Does a simple syringe applicator enhance bone cement set up time in knee arthroplasty?

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Background: The time required for polymethylmethacrylate (PMMA) cement curing or hardening can be modified by a number of variables including the mixing technique, and the temperature and pressure at which the process is taking place. Therefore, the purpose of this study was to evaluate two different methods of PMMA application in terms of set up time. Specifically, we (I) compared the PMMA set up time of cement that remained in the mixing bowl to cement that was placed in a syringe and (II) extrapolated the associated annual cost difference on the national and individual surgeon levels.

Methods: The cement set up time was measured for a total of 146 consecutive patients who underwent either unicompartmental knee arthroplasty (n=136) or patellofemoral arthroplasty (n=10) between January 2016 and April 2017. One pack of PMMA powder and monomer were mixed, placed in a 300 mL small plastic bowl, and mixed with a tongue depressor. Then, 50 mL of the mixed PMMA was placed in a sterile 60 mL syringe with the tip cut to a 6-mm opening, and the syringe was used to apply the cement to the bone and the prosthesis surface. The remaining unused cement in the syringe (syringe group) and the remaining unused cement in the plastic bowl (bowl group) were removed and formed into a two separate 2 cm diameter cubes that were allowed to cure at room temperature on a sterile set of osteotomes. The two cubes of cement were timed for complete PMMA curing. A two-tailed student's *t*-test was used to compare the curing time for the two groups. Annual cost differences were calculated on the national and individual surgeon level. The total number of daily cases performed and the operative time savings using the syringe applicator was used to find daily and annual cost savings.

Results: The mean time for the cement to set up in the bowl group was 16.8±2.1 minutes, and the mean time for cement set up in the syringe group was 15.1±1.7 minutes. Compared to the bowl group cement set up time, the syringe group set up time was significantly lower (P<0.0001). An estimated 350,000 cemented knee arthroplasties are performed each year in the United States. With 1.7 minutes saved per case, 595,000 operating room minutes per year could be saved, resulting in a nearly $71,000,000 national and $110,000 individual surgeon annual cost savings.

Conclusions: The results of the present study demonstrated that the utilization of a simple, inexpensive syringe applicator enhanced the cement set up time by over one and a half minutes. This may be a result of the pressure differences in the syringe applicator. In addition to the control of and precision of where the cement is placed, the syringe applicator could provide an important potential time advantage to the arthroplasty surgeon.

Keywords: Cement; knee arthroplasty; set up time

Submitted Sep 19, 2017. Accepted for publication Nov 10, 2017.
doi: 10.21037/atm.2017.11.17
View this article at: http://dx.doi.org/10.21037/atm.2017.11.17

Introduction

Cemented fixation has been the most common technique for total knee arthroplasty (TKA) implant fixation as it has shown good longevity and clinical outcomes (1). However, even though cement fixation is the more common implant fixation technique, there are a number of different techniques used to apply the cement (2-4). A 2002 survey of orthopaedic surgeons in Australia by Lutz *et al.* (4) found that 95% of surgeons applied cement by hand only. It was also found that the pressurization of cement is related to the depth of its penetration into bone (5,6), an important factor in determining strength at the implant interface (7,8). A 2009 study by Lutz *et al.* (6) further showed that the use of a cement syringe improved tibial cement penetration and reduced radiolucent lines when compared to cement applied by hand. Although these studies addressed potential cement application techniques, there is a lack of data comparing the use of a syringe applicator on cement curing time.

Some surgeons do not use cemented fixation due to the extra steps involved with cement curing, potentially resulting in longer operative times. The curing process can be broken down into four stages: (I) mixing of cement; (II) waiting for cement to thicken; (III) working the cement onto the bone and implant; and (IV) hardening of the cement (9). Many times, a 5th step involving meticulously removing excess cement from the implant and joint is also needed, further increasing operative times. With an increase in operative time comes an increase in operating costs. In fact, some studies have even estimated that operating room costs are as high as $66/minute (10,11), so even short time savings per case could add up to a large sum of money saved.

Given the excellent clinical outcomes and common use of cemented fixation for knee arthroplasties, additional studies are warranted to find an ideal cement application method. As one of the hesitations of cement fixation is potential longer operative times, finding a better, more efficient method of cement application could not only result excellent clinical results but also lower operating times resulting in lower operating costs. Therefore, the purpose of this study was to compare the outcomes of cement application techniques and their potential to provide time and cost savings in the operating room. Specifically, we (I) compared cement curing times of polymethylmethacrylate (PMMA) cement in a syringe versus the conventional, mixing bowl method; and (II) extrapolated the associated annual cost difference on the national and individual surgeon levels.

Methods

Patient selection

A total of 146 cases between January 2016 and April 2017 were included for analysis after Institutional Review Board approval. Patients either underwent primary unicompartmental knee arthroplasty (n=136) or patellofemoral arthroplasty (n=10). The first consecutive 73 patients received cement application via syringe (syringe cohort), while the next consecutive 73 patients received cement application via the conventional method from the mixing bowl (bowl cohort). There were 45 women and 28 men in the syringe cohort, while there were 43 women and 30 men in the bowl cohort (P>0.05). A total of 42 patients had right knee operations, while 31 patients had left knee operations in the syringe cohort. In the bowl cohort, a total of 41 patients had right knee operations, while 32 patients had left knee operations. There was no statistical difference based on laterality noted between either cohort (P>0.05). The mean age for the cement syringe cohort was 66 years [range, 51 to 88 years; standard deviation (SD): 8 years], while for the bowl cohort was 67 years (range, 47 to 86 years; SD: 9 years) (P>0.05).

Cement application

One pack of PMMA powder and monomer were combined and placed in a 300 mL plastic bowl, then mixed with a tongue depressor under normal atmospheric pressure. In the bowl group, cement was left in the mixing bowl and applied to the surfaces of the bone and component in the conventional manual method. In the syringe group, 50 mL of the mixed PMMA was placed in a sterile 60 mL syringe, the tip of which had been cut to a 6 mm opening. The syringe was used to apply cement to the surfaces of

the bone and prosthesis. The remaining unused cement in the syringe and the remaining unused cement in the plastic bowl were removed and formed into a two separate 2 cm diameter cubes that were allowed to cure on a sterile set of osteotomes at room temperature. Curing time was measured from the time of formation of the cubes to complete cement curing on the osteotome.

Annual cost savings calculation—national projection

Once the cement curing time differential was found, this data was correlated with current literature to estimate the potential annual cost savings. The Google and PubMed databases were queried with search terms "number of total knee replacements per year in the United States" and "knee replacement projections" in order to identify the total number of knee arthroplasties performed in the United States. The same databases were queried with the search terms "operating room costs," "operating costs per minute," and "operating room per minute costs" in order to find primary literature describing per minute operating room costs. Because cement fixation is a common technique, we estimated 90% (range, 50% to 98%) of the knee arthroplasties performed per year to be cemented. This total number of cemented knee arthroplasty cases per year was then multiplied by the time difference found from the cement application analysis to yield a total time savings per year (operating room minutes/year). Next, based on the published literature, a mean, minimum, and maximum operating room cost per minute was found. These values were then multiplied by the total time saved per year, resulting in an overall estimated annual cost savings. The overall formula for this calculation was: [(700,000 cases)×(90% cemented)×(1.7 minutes saved/case)×($66/minute)].

Annual cost savings calculation—individual surgeon projection

We performed an annualized cost savings analysis to evaluate the potential savings from using the cement applicator technique described in this study. We used a standardized work day of 10 hours, an estimated 160 operative days per year (365 days/year, less 104 weekend days, less 14 days for vacation, less 5 federal holidays, less 1/3 of remaining days for non-operative days), and a surgeon running 1 operating room. Using published mean operative times for primary TKAs, 93 minutes (12), the number of cases performed running 1 operating room was calculated. This number of cases was multiplied by the 1.7 minutes/case time savings found in the present study, to yield a total minute savings per day. This value was multiplied by the cost per minute for running the operating room, $66/minute (range, $24 to $139/minute) (10,11). Furthermore, this dollar amount was then multiplied by 160 to yield a total cost savings per year for 1 adult reconstructive surgeon who performs TKAs. The overall formula for this calculation was: [(6 cases/day)×(1.7 minutes saved/case)×($66/minute)×(160 operative days/year)].

Data analysis

All data were extracted and organized in a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA). A student's *t*-test was used to compare the mean curing times of the syringe and bowl groups. All tests were two-tailed. A P value of less than 0.05 was used as the threshold for statistical significance. Statistical analysis was performed using SPSS version 24 (IBM corporation, Armonk, NY, USA).

Results

Cement curing times

The mean time and SD for cement curing in the bowl group was 16 minutes and 48 seconds (SD: ±2 minutes 6 seconds). The mean time for cement curing in the syringe group was 15 minutes and 6 seconds (SD: ±1 minute 42 seconds). Curing time was 1 minute 42 seconds shorter in the syringe group than the bowl group. The difference in the means was statistically significant (P<0.0001).

Annual cost savings calculation—national projection

Roughly 700,000 total knee arthroplasties are performed each year in the United States (13,14). Because cement fixation has been the most common fixation method (4,15), if 90% (range, 50% to 98%) of these case were cemented (630,000 cases, range, 350,000 to 686,000 cases), with the use of this technique, 1,071,000 minutes/year (range, 595,000 to 1,166,200 minutes) could be saved in the operating room. Recent studies have estimated operating room costs to be a mean of $66/minute (range, $24 to $139/minute) (10,11). Based on these data, the use of the syringe cement technique presented in this study, nearly $71,000,000 (range, $14,280,000 to $162,101,800) could be saved annually.

Annual cost savings calculation—individual surgeon projection

Given a standard 10-hour operative day, and a mean of 93 minutes per TKA, a typical surgeon was calculated to be able to perform 6 TKAs per day. With a savings of 1 minute and 42 seconds per case, a total of 10 minutes and 12 seconds of operating time per day could potentially be saved. Converting this value to a dollar amount using the published $66/minute (range, $24 to $139/minute) (10,11), a net of $673.20 (range, $244.80 to $1,417.80) per day could be saved by a single physician. Annualized for 160 operating days, a total sum of $107,712.00 (range, $39,168.00 to $226,848.00) per year could be saved by a single surgeon using this cement application technique.

Discussion

Cement application by syringe has been associated with favorable functional and radiographic outcomes in knee arthroplasty (5,6), but its effect on cement curing time has not yet been evaluated. In this study, we examined the effect of implementation of a simple syringe applicator on cement curing time in unicompartmental knee and patellofemoral arthroplasty. We found that syringe use significantly decreased the cement curing time ($P<0.0001$). The mean curing time of cement that had been in the syringe was 1 minute 42 seconds less than the mean curing time of cement that remained at atmospheric pressure in the mixing bowl. The syringe is therefore a simple, inexpensive intervention that decreased the cement curing time and has the potential to reduce operative time.

We acknowledge that this study is limited by its non-randomized design. However, patient variables, such as age, gender, and joint laterality, were evaluated for statistical differences, but they were not shown to be different based on student's *t*-test and Fisher's exact test ($P>0.05$). Furthermore, operative variables, such as the operating room and team, as well as the equipment, and cement powder, remained constant for all cases. Nevertheless, randomized-control trials furthering the investigation on the use of the syringe applicator are necessary. These studies should correlate the saved operative times with an actual dollar amount, and analyze the quality of cement application through clinical and radiographic measures.

Similar to our study, other studies have supported the benefit of cement application by syringe in knee arthroplasty. A 2009 study by Lutz *et al.* (6) found that, compared to cement applied by hand, cement applied by syringe improved cement penetration into the tibial plateau and was associated with a decreased incidence of radiolucent lines on radiographs within the first postoperative year. An early study by Walker *et al.* (7,8) showed that strength at the tibial-bone interface was correlated with strength at the cement-bone interface. While the significance of radiolucent lines is not completely understood, it has been suggested that they may represent a route by which debris particles associated with osteolysis can enter the interface (16). Other investigators have demonstrated an economic advantage of cemented arthroplasty compared to cementless, which is of particular importance given the frequency at which TKA is performed (17-19). Beaupré *et al.* (20) cited that the hydroxyapatite-coated prostheses used for cementless fixation cost three times more than their cementless counterparts. Maheshwari *et al.* (21) found that using one packet of cement in TKA rather than two packets, and mixing cement by hand resulted in an average cost savings of $1,000 per case without altering clinical outcomes at mid-length follow-up; implementation of such techniques would give cemented fixation a more meaningful economic advantage over cementless. As our data showed, use of a simple syringe applicator would decrease cement curing time, potentially furthering cost savings as well as providing a time advantage to the surgeon. The increased curing time may have been related to the increased pressure from the syringe.

Some investigators, however, have argued that the advantages of cemented arthroplasty are less significant. Kamath *et al.* (22) found that cementless TKA was associated with shorter operative times (approximately 12 minutes) and less cement use. They also found that components for a cementless TKA can cost $596 more than cemented components. Gicquel *et al.* (23) performed a randomized controlled trial on 96 knees and found the mean operative time to be significantly longer for the cemented knee cohort (more than 10 minutes). However, the group also noted that the quality of implant fixation was significantly better in the cemented group than it was in the uncemented group.

Conclusions

Cemented versus non-cemented implant fixation in knee arthroplasty continues to remain a debate in the orthopaedic community. Although cement fixation

generally provides better fixation, this technique comes at the expense of longer operative times due to cement curing time, potentially resulting in increased costs. Thus, it would be beneficial if surgeons were able to continue the use of the cement technique, but with a decreased cement curing time. Therefore, the purpose of this study was to compare the outcomes of cement application techniques and their potential to provide time and cost savings in the operating room. The results from this study demonstrated that application of cement with a syringe significantly reduced curing time by more than one and a half minutes compared to the conventional manual method. Implementation of this simple and inexpensive intervention could result in cost and time savings in associated with knee arthroplasty.

Acknowledgements

None.

Footnote

Conflicts of Interest: Dr. Barrington is a consultant for or has received institutional or research support from the following: Biomet, DJ Orthopaedics, Iconacy, Mallinckrodt, Pacira, Professional Communications, Inc., Smith & Nephew, Tier 1 Healthcare and Education Research, and Zimmer. Dr. Mont is a consultant for or has received institutional or research support from the following: Stryker, Cymedica, DJO Global, Johnson & Johnson, Microport, National Institutes of Health, Ongoing Care Solutions, Orthosensor, Pacira Pharmaceuticals, Peerwell, Performance Dynamics Inc., Sage, TissueGene. The other authors have no conflicts of interest to declare.

Ethical Statement: The study was deemed exempt from the hospital's institutional review board since no identifiable patient information was obtained.

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Cite this article as: Sodhi N, Dalton SE, Khlopas A, Sultan AA, Curtis GL, Harb MA, Naziri Q, Newman JM, Barrington JW, Mont MA. Does a simple syringe applicator enhance bone cement set up time in knee arthroplasty? Ann Transl Med 2017;5(Suppl 3):S25. doi: 10.21037/atm.2017.11.17

