication for surgical treatment when there are open, bilateral, pathological, ipsilateral forearm and humeral fractures (floating elbow), fractures associated with vascular lesion and those associated with soft tissue injury (burns, open fractures, crush injuries, etc.). Surgical treatment is also indicated for polytrauma and multiple-fracture patients, as it lessens the risk of delayed union and inadequate consolidation, in addition to facilitating the management of the patient confined to bed.

Transverse, short oblique, proximal or distal fractures, as well as fractures in women who have morbid obesity or very large breasts are considered as relative indications for surgical treatment, since treatment with plaster devices or ortheses presents more difficulties and unpredictable results.

Surgical anatomy of the arm

The diaphysis of the humerus extends from the surgical neck to the supracondylar region. This bone has the form of a cylinder proximally, becomes conic in its middle third and acquires the form of a trumpet in its distal portion. Fractures between the rotator cuff region and the pectoralis major, as well as fractures below the deltoid muscle, present deviation of the proximal fragment in abduction and internal rotation along with abduction, respectively. In fractures between the pectoralis and deltoid muscle insertion, the proximal fragment remains in adduction and the distal remains laterally deviated.

The arm is composed of two different compartments, the anterior (or flexor) and the posterior (or extensor). The neurovascular structures at risk during the surgical procedure are not clearly located within the surgical field, but cross over from one compartment to the other in their pathway toward the humerus (Figure 1).

In the anterior compartment, there are the coracobrachialis, biceps brachii and brachialis. The two last ones are also elbow flexors and all of them are innervated by the musculocutaneous nerve. The posterior compartment or extensor contains only one muscle, the triceps brachii, supplied by the radial nerve. In the two distal thirds of the arm the muscular compartments are separated by the lateral and medial intermuscular septa.

At approximately 6 cm below the acromion are found the axillary nerve and the posterior circumflex artery, which runs around the surgical neck of humerus. The radial nerve is the continuation of the posterior chord of the brachial plexus (C5, C6, C7, C8 and T1). It starts on the shoulder, behind the axillary artery, follows along the posterior axillary wall (in front of the subscapularis, latissimus dorsi and teres major muscles) and crosses the triangular space between the long portion of the triceps brachii muscle and humeral diaphysis, below the teres major muscle. In the arm, the nerve is situated in the groove with the same name, in the posterior surface of the humerus, between the lateral and medial portions of the triceps brachii muscle. After crossing the posterior humeral surface, the nerve crosses the lateral intermuscular septum and goes into the anterior compartment, between the brachialis and brachioradialis muscles.

Whitson (1954) demonstrated that the radial nerve does not cross the radial groove, located in the diaphysis of the humerus. The nerve is closely related to the inferior portion of the radial groove, but is not in direct contact with it. Only in a small part of the supracondylar ridge of the humerus which the radial nerve is in close contact with the bone. It is in this region that the nerve crosses the lateral intermuscular septum before reaching the surface of the brachioradialis muscle. At this point the nerve has less mobility and is more susceptible to mechanical lesions.

The median nerve remains in the anterior compartment, at the anteromedial aspect of the humerus. It runs close to the brachial artery, laterally to the artery in the upper part of the arm and medially to it in the cubital fossa.

The ulnar nerve is located behind the brachial artery, in the anterior compartment of the arm. It originates in the medial fasciculus (C8 and T1) and it usually has a lateral root containing C7 fibers. At its origin it is located between the axillary artery and vein, in front of the teres major, then crosses the medial intermuscular septum at the inferior third of the arm and enters the posterior compartment of the arm, close to the triceps brachii muscle. Subsequently the nerve passes dorsally to the medial epicondyle of the humerus, almost subcutaneously.

The musculocutaneous nerve originates in the lateral fasciculus (C5, C6 and C7), goes across the coracobrachialis muscle, usually 5.0 or 6.0 cm below its origin in the coracoid process, although it may present several variations. The musculocutaneous nerve innervates the arm flexors, the lateral skin of the forearm and the elbow articulation. It ends as lateral cutaneous nerve of the forearm, crossing the fascia laterally to the biceps tendon above the elbow.

The brachial artery is the continuation of the axillary artery, starting at the lower border of the teres major, the distal limit of the posterior wall of the axilla. It runs together with the median nerve, distally to the medial border of the arm, covered by the biceps brachii and brachialis muscles. The deep brachial artery accompanies the radial nerve, which supplies the triceps brachii muscle, while the collateral ulnar artery, also a collateral branch of the brachial artery, accompanies the ulnar nerve.

Surgical treatment methods

The most commonly used surgical access routes for the treatment of humeral diaphyseal fractures are anterolateral, used for fractures of the middle and upper third, and posterior, mainly used for fractures of the distal third.

At present, the most frequently indicated implants are plates and interlocking intramedullary nails. Theoretically, plates and nails would be more indicated for simple fractures (absolute stability), while interlocking intramedullary nails would be more indicated for complex fractures (relative stability). These techniques are currently standardized and are present in the majority of textbooks.

From a practical viewpoint, open reduction and internal fixation by plates continues to be a largely utilized method for the treatment of humeral diaphyseal fractures. If the option has been for the use of a plate, the most indicated would be large fragment bone plate, narrow, with 6 to 8 holes, which may be placed on the lateral surface or posterior to the humerus. The nails should be non-aligned to reduce the risk of stress fractures caused by torsion movements of the arm. However, this method has as main disadvantage the ample exposure of the fracture focus, the bone fragments, with higher risk of infection, delayed union and radial nerve lesion.

The two most frequently utilized routes of access for open reduction and fixation of humeral diaphyseal fractures are the posterior and the anterolateral. The anterolateral route offers lower risk of radial nerve lesion, but greater possibility of musculocutaneous nerve lesion. The patient needs to be placed in dorsal decubitus and the plate may be fixed on the anterolateral surface, without molding. On the other hand, the dorsal access route presents the inconvenient of having to place the patient in lateral or ventral decubitus. However, although technically more demanding, it offers excellent exposure of the radial nerve and also does not require plate molding.

The good outcomes obtained with the interlocking intramedullary nails in the lower limbs led to the utilization of these implants for the treatment of the fractures of humeral diaphysis. Nevertheless, the results were not as encouraging as expected.

If the option is made for the intramedullary nail, the preference is for a solid nail, with diameters between 6.7 and 9.5 mm, locked both proximally and distally. The proximal access route (anterograde), despite seeming anatomically sound may result in lesion of the rotator cuff and impact syndrome, at the point of entry. The nail may move distally against the cortical posterior and produce fracture in that region, or fracture of the distal extremity of the humerus, due to the trumpet form of this bone (decrease of its anteroposterior diameter, increase of the laterolateral diameter and anterior inclination of its distal extremity).

On the other hand, in order to reach the medullary canal by distal access (retrograde) the surgeon will have to begin perforation immediately above the olecranon fossa, inclined at approximately 45°, with risk of cortical posterior fracture, which may occur mostly at the moment the nail is introduced. From a functional point of view, this access route may result in restriction of elbow mobility, myositis ossificans and lesion of the axillary nerve during the locking process proximal to the nail. Such complications, both in the anterograde and the retrograde routes, can be avoided or minimized by keeping the nail in the anterograde route, below the articular cartilage, and introducing it manually through the retrograde route, without making use of impaction instruments.

Special care should be taken with intramedullary nails placed by means of canal widening, which may result in avascular bone segments, with possible segmental bone loss. This complication may occur in fractures of the humeral distal third, associated with large lesions of soft tissue, where periosteal circulation is compromised. Under these circumstances, the widening of the medullary cavity upon introduction of the nail may injure the nutrient artery of humerus, located in the mid-diaphyseal region, thus drastically reducing blood supply to this bone segment. According to Rommens and Blum (2000), the locked nails do not offer sufficient control of rotational movements in proximal, distal or spiral fractures, which make the use of cerclage indicated, in order to increase osteosynthesis stability. In our opinion, this conduct may be questionable and in these circumstances it would be convenient to use another type of implant that might offer, by itself, a better mechanical condition.

Although plates have already been considered as the gold standard for the treatment of humeral diaphyseal fractures, recent publications have shown that the outcomes obtained with intramedullary nails practically outperform those obtained with the plate.

Recently, Bhandari et al (2006) analyzed studies that employed plates or intramedullary nails for surgical treatment of humeral diaphyseal fractures between 1969 and 2000. Among 215 articles identified in the literature, only three met the quality criteria defined by the authors as being necessary, in a total of 155 patients. It may be concluded that the use of plates reduces the risk of repeated surgery and the incidence of shoulder impact syndrome. Demirel et al (2005) retrospectively analyzed the outcome of 114 patients with humeral diaphyseal fractures, who were treated with the interlocking intramedullary nail, or unreamed humeral nail (UHN®). Of these 114 patients, 42 were polytraumatized and 22 had open fracture of the humerus. After mean follow-up of 41 months, 109 of the 114 fractures had consolidated, and 105 patients had shoulder and elbow function considered excellent or satisfactory. Paralysis of the radial nerve occurred as a transitory disorder in only four patients. The authors concluded that the UHN nail, inserted by anterograde route, is a viable and effective method for the treatment of humeral diaphysis, even in polytraumatized patients.

Changulani et al (2006) published a prospective study where 47 patients with humeral diaphyseal fractures were randomly submitted to open reduction with internal fixation by means of intramedullary nail or fixation with a plate of the DCP® Type. Patients with open fractures type I and II, polytraumatized, with unstable fractures and recent failure of non-surgical treatment were included. Twenty-three patients were treated with nails and 24 with plates. The nails were introduced by anterograde route after the medullary cavity and the plates were reamed by the anterolateral or posterior routes. The evaluated outcomes, according to the criteria of the American Shoulder and Elbow Surgeons' Score (ASES), showed that mean union time was significantly shorter with nails; the infection was more frequent with plates, while shortening and restriction of shoulder movements

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occurred more repeatedly with the nails. However, all of the patients with the impact syndrome improved after the intramedullary nails were removed. The authors concluded that the intramedullary nail might be considered the best option for surgical treatment, since it requires shorter fracture union time and lower incidence of severe complications.

As regards complications, the literature describes extremely varied rates, with indices from 1% to 12% of union delay in patients treated by the conservative method; 3% to 20 % when treated with plates and 0 to 29% when treated with nails. In relation to infection, rates are around 5% for patients treated with plates and from 0 to 3% for those treated with nails. Iatrogenic lesion of the radial nerve affects around 8% to 14% of patients treated with plates and 0 to 5% of those with intramedullary nails.

The biological treatment of fractures by indirect reduction, preservation of soft tissue cover and bone union with callus formation has been increasingly utilized, mainly for lower limb fractures. However, minimally invasive procedures have been applied to the upper limb, with some restrictions imposed by anatomic characteristics inherent to thee segments.

Concerning fractures of the diaphysis of the humerus, the technique known as minimally invasive plate osteosynthesis (MIPO) was first presented by Livani and Belangero in two studies. The main question regarding the minimally invasive technique for the humerus concerns the radial nerve injury, especially since it is not identified in this procedure. However, by means of studies in cadavers, the authors were able to establish anatomic landmarks for the best access route, implant positioning and size, as well as to define parameters to orient rotation control of fragments, without risk of injury to the radial nerve and/or other neurovascular structures.

When the anterior or anterolateral Access routes are used it is possible to avoid all the neurovascular structures of the arm, including the radial nerve, which is the most threatened structure during humeral osteosynthesis. In addition, the brachialis muscle, since it has the lateral portion innervated by the radial nerve and the medial portion innervated by the musculocutaneous nerve, may be longitudinally divided in its entire extension, allowing access to the diaphysis of the humerus, without compromising its function (Figures 2 and 3).

Rotation deviation of the distal fragment may be avoided by utilizing as anatomic parameters the bicipital groove (proximal fragment), which is on an orthogonal plane to the axis formed between the medial and the lateral condyle (distal fragment). The bicipital groove, identified intraoperatively, orients the rotation position of the distal fragment by palpation of humeral condyles.

DCP® or LC-DCP® plates adapt to the anterior surface of the humerus perfectly, with no molding required. In order to reach the lateral column of the humerus, on its anterior surface, the plate should be slightly molded anteriorly and medially twisted, so it can be fixed on the anterior surface of the humerus and on its lateral column, without occlusion of the coronoid or of the olecranon fossae. (Figures 4, 5, 6 and 7)

The only structures potentially at risk using this approach are the lateral cutaneous nerve of the forearm, a sensitive branch of the musculocutaneous nerve located between the biceps brachii and brachialis muscles (Figure 8), and the radial nerve, located between the brachialis and brachioradialis muscles. Such risks may be considered more theoretical than practical, since the lateral cutaneous nerve of the forearm is easily seen during distal access to reach the brachialis muscle. Regarding the radial nerve, it is not within the surgical field in anterior approaches (proximal and distal to the humerus) for fractures up to the medial third of diaphysis, and may be endangered in the lateral column approach for distal fractures of the humerus. Even in such circumstances (lateral column approach) its identification is not required, as the exposure of this region may be done through subperiosteal dissection, with joint retraction of the radial nerve and of the origin of the brachioradialis and long radial carpal extensor muscles at the lateral supracondylar ridge of the humerus, as described in Kocher's access route. In the proximal, media and distal diaphyseal regions, the implant also remains in a safe zone, as previously mentioned, without risk of radial nerve injury.

Surgical Technique Presentation (MIPO)

The patient is placed in dorsal decubitus on a conventional operating table, the arm with partially bent elbow resting on the table. The surgical team should be composed of three individuals, the surgeon and two assistants. One of the assistants holds the forearm and elbow of the patient, keeping them propped on the table with slight traction, while the other assistant helps in the procedure itself. There is no need to use the image intensifier and it is perfectly feasible to operate with other teams concomitantly, when necessary. Two access routes for surgical treatment of diaphyseal fractures of the humerus with a minimally invasive technique (MIPO) can be described: one for fractures located up to the medial-diaphyseal region and another for distal fractures (Figure 9).

In the case of fractures up to the medial-diaphyseal region, a large-fragment DCP® plate, narrow, with 12 holes and no previous molding is utilized. Access points of approximately 3.0 to 5.0 cm are made on the anterior face of the arm, one proximal and another distal in relation to the fracture focus, accompanying the lateral border of the biceps brachialis muscle. At the proximal access point, the dissection plane lies between the biceps muscles medially and the deltoid together with the cephalic vein, laterally. At the distal route, the dissection plane lies between the biceps and the brachialis muscles, where the lateral cutaneous nerve of the forearm can be easily seen in the medial and superior region above the brachialis muscle. The brachialis muscle is open longitudinally to its lateral third, for an extension of 3.0 to 5.0 cm, to expose the anterior face of the humerus. The plate is introduced close to the anterior face of the humerus through the proximal access route, toward the distal. Once the plate is positioned on the anterior face of the humerus, the last distal nail is inserted, which is kept relatively loose to allow fracture reduction and adaptation of the plate onto the bone. The arm is then abducted to around 60° to correct the angular deviation, which is usually varus. With a slight traction the distal fragment is twisted until the axis between the medial and lateral condyles is perpendicular to the biceps brachialis tendon. With the arm thus held by the assistant, the first proximal nail is inserted and the distal nail is tightened, bringing the bone against the plate. The quality of reduction is clinically and radiographically assessed, then two more nail are placed in each fragment. (Figures 10, 11, 12, 13, 14 and 15)

In distal fractures, when there is not sufficient space to fix the plate on the anterior face of the humerus, the option is made for the alternative distal access. As previously described, by means of subperiosteal dissection of the lateral supracondylar ridge of the humerus, the brachioradialis and the long radial carpal extensor muscles, as well as the radial nerve may be retracted, even though unseen. In these procedures the narrow, large-fragment DCP® plate is molded and twisted medially to adapt to the anterior face of the humeral lateral column, thus avoiding occlusion of the coronoid or of the olecranon fossae, and to the anterior face of the diaphysis exposed through the proximal access route. The plate should be introduced from the distal to the proximal access point and the fracture should be reduced and fixed, as previously described. (Figures 17 and 18)

The closure of the wound is performed in the habitual manner and does not require the use of the aspiration drain and external immobilization. The patient is encouraged to move the elbow and the shoulder in the immediate postoperative period. In the first days some limitation of complete elbow extension may occur, which is usually spontaneously resolved. The fracture should be monitored with radiographic control at four-week intervals and consolidation should be achieved in approximately 10 weeks. Transverse fractures are the most difficult to be indirectly reduced and the lack of contact as a result of excessive traction at the fracture site should be avoided at all costs, as this may lead to delayed union. When these steps are taken, even simple trace fractures present good progression with this treatment method, although such fractures have a high rate of relative deformation.

The fractures associated with radial nerve injury, despite having been specifically investigated since the 60s decade, still lack a conduct defined in a consensual manner. Such association occurs in between 1.8% and 18% of the humeral diaphysis fractures, with an approximate mean of 11%.

Recently, Shao et al (2005) carried out a systematic survey of all studies published in the last forty years (391 studies) about this subject and selected 35 which met adequate criteria of methodological quality. It was observed that this type of association took place in 11.8% of fractures (532 paralysis in 4,517 fractures), mainly those in the medial and distal third, as well as in transverse and short spiral fractures, as already mentioned. The authors concluded, based on this meta-analysis, that the immediate surgical approach of the radial nerve did not offer a better final outcome than the non-surgical treatment. The total mean recovery rate of the radial nerve was 88.1% (921 of 10451) and the spontaneous recovery rate was 70.7% (411 of 581) in patients treated non-surgically, corroborating earlier findings of Pollock, 1981 and of Hall and Pankovich, 1987. Based on these observations, the authors recommend an expectative conduct when facing such lesions.

Despite these considerations, when deciding on the best approach in cases of humeral fractures, associated with radial nerve injury, some anatomical peculiarities of the nerve, which may interfere in the recovery process, should be taken into consideration. In the medial third, the radial nerve is still not fixed by the intermuscular septum and there is a good muscular cushion between this nerve and the bone tissue. At this level, lesions are usually caused by contusion, therefore with a higher potential for spontaneous healing. On the other hand, in distal third fractures the nerve is fixed by the intermuscular septum and in close contact with humeral diaphysis. Paralysis occurring during trauma or during the non-surgical treatment may have a further meaning. In general, besides the contusion, there is a higher risk of nerve entrapment at the fracture focus, making spontaneous recovery improbable or unpredictable, as emphasized by Holstein and Lewis (1963).

Thus, fractures of the distal third, spiral fractures or those with a third wedge-shaped fragment, when associated with radial nerve injury, would be the most indicated to be submitted to surgical exploration of the nerve, fracture fixation and nerve bed protection with a muscles. Technically, such fractures are more difficult to treat with intramedullary nails, so that the most frequently used option is open facture reduction and internal fixation with plates, despite the higher morbidity of the procedure.

The technique described below permits that patients with fractures of the distal third of the humerus, with a Holstein and Lewis (1963) pattern and paralysis of the radial nerve be treated with indirect fracture reduction and percutaneous fixation with a plate.

MIPO technique for distal humerus fracture with radial nerve injury

The patient is placed in horizontal dorsal decubitus on a regular operating table, with the arm reclined on the table. The radial nerve is found between the brachialis and brachioradialis muscles by means of an oblique access route in the distal third of the arm (Figure 18). After identifying its most superficial region, the nerve is individualized and released from distal toward proximal until it emerges in the lateral intermuscular septum or at the fracture focus (Figure 19). Once release is completed and the nerve is inspected, the two access procedures already described are carried out for treatment of the humeral distal fractures. With the nerve protected, the moulded plate is inserted from distal toward proximal and fixed as previously described (Figures 20 and 21).

Until the present date we have treated six patients with this association, having achieved consolidation and recuperation of the radial nerve in all of the patients. Early surgical exploration resulted in evident benefits, with fast recovery (1 to 5 months) of the nerve injury, probably due to stabilization of the fracture focus.

In conclusion, it may be affirmed that the fractures of the diaphysis of the humerus, when surgically approached, should be treated by minimally invasive technique, using interlocking intramedullary nails or plates with the MIPO technique. For distal third fractures, where the intramedullary nails do not present reliable results, the best option is the plate inserted with the MIPO technique. Likewise, distal fractures associated with radial nerve injury may be treated by MIPO technique or a conventional approach, with plate internal fixation with open anatomic reduction after exploration of the radial nerve.

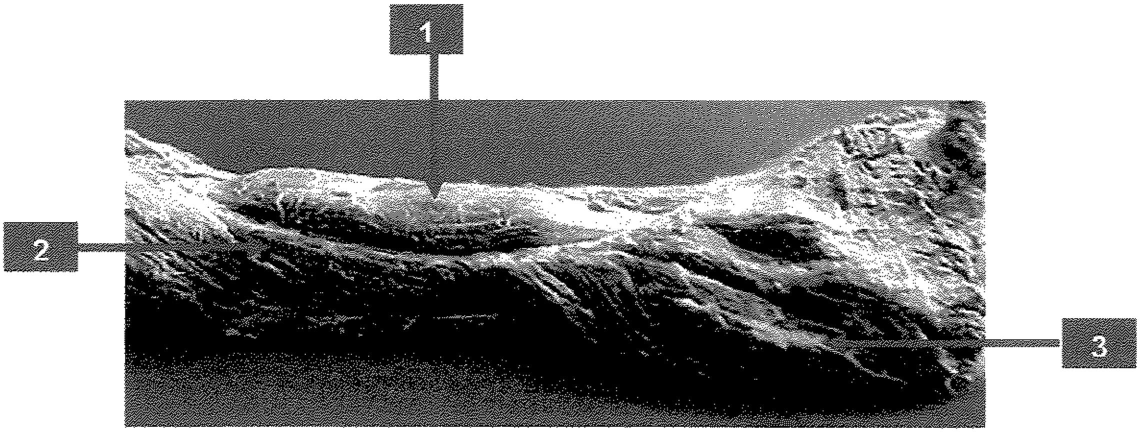


Figure 1: bíceps muscle (1), brachial muscle (2) and deltoid muscle (3)

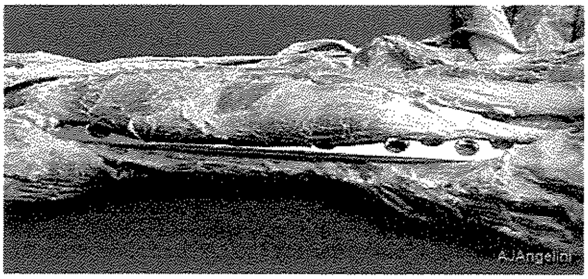


Figure 2: plate between bíceps ad brachial muscles

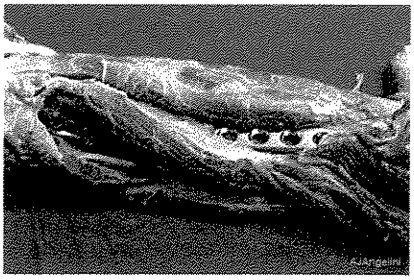


Figure 3: radial nerve and plate relationship

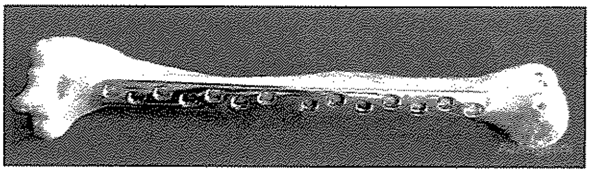
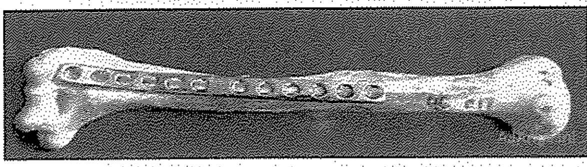


Figure 4: plate on the anterior surface of humeral shaft.

Figure 5: plate on the anterior surface of humeral shaft. No plate moulding is needed



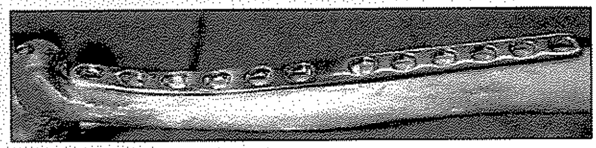


Figure 6: plate on the anterior surface of anterior column of humeral shaft

Figure 7:.plate on the anterior surface of anterior column of humeral shaft . Slight plate moulding is needed

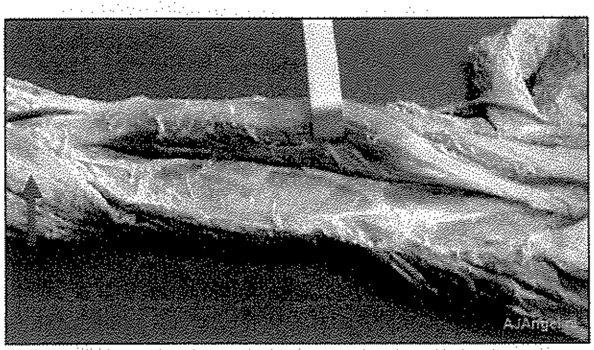


Figure 8: musculocutaneous nerve between bíceps and brachial muscles

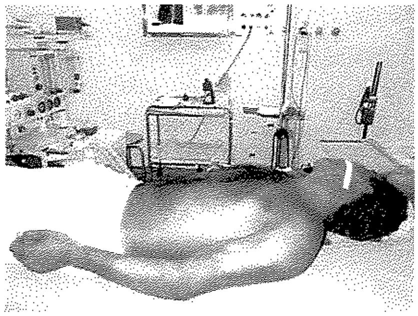


Figure 9: patient in supine position in a conventional operating table

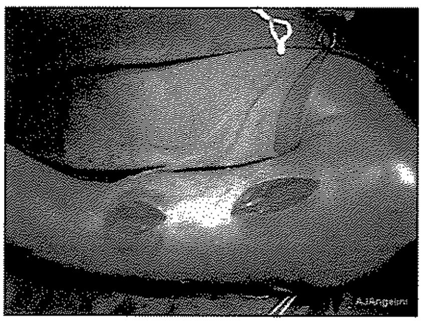


Figure 10: surgical approaches

Figure 11: proximal surgical access betwee bíceps and cephalic vein and deltoid muscle

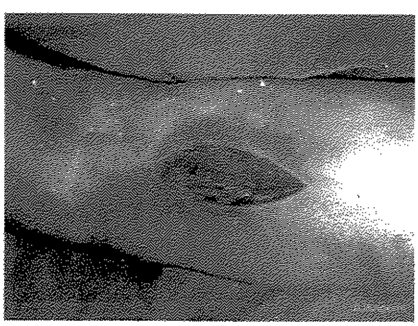
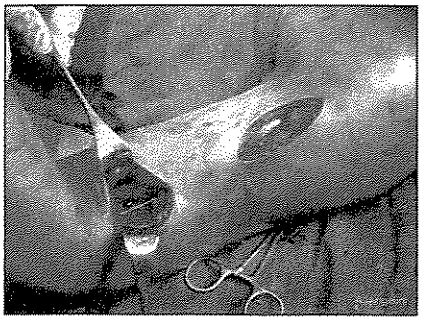


Figure 12: distal surgical access between bíceps and brachial muscles

Figure 13: plate insertion



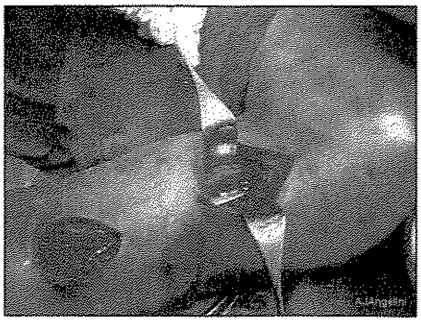


Figure 14: plate fixation distally

Figure 15: plate fixation proximally

Figure 16: plate fixation on the anterior face of lateral humeral shaft column

Figure 17: conventional wound closure

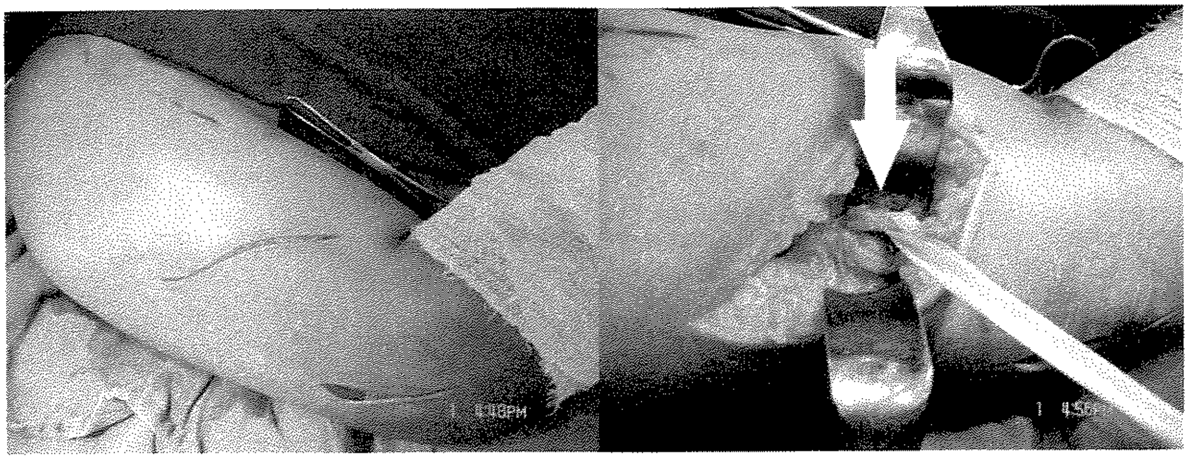


Figure 18: radial nerve identified by a intermediate surgical approache.

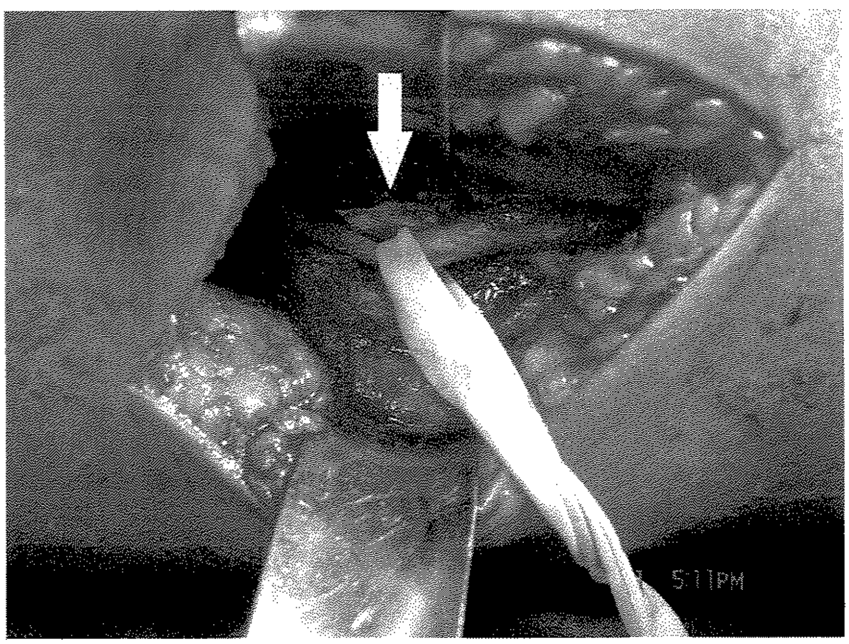


Figure 19: radial nerve compressed by a distal bony spike

Figure 20: distal third humeral shaft fracture with radial nerve palsy treat by MIPPO

Figure 21: Patiente regarding figure 20 with radial nerve palsy and complete nerve recovery at 10 months postoperative.

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APÊNDICE 6

DOCUMENTO

Comentário do Prof. Rolfe Birch – Royal National Orthopaedic Hospital – University College London, referente à tese.

Royal National Orthopaedic Hospital NHS

PERIPHERAL NERVE INJURY UNIT

NHS Trust

Fax: 020 8420 6582
Email: benita.patel@rnoh.nhs.uk

Professor Birch's secretary: 020 8 909 5567
Prof Carlstedt's secretary: 020 8 909 5794
Dr Sinisi's Secretary: 020 8 909 5567

Mrs Benita Patel, Unit Manager/Co-ordinator: 020 8 909 5803

RNOH Stanmore
Brockley Hill
Stanmore
Middlesex
HA7 4LP
Tel: 020 8954 2300
www.rnoh.nhs.uk

Our ref: Document3
Your ref:

3rd January 2007

Dr B Livani MD
Orthopaedic Surgeon
Rua Vicente Porto 208
Residencial Barao Do Café 03
Bairro Barao Geraldo
CEP 13085-895
Campinas
Sao Paulo
Brazil

Dear Dr Livani

I am so pleased to see this paper out now, I think that it is quite admirable work and it represents a truly excellent contribution from you and your colleagues. I hope that it is widely read and its lessons grasped as they deserve.

Yours sincerely

Rolfe Birch MChir FRCS, FRCS Eng by election
Professor in Neurological Orthopaedic Surgery

A.D.C.C.
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