

Knee Ligament Injuries in Children

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ABSTRACT: Nine children who were less than fourteen years old and had open physes and ligament injuries of the knee were studied. Despite an initial thorough physical and roentgenographic evaluation, the full extent of the lesion was determined only at operation in seven of the nine patients. The intercondylar eminence of the tibia was avulsed in five patients, four of whom had associated collateral ligament injuries and a positive anterior drawer sign. Despite surgical repair, all nine patients demonstrated some degree of postoperative ligament instability. This was increased in those patients in whom meniscectomy had been performed concomitantly with ligament repair. Although none of the children were symptomatic at the time of writing, development of degenerative arthritis in the future must be considered. Ligament injury must be considered in the differential diagnosis of the child suffering from knee trauma. The association of avulsion of the tibial spine and collateral ligament injury is emphasized.

Injury to the ligaments of the knee in children who are less than fourteen years old is unusual, presumably because the resiliency and strength of the ligaments are greater than those of the physis and bone³⁷⁻³⁹. To our knowledge, no previous series of knee ligament injuries in children with open physes has been published.

A review of the literature in English on knee ligament injuries revealed 1,749 cases. Nine patients were less than fourteen years old^{2,9,30,32,40,41,45,48}, of whom only two were discussed in any detail³².

Isolated reports of children's knee-ligament injuries have been presented. Joseph and Pogrund¹⁹ reported on a four-year-old boy with a medial ligament injury. Hyndman and Brown¹⁷, in 1978, reported to the Canadian Orthopaedic Association on fifteen cases of acute knee-ligament injuries in children between the ages of nine and fifteen years.

Materials and Methods

Clinical Material

Nine hundred and thirty-two patients with knee injuries were treated at the University of Texas Health Science Center in San Antonio between June 1971 and May

1978. Of these, there were nine children under the age of fourteen, all of whom had open physes.

The average age of these children was 10.4 years (range, 6.2 to 13.5 years). There were seven boys and two girls. The right knee was involved in five patients and the left knee, in four. All patients but one were seen on the day of injury, and all underwent operative repair within ten days. There were no patients in our series who were treated non-operatively. Clinical and roentgenographic follow-up evaluation was obtained in all patients. The average follow-up was 4.3 years (range, eight months to 7.3 years).

Significant trauma was the mechanism of injury in all nine patients. Five children were hit by automobiles: two while riding their bicycles and three as pedestrians. One patient was hurt in a motorcycle accident and another, in a go-cart accident. The final two injuries occurred in falls from a moving vehicle and from a merry-go-round. Despite the severity of the trauma, only one patient (Case 4) had other major injuries: a ruptured spleen and a cerebral concussion.

All nine patients had knee pain, hemarthrosis, and decreased range of motion, and were unable to bear weight on the injured side. One patient (Case 9) had an obvious knee dislocation.

A thorough knee evaluation was attempted in the emergency room, but it was frequently not possible to determine the full extent of the lesion because of the child's pain and apprehension. Routine roentgenograms were made in all cases, revealing six avulsion fractures — four involving the intercondylar eminence and two involving the collateral ligaments. Examination under anesthesia for diagnosis alone was performed in three patients; stress roentgenograms (Fig. 1-B) were made in six patients; and arthroscopy was done in three patients. It has become our policy to perform an examination under anesthesia and to make stress roentgenograms in patients who have signs and symptoms of significant lesions at the knee but whose diagnosis is unclear on completion of the standard history, physical examination, and roentgenograms. Opening at the joint line on stress roentgenograms of eight millimeters or greater than that in the stressed normal knee has been our criterion for operative treatment.

As already noted, arthroscopy was performed in three patients. This was of no value in one patient (Case 8), in whom poor visualization was due to large clots which could not be removed by suction-irrigation. In the second

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TABLE I

Case	Age, Sex (Yrs.)	Findings				Treatment*	Follow-up (Mos.)	Results*
		Exam. under Anesthesia	Stress Roentgenogram	Arthroscopy*	At Operation*			
1	13.5, M	Not recorded	Not performed	Not performed	Ant. tibial spine avulsion; medial ligaments torn from tibia; medial meniscus detached	ACL reattached with suture through drill holes; medial ligaments repaired; medial meniscect.	87	1+ ant. drawer; 2+ medial laxity
2	7.7, M	3+ medial laxity at 30° flexion; 3+ ant. drawer in neutral and ext. rotation and 1+ in int. rotation	Ant. sublux. of tibia; medial opening at joint line of 21 mm (normal, 13 mm)	Complete periph. detachment of medial meniscus from menisocofemoral and meniscotibial ligaments; tear of TCL; stretching and hemorrhage in substance of ACL over entire length	ACL attenuated; medial ligaments torn in mid-substance; medial meniscus detached	ACL reefed with suture; MCL and TCL repaired and reefed; medial meniscus reattached; POL reefed	9	1+ medial laxity
3	11.8, F	Not recorded	Medial opening at joint line of 22 mm (normal, 14 mm)	Not performed	ACL attenuated; ant. tibial spine avulsion; PCL attenuated; medial ligaments torn from tibia; both menisci detached	TCL stapled back to tibia; deep MCL repaired; POL reefed; medial and lat. meniscect.	57	2+ ant. drawer; + pivot shift, anterolat. instability; 2+ medial laxity
4	12.0, M	Not recorded	Medial opening at joint line of 21 mm (normal, 12 mm)	Not performed	Medial ligaments torn from tibia; medial meniscus detached	MCL and TCL repaired; POL reefed; medial meniscect.	81	1+ medial laxity
5	12.9, M	Not recorded	Medial opening at joint line of 24 mm (normal, 14 mm)	Hemorrhage in mid-capsule noted outside synov.; tear at menisocofemoral junction; ACL uninvolved	Medial ligaments torn in substance; medial meniscus detached	MCL and TCL repaired and reefed; medial meniscus reattached	8	1+ medial laxity
6	12.3, F	Not recorded	Lateral opening at joint line of 22 mm (normal, 9 mm)	Not performed	Ant. tibial spine avulsion; LCL avulsed from femur	ACL reattached with suture through drill holes; lat. ligament reattached with staple	72	1+ ant. drawer; 2+ lat. laxity
7	8.0, M	Not recorded	Not performed	Not performed	ACL attenuated; ant. tibial spine and anterior horn of lateral meniscus avulsion	Lat. meniscus and ACL reattached with suture through drill holes	68	1+ ant. drawer
8	6.2, M	3+ post. drawer	18 mm post. sublux. of tibia on femur	Unable to visualize due to large clots of blood	PCL avulsion from femur with cartilage	PCL reattached with suture through drill holes	26	ROM = 5 to 130°; 1+ post. drawer
9	9.0, M	3+ post. drawer, 3+ lat. laxity	Not performed	Not performed	ACL avulsed from tibia with cartilage; PCL avulsed from femur with cartilage; LCL and arcuate ligament torn; medial meniscus detached	ACL and PCL reattached with sutures through drill holes; post. capsule, LCL, and arcuate complex all reefed; medial meniscect.	52	1+ ant. drawer; 1+ lat. laxity

* TCL = tibial collateral ligament; ACL = anterior cruciate ligament; PCL = posterior cruciate ligament; LCL = lateral collateral ligament; MCL = medial collateral ligament; POL = posterior oblique ligament; and ROM = range of motion.

patient (Case 2), arthroscopy demonstrated menisocofemoral and meniscotibial tears in the medial capsular ligament, torn fibers of the tibial collateral ligament, and marked hemorrhage and stretching of fibers of the anterior cruciate ligament. In the third patient (Case 5), arthroscopy confirmed a suspected injury of the medial ligament and showed no injury to the anterior cruciate ligament or other structures. This was important in planning the operative approach in this patient.

Despite the aforementioned evaluation procedures, in seven of the nine patients the full extent of injury was determined only at operation (Table I). It was only in the two patients who had successful arthroscopy that the severity

of the injury was known preoperatively.

Surgical Findings

The intercondylar eminence of the tibia was avulsed in five patients. Of these five, all had associated injury of the anterior cruciate ligament while four had associated injury of the collateral ligament. A positive anterior drawer sign was present in the latter four patients.

Both the tibial collateral and medial capsular ligaments were disrupted in five patients. Of these five, the tibial collateral ligament was avulsed from the tibia in three, from the femur in one, and torn in its substance in the fifth patient. The medial capsular ligament was torn in the

meniscotibial portion in three patients and in the meniscofemoral portion in two. Three of the patients with medial ligament injuries had associated lesions of the anterior cruciate ligament — two avulsed from the tibia and one severely attenuated. One also had an attenuated posterior cruciate ligament and detachment of the lateral meniscus. All five patients had peripheral detachment of the medial meniscus.

There was one patient (Case 6) with avulsion of the lateral collateral ligament from the femur associated with avulsion of the anterior cruciate ligament from the tibia and no meniscal injury.

One patient (Case 7) sustained a 75 per cent in-substance tear of the anterior cruciate ligament, an avulsion fracture of the tibial spine, and avulsion of the lateral meniscus.

One patient (Case 8) had an isolated avulsion of the posterior cruciate ligament from the femur.

The final patient (Case 9) sustained a posterolateral dislocation of the knee with injury to the anterior and posterior cruciate ligaments, peripheral detachment of the medial meniscus, and tears of the lateral collateral and arcuate ligaments.

Treatment

All of these nine patients had surgical repair of their ligament injuries. All five of the medial ligament injuries were reconstituted by primary repair of the medial capsular ligament with sutures. The tibial collateral ligament was sutured in four patients and was stapled to the tibial insertion in one. The avulsion of the lateral collateral ligament was stapled to its origin and the torn lateral collateral was repaired with suture and imbricated in one patient.

The avulsions of the anterior cruciate ligament included bone from the intercondylar eminence in four patients and cartilage alone in one (Case 9). The three displaced avulsions were reattached using sutures tied through drill-holes in the bone epiphysis of the anterior aspect of the proximal end of the tibia, taking care not to cross the physis. Two patients with non-displaced avulsion fractures were treated with immobilization in long casts positioned with consideration of their other ligament injuries. Neither of these two avulsions subsequently became displaced. In Case 2, an attenuated anterior cruciate ligament was reefed using sutures.

No repair was attempted in one case of attenuation of the posterior cruciate ligament. The two avulsed posterior cruciate ligaments were replaced with sutures through drill-holes through the medial femoral condyle.

Five meniscectomies were performed — four medial and one lateral. Peripherally detached medial menisci were repaired in two children and a detached lateral meniscus was replaced in another.

Postoperative immobilization, consisting of a long cast with the knee positioned to take stress off the repair, was maintained for six weeks in all patients. A Steinmann pin through the proximal end of the tibia was incorporated

in the cast to support the two posterior cruciate ligament repairs by holding the tibia anteriorly.

Results

All nine children had occasional pain in the knee following vigorous activity, although this had no effect on their performance or level of activity. No patient complained of effusion, locking, or instability. Two of the nine patients had symptoms of chondromalacia patellae with mild pain in the anterior aspect of the knee, accentuated by stair-climbing. Four of the children subsequently participated in high-school sports including football, track, and swimming.

On follow-up clinical examination, eight of the nine patients had a full range of motion from zero to 135 degrees. One patient (Case 8) lost 5 degrees of flexion and 5 degrees of extension, but this could not be correlated with the extent of his injury or its repair. All patients had some degree of residual ligament laxity related to the injury. The degree of instability determined by stress testing was graded from 1+ to 3+. Instability of 1+ indicated five millimeters or less of joint separation; 2+ meant five to ten millimeters of separation; and 3+ indicated more than ten millimeters of separation¹⁶.

Of the two patients with injury to the medial collateral and anterior cruciate ligaments, one (Case 1) had a 1+ anterior drawer sign and 2+ medial laxity, while the other (Case 2) had no anterior drawer and 1+ medial laxity. In Case 1 the medial meniscus was removed, and the meniscus was reattached in Case 2.

One girl (Case 3) had avulsion of the anterior cruciate and medial collateral ligaments with attenuation of the posterior cruciate ligament and detachment of both menisci. She had 2+ medial laxity, a 2+ anterior drawer sign, and anterolateral rotatory instability with a positive pivot shift.

Both boys (Cases 4 and 5) with isolated injuries of the tibial collateral and medial capsular ligaments had 1+ medial laxity. In Case 4 the medial meniscus was removed.

The child (Case 6) with avulsion of the anterior cruciate and lateral collateral ligaments had 2+ lateral laxity and a 1+ anterior drawer sign.

The patient (Case 7) with the anterior cruciate injury and associated detachment of the lateral meniscus had 1+ anterior laxity.

The isolated posterior cruciate ligament avulsion (Case 8) produced 1+ posterior laxity and a 5-degree loss of motion in both flexion and extension.

The last patient (Case 9), with posterolateral dislocation, had 1+ anterior laxity and 1+ lateral laxity.

Roentgenographic evaluation at follow-up showed mild hypertrophic bone formation in the intercondylar notch of both patients with avulsion of the posterior cruciate ligament and similar changes around the tibial spine in three of five patients with avulsion of the tibial spine. There were no cases of growth disturbance of the

epiphyseal growth plate from the injury or its repair. There were no roentgenographic signs of osteoarthropathy at follow-up in any of the nine patients.

Discussion

Trauma to the knee in children produces fractures or physeal injuries more commonly than ligament disruptions^{37,39}.

Force applied to the lower extremity of the child is most often dissipated by fracture of the femur or tibia, as suggested by the relative frequency of these injuries. Patients with these fractures do not ordinarily have symptoms suggesting a lesion at the knee. Such symptoms do occur, however, with injury to the distal femoral or proximal tibial physes, which constitute approximately 2 per cent of all physeal injuries⁴³. Fractures of the patella sustained from direct trauma, traumatic dislocation of the patella with retinacular disruption, and avulsion of the tibial tubercle and tibial spine are other relatively common injuries in children that cause knee symptoms and signs. Knee ligament injuries produce similar symptoms at the knee but are much rarer^{8,12,33,37,43}.

Meyers and McKeever^{25,26} noted no associated ligament injuries in ten children with anterior spine avulsions who were operated on between the ages of seven and fourteen. Zaricznyj⁴⁹ had one case of tibial spine fracture and tear of the associated medial collateral ligament. Hyndman and Brown¹⁷ noted seven cases of avulsion of the tibial spine associated with medial ligament disruption. Our experience with four cases of anterior spine avulsion and collateral ligament injury confirms this as an injury complex that should be suspected.

The anterior cruciate ligament does not insert directly into the tibial spine but rather anterior and lateral to

it^{11,13,20,24,27}. Trauma that might cause a rupture of the anterior cruciate ligament in an adult most often results in avulsion of the anterior cruciate ligament in a child, with a bone fragment from the tibia^{4,6,33,37,38,42,43}. Garcia and Neer¹⁰ reported a series of forty-two fractures of the tibial spine in patients from seven to sixty years old, with eleven of them under the age of ten. They found a positive anterior drawer sign in six patients who had a concomitant tear of a collateral ligament, but the ages of these six patients were not mentioned. We agree with their statement that a positive anterior drawer sign in the presence of an avulsion of the tibial spine is indicative of an associated tear of a collateral ligament.

Meyers and McKeever^{25,26} classified fractures of the intercondylar eminence into Type I, non-displaced; Type II, displacement of only one-third to one-half of the fragment; and Type III, in which the fragment is completely displaced from its bed. In their thirty-five cases involving children, they reported finding only minor anteroposterior instability, regardless of the type of fracture. No instability was noted in the thirteen cases presented by Zaricznyj⁴⁹. Similarly, the presence of an anterior drawer sign was not mentioned by Hyndman and Brown¹⁷. In four of our five patients with avulsion of the intercondylar eminence of the tibia, a significant (2+ or greater) anterior drawer sign was noted during examination under anesthesia. All four of these patients had an associated collateral ligament injury. In the fifth patient with an avulsion of the tibial spine, there was no significant anterior drawer sign, but at operation a portion of the anterior cruciate ligament was seen to have remained attached to the tibia, and there was no concomitant injury to the collateral ligament.

Jones and Smith¹⁸ pointed out that not all fractures of the tibial spine are the result of cruciate ligament avulsion,

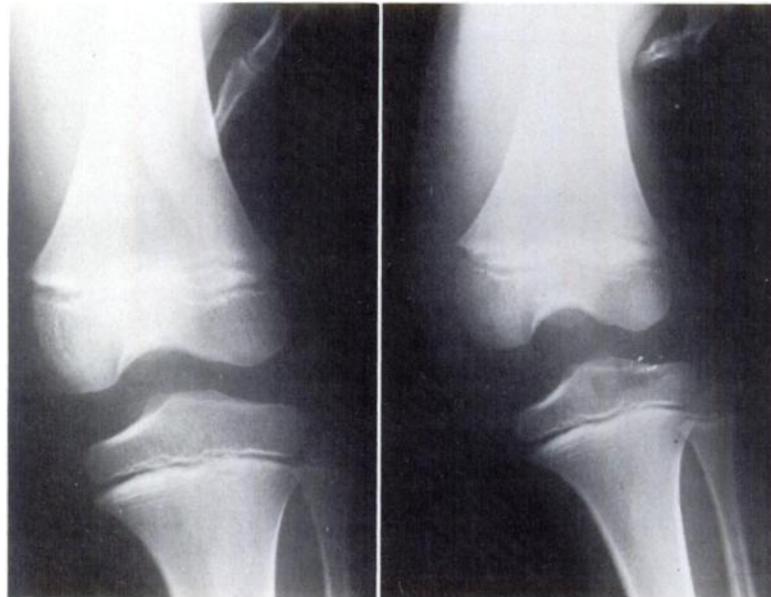


FIG. 1-A

FIG. 1-B

Fig. 1-A: Anteroposterior roentgenogram made without stress. The physes are open.

Fig. 1-B: Anteroposterior roentgenogram made with valgus stress, demonstrating damage to the medial ligament.

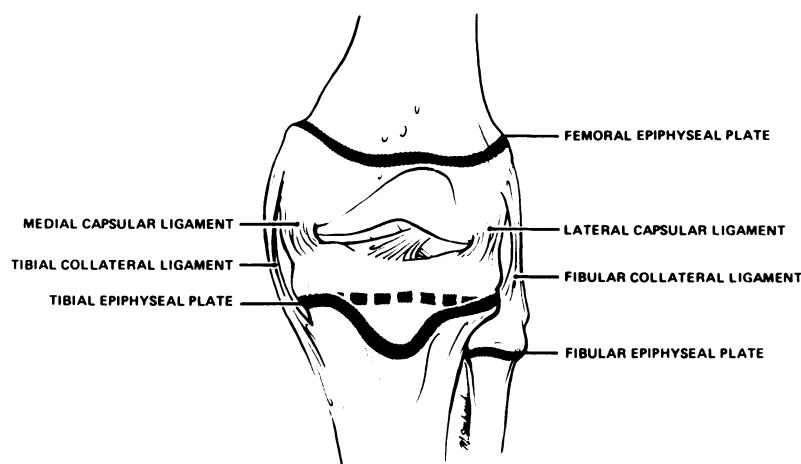


FIG. 2

The origin and insertion of the ligaments of the knee and their relationship to the tibial and femoral epiphyseal plates favor epiphyseal disruption rather than damage to the ligaments.

as initially proposed by Pringle³⁵. Their classification included: (1) avulsion of the tibial spine or its "internal tubercle"; (2) fracture of the "external tubercle" of the spine; and (3) injury of the spine combined with fracture of the tuberosity of the tibia. The first type was thought to be caused by tension on the cruciate ligaments. Three cases of the second type were presented, which they thought were due to the spine being shorn off by the inner margin of the lateral femoral condyle with either forced anterior motion of the femur or posterior motion of the tibia. While it is our impression that the tibial spine can be fractured by other mechanisms, such lesions must be extremely rare. All five such fractures in our patients apparently were the result of traction on the anterior cruciate ligament causing avulsion of a variable amount of its bone insertion.

Kennedy and co-workers²⁰ found only two cases of bone avulsion in fifty patients with anterior cruciate ligament injury. Nine of the sixteen ligament injuries in our series were avulsions of cartilage or bone, six being visible on the initial roentgenograms.

Numerous factors are involved in determining the site of ligament disruption, including the structure of ligament, bone, and growth plate as related to age^{7,21,28,46,47}. The rate of strain has been shown to be important, as well as the site and direction of application of force related to the position of the knee at the time when the strain is applied^{7,29}. The relationship of the attachment of the collateral ligaments and joint capsule to the epiphyseal growth plate and the fact that the ligaments are stronger than the growth plate may influence the site of injury (Fig. 2)^{37,39}.

Since ligament ruptures are uncommon in children, one must be aware of their existence when examining a child with knee complaints following trauma. After the standard history, physical examination, and roentgenograms, several other diagnostic alternatives are available to fully delineate the lesion. Aspiration of the knee may allow a more thorough examination, especially when a local anesthetic agent is instilled. Occasionally stress

roentgenograms can be obtained at this point. Should this fail to provide a thorough assessment, examination under anesthesia and stress roentgenograms in the operating room can be diagnostic (Figs. 1-A and 1-B). Arthroscopy of the knee is another useful tool, offering much potential for definition of the location and extent of the lesion while adding little to the morbidity.

The best method of treatment of knee ligament injuries in children has not been defined. If one were to extrapolate from experience with children's fractures, one might conclude that knee ligament injuries in children would fare better than those in adults. Our study does not bear this out. Despite primary surgical repair followed by six weeks of plaster-cast immobilization, some degree of ligament laxity persisted in our patients. This suggests that such injuries are analogous to adult ligament injuries in this respect. Documented studies of ligament healing in children compared with adults have not been reported.

Seven of our nine patients had meniscal detachment; five of these menisci were removed. The results might conceivably have been better with surgical reattachment, thus contributing some stability to the knee. The concept of meniscal preservation and partial meniscectomy seems to be gaining acceptance due to the decreased incidence of subsequent degenerative joint disease and the maintenance of joint stability that have been reported by a number of authors^{1,3,5,14,15,22,23,31,34,36,44}.

Although some degree of objective knee-ligament laxity persisted in all of our patients, this did not result in subjective symptoms of instability. Even in adults, ligament laxity is not always associated with symptoms of instability. Nevertheless, long-term follow-up of these surgically treated patients is needed to determine if instability will eventually lead to arthritic changes.

Conclusions

One must be aware of the possibility of ligament injury in the child with open physes who has symptoms and signs in the knee secondary to trauma.

A child's pain and apprehension often preclude a complete physical examination and roentgenograms may not reveal the extent of the lesion. Therefore, examination under anesthesia together with stress roentgenograms and arthroscopy should be considered. Concomitant ligament injuries should be sought in patients with avulsion of the tibial spine.

Surgically repaired knee-ligament injuries in the patients in our series did not appear to fare any better than similar injuries in adults. Experience with such ligament disruptions in adults favors surgical repair. Nevertheless, this experience, plus the possibility of reparable meniscal detachments, leads us to recommend surgical treatment for knee ligament injuries in children.

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Editorial

Mutagenesis versus Carcinogenesis of Plastic Implants

The following study on the mutagenic properties of monomeric methylmethacrylate by Poss and associates is of great general interest. Its special concern to orthopaedists, neurosurgeons, and dentists has stimulated this editorial. The investigation of Poss and co-workers has used a variation of the well accepted Ames methodology, in which chemical substances or their metabolites can be assayed for their ability to induce mutagenesis in mutant strains of *Salmonella typhimurium*. The authors' considered conclusion that persons exposed at currently "safe" levels of methylmethacrylate could be at hazard is the real burden of their investigation and is a reasonable cause for concern. In this instance the authors have demonstrated that a metabolic product of methylmethacrylate, not the monomer itself — nor, indeed, the polymeric form — is the mutagen. It is crucial to understand, however, that in the Ames test all mutagens are not necessarily carcinogens, although a very significant number of mutagens do prove to be carcinogenic when tested in accepted animal bioassay systems. Conversely, about 10 per cent of known carcinogens are *not* mutagenic in this test system. The potentially alarming central issue of any such study is that those exposed to repeated doses of monomeric methylmethacrylate may be at more risk than was expected. It is essential, however, to avoid the facile (and erroneous) extrapolation that any such mutagenic material is a carcinogen and that patients with polymeric methylmethacrylate implants are at special risk for cancer.

This raises the problem of the current technology for determining carcinogenicity. Are megadoses of any substance repeatedly administered to mice a reasonable way to assess risk to humans, irrespective of the exposure a human may receive? The consensus response to this question is yes, for in addition to solid epidemiologic evidence in humans there is no better way at this time to make a

judgment on a chemical's carcinogenic potential. Are the several current methodologies using bacteria, such as the Ames technique employed by Poss and associates, relevant to determine carcinogenicity in humans? The answer to this is a qualified no or, at best, a perhaps. Significant false negatives and false positives occur in these microbial test systems. However, a more salient reason for such a tenuous conclusion on the role of these procedures is that we clearly do not as yet understand the molecular events in the initiation and promotion of chemical carcinogenesis in animal models or in humans, and the utilization of a mutagenic change in bacteria induced by a toxic chemical cannot be accepted without question as *proof* of its carcinogenicity. Nonetheless, such methods as the Ames test are invaluable to screen the enormous number of potentially mutagenic and carcinogenic chemicals and their metabolites for further testing. It is obvious that accepted bioassay methods of animal tumorigenesis are too consuming of skilled professional and technical resources, time, and money to cope with the enormous number of chemicals requiring evaluation.

At the moment, the method used in this study is "good science", but a hasty judgmental action, even though based on good science, may not reflect good sense. Rational decision-making based on good science needs to be examined in detail. The study of Poss and colleagues provides an opportunity to do this, as it is almost as inevitable as it is inappropriate that careless interpretation of this careful study's results will suggest that countless patients with various prostheses, dentures, implants, and so on are destined to have cancer. It is equally erroneous to jump to the hasty conclusion that thousands of professionals and industrial workers whose exposure to methylmethacrylate is greater than that of patients are even more at risk of the development of cancer. The authors quite